The Bogs of Ireland

An Introduction to the Natural, Cultural and Industrial Heritage of Irish Peatlands

Revised Edition

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FOREWORD

Throughout the later part of geological time, there have always been places on the earth's surface where plant debris accumulated more rapidly than it decayed. Given the right conditions of later entombment, such debris could be transformed into coal, or provide the raw material for oil creation. To-day in temperate latitudes such accumulation is especially favoured in cool oceanic areas, particularly where moisture is constantly high. Such has been the case in Ireland in recent millennia, and deposits have formed very widely.

Accumulation takes place beneath a skin of living vegetation, and the deposits are known to us as peat. As it lies in situ below its living skin, the peat is saturated with water, just as our bodies, inside their living skin, are also saturated. But if the water content of the bog is reduced by drainage, the dried peat becomes a valuable fuel - turf. But the drainage kills the bog, just as haemorrhage can kill us if our skin is ruptured.

The practice of burning turf as fuel goes back in Ireland at least to the early centuries of the Christian Era, and may go back much further in prehistory. For long the fuel was cut for local use only, but as towns developed they demanded turf, and river barges were used for transport. When Dublin became accessible by canal, the rate of peat-cutting accelerated sharply. In recent years cutting - now mechanised to provide fuel for the generation of electricity - has been far too fast. But in Ireland there are still some bogs, and these are very precious, because in several European countries they have virtually disappeared.

The peat-cutter rips away the plant communities that form the living surface of the bog. Because they are growing on decaying vegetation, supplies of plant nutrients available are very restricted, and the plants of the communities are very specialised, and of great interest to botanists.

Our remaining bogs are under very great threat, and this is the particular reason that makes the appearance of this book by John Feehan and Grace O'Donovan so important. It is a book which is encyclopaedic in its scope, and very timely in its appearance. It provides us with a comprehensive overview of all aspects of peatland heritage: natural, cultural and economic. It is a book which is as likely to be picked up by a developer as by somebody interested in natural history or archaeology, and although the developer may be interested primarily in the chapter on the early history of the mechanical exploitation of the peat resources of Ireland, he is very likely at least to browse through the chapters on plants, animals and archaeology. Vice versa for the naturalist or historian, but in both cases there should be a broadening of horizons.

The book also looks to the future, to the conservation of what remains, and the rehabilitation of the very considerable areas that have already been cut away. The authors have been studying the bogs of Ireland for many years, and their views on conservation and rehabilitation are both valuable and timely.

As well as holding much that is new, the book draws together a vast amount of scattered material, and through its bibliographies makes it available to other workers. This is an important book, which should be - not on the shelf - but continually in the hands of all interested in our unique Irish bogs.

Frank Mitchell
Townley Hall

PREFACE AND ACKNOWLEDGEMENTS

Ireland is one of the boggiest places on earth: a peat deposit of some kind underlies nearly a quarter of its surface area. The bogs of Ireland have a special importance from a European perspective, because the island's outpost location and wet climate have given them a special character: and they survived industrial exploitation for longer than most of the great peatlands of northern Europe. In earlier centuries Ireland's bogs were vast, open, treeless tracts of wilderness that hindered communications and development and put a limit on the march of agriculture. But they also provided the all-important fuel so essential in the cold, damp winters of a country that had little coal and, in modern times, few forests. On another level, the growing bog has kept a meticulous record of our doings down the centuries. Its successive layers are the leaves of a book in which hieroglyphic pollen and other fossils document the changing Irish landscape; behind the evidence of the record we see the shadows and hear the echoes of 0ltr own comings and goings through history and prehistory. Sometimes, the bog brings us face to face with the communities which peopled the past, because it is the great treasure-house of Ireland's archaeology.

The seasonal turf harvest, and in more recent times the mechanical conquest of the peatlands, have woven the bogs into the Irish psyche. And there is no more wonderful place than the bog. Beyond the limits of the farm and defying for so long our efforts to tame it, the bog in all its guises is the greatest reservoir of natural diversity we possess. Much of its wonder and complexity is on the fringe of visibility: we need to focus our eyes to be able to see it. But we have taken it all for granted for too long, and scarcely bothered to examine how much it means to us. We can no longer afford to take it for granted. The pace of change is so great today that if we are to preserve the irreplaceable heritage of the bogs we have to act now. The great challenge for us is to do this in a way which takes account of economic and social reality.

We cannot hope to meet this challenge without understanding what the bogs of Ireland are all about. It is our hope that this manual will provide some of the information that can contribute to that understanding, and that it will help to inform decision-making and planning. In particular, we hope it will find it way into the hands of all who work with peat, all who teach about the Irish landscape, and all those who influence or make decisions about its future.

The various chapters in the book introduce the many facets of peatland heritage, but there is almost limitless scope for further research in every area. How much still remains to be discovered in the field of industrial archaeology alone is illustrated by the ongoing investigation of the extensive remains at Creevelea, and Daphne Pochin-Mould's research on the works at Slieve Each

The quotation from Montaigne (on the last of these preliminary pages) justly expresses our debt to all who have written on Ireland's bogs before us, for much of the material in this volume has been distilled from the work of others. But we are equally indebted to the many colleagues and friends who have guided us in the areas of peatland study with which we are less familiar, on more than one occasion saving us from drowning in our own misinterpretations.

The chapters of the history of peat technology and Bord na Mona have benefited enormously from the help of Jim Martin, whose countless comments and suggestions on a succession of drafts have at least helped these chapters to approach the standard of the account he might himself have written. Maura Scannell performed a similar service for Chapter 6 in particular, and Howard Fox effectively held the pen for much of the section on lichens. Ted Farrell helped to shape the chapter on forestry, and provided much help with agricultural aspects of peatland development. Shane Ward and John Crowe gave much help with parts of Chapters 3 and 4 , Hubert Fuller with Chapter 9, and Donal Daly with parts of Chapter 12. Michael O'Connell guided our unsteady hand through the pitfalls of dating and much else in the chapters on the peat archives, which have also benefited from the critical comments of Gabriel Cooney. Gerry McNally provided much useful critical comment on Chapter 16. Apart from providing the Foreword to the book, Frank Mitchell made many valuable suggestions on an early draft of the text.

Without the financial support of Bord na Mona the book might have taken much longer. Above all, our thanks to Donal Wynne and Paddy Hughes, whose special interest enabled the book to get between covers sooner than it might otherwise have done. A very particular and heartfelt thank you to Valentine Trodd, long-term friend and advisor in ways within and outside the scope of the book itself. Our thanks also to the many others in Bord na M6na who have helped in all sorts of ways over the years, among them

Joe Craven, Tom Egan, Tom Feighery, Sean Ganly, Bi II McCarthy, James McConigley, Tom O'Donnell and Brendan Walsh.

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Above all others is the debt we owe to our families for their patience and forbearance at a project which at times they might have envisaged would go on forever.

The colour photographs of Robert Thompson have greatly enhanced the book, bringing many of the pages to life. Bord na Móna kindly contributed the cover image for the revised edition. The staff at UCD's Audio Visual Centre prepared most of the illustrations, and we are especially grateful to Sarah Cully and Herma Boyle. Barry Cregg provided the beautiful mite SEMs on pages 350-51, and Declan Murray those on pages 334-35, 345 and 398. We have leaned heavily in Chapters 6 and 7 on the illustrations in Sowerby's magnificent *English Botany;* most of the moss drawings are from Braithwaite and the liverworts from Muller. Our thanks also to Michael O'Connell and Karen Molloy for Figure 13.3 (page 437), and to the many others whose work provided material for illustrations.

Our deep thanks to Des Walsh and his staff, especially Andrea and John, who bore much of the burden, and who must at times have cursed the safely distant authors who brought it on their shoulders. The final appearance of the book is due in large measure to Bernard Kaye, who designed the cover and prepared the plates, and who was at all times ready to shore up our feeble grasp of the cybernetic mysteries of which he is such an adept.

We acknowledge the following permissions to make use of illustrations and other copyright material: John Wiley and Sons Ltd. for Tables 13.1 and 13.2 (pp. 432-33) from Mitchell *et al.* Ireland: in Berglund *et al.* (Eds.) *Palaeoecological Events During the Last 15,000 Years;* Koninklijke Nederlandse Natuurhistorische Vereniging Uitgeverij for some of Elbert Hennipman's superb *Cladonia* drawings from E. Hennipman and H. J. M. Sipman *De Nederlandse Cladonia's (Lichenes)* (KNNV Uitgeverij, Utrecht, 1978) (Figure 9.7, pp. 325-26); Academic Press Ltd. for Figures 6.12(d) (p.231) and 6.14 (p. 233) from *The Carnivorous Plants* by B. E. Juniper, R. J. Robins and D. M. Joel; An Post for the pictures of the postage stamps depicting lizard, newt and frog (Figure 10.8, p. 359); Faber and Faber Ltd. for the lines from Seamus Heaney's poem 'Belderg' at the head of Chapter 13 (p. 430); Jon Pilcher and the Royal Irish Academy for the 'skyscraper' diagram in Figure 14.3 (p. 451); Margaret Cruickshank and the RIA for the map in Figure 5.17 (p. 1189)); the Ulster Folk and Transport Museum for Figure 1.16 (pp. 22-23); National Museum of Ireland for the silver cake basket (Figure 2.3, p. 44), Boora stone age (Figure 15.4, p. 462), the Altarte cauldron, Cloonlara shield and

Ralaghan statue (Figure 15.6, pp. 464-65), the Lemonaghan crozier (Figure 15.9, p. 468), bog body (Figure 15.11, p. 470) and bog butter (Figure 15.12, p. 471); the Irish Archaeological Wetland Unit for the Blackwater paddle drawing (Figure 15.9, p. 468); Seamas Caulfield for the map of the Ceide Fields (Figure 13.6, p. 442); Valentine Trodd for the Littleton Sword (Figure 15.13, p. 472) and the ancient shoreline at Lough Boora (Figure 15.2, p. 461); Offaly County Council for permission to reproduce the Offaly County Crest in Figure 6.5 on page 221; Ordnance Survey of Ireland for permission to reproduce sections of Offaly six-inch Sheets 6, 8, 23 and 30, and Westmeath Sheet 46.

PREFACE TO THE REVISED EDITION

Since the publication of The Bogs of Ireland in 1996, research on Irish peatlands has been concentrated on two main areas: carbon sequestration and a re-evaluation of the prospects for afforestation of the cutaway. Apart from some minor corrections, the text of this digital version is essentially that of the original printed edition of 1996, with the exception of Chapters 5, 7 and 16, which have been expanded and rewritten to take account of recent and ongoing research and developments in these two areas.

COLOUR PLATES

Unattributed photographs are by the authors.

Plate 1
Satellite images: ERA Maptec, and Corine Land Cover Project.

Plate 2
Close-up of heather leaf: Jane Feehan.
Cranberry: Robert Thompson.

Plate 3
Bladderwort flowers and bog asphodel: Robert Thompson.

Plate 4
Lousewort: Sharon Parr.
Heather with lichens: Robert Thompson.

Plate 5
Marsh helleborine, common twayblade, heath spotted-orchid, early marsh-orchid, northern marsh-orchid, greater butterfly orchid: Robert Thompson.
Bog orchid and lesser twayblade: Michael Troy. Early marsh-orchid: Sharon Parr.

Plate 6
Fly agaric, jelly-babies fungus, birch bolete, *Cordyceps ophioglossoides, Cladonia coccifera:* Robert Thompson.
Hymenoscyphus erime: Derek Mitchell.

Plate 7
Large heath, marsh fritillary, green hairstreak: Robert Thompson.
Heather case-carrier: Jane Feehan.

Plate 8
Emperor moth, oak eggar caterpillar, eyed hawkmoth caterpillar: Robert Thompson.

Plate 9
All pictures by Robert Thompson.

Plate 10
All pictures except bog spider by Robert Thompson.

Plate 11
Volcanic shards in peat: Rosaleen Dwyer.
Palpeosol profile: Pete Coxon.
Chlamydophrys labyrinthuloides: from Archer (1875-77).

Plate 12
Bog burst: Michael Conry.
Erosion of blanket peat in the Erriff Valley: David Hickey.
Birchwood on cutover bog at Lackan Bog: Robert Thompson.

Comme quelqu' un pourrait dire de moi que j' ai seulement fait ici un amas de fleurs étrangeres, n'y ayant fourni du mien que le filet ales lier.

One could say of me that all I have done here is to make a bunch out of flowers gathered by others, my only contribution being the string that ties them together.

MONTAIGNE

To the memory of Michael Feehan (1949-1995), Wildlife Ranger,
my beloved brother.

J.F.

Chapter One

Saving the turf

Tho' they are very inconvenient to us, yet they are of some use; for most of Ireland have their firing from them; Turf is accounted a tolerable sweet fire, and we having very impoliticky destroyed our wood, and not as yet found stone coal, save in few places, we could hardly live without some Bogs: I have seen turf charc'd it serves to work iron, and as I have bin informed, will serve to make it in a bloomery or iron-work: turf charcoal I reckon the sweetest and wholsomest fire, that can be; fitter for a Chamber, and consumptive People, then either wood, stone-coal or char-coal.

William King (1685): ***Of the Bogs and Loughs of Ireland***

Figure 1.1: The slanesman. Oisin Kelly's bronze sculpture outside the Blackwater works of Bord na Móna.

Introduction

The bogs were the last wilderness to take shape in the Irish landscape in the wake of the Ice Age. As they expanded, they forced back the tide of farming, and then kept the fields at bay along their inhospitable frontiers. During the first farming millennia little could be done to reclaim these barren, wet deserts and replace them with friendly fields as had been done with most of the forest wilderness. Only rarely were the bogs resorted to – to bury butter, to take a short cut, to hide the bodies of the murdered. This outlook on the bog changed for two related reasons. One was the disappearance of woodland, and the increasing scarcity of wood as a domestic fuel; the second was the increasing population.

As the woods contracted and the bogs increased in area, turf began to be used more widely as domestic fuel. The discovery that turf burns was easily made: the conflagrations that periodically swept across the heathery expanses in hot summers provided the clue. Where houses were made of wood, which was almost always the case, turf had certain advantages as a fuel. The evidence suggests that turf was not considered an inferior fuel; it burned low and evenly, and there was much less danger of a burning splinter setting fire to the house. In medieval times it was burnt in monastery and manor as well as in the cottages of tenants, and the cutting, saving and transport of turf formed part of the customary duties levied by the owners of the land on their tenants. As farming people became more familiar with the edges of the bog, they began to realise that peatlands were not as intractable to farming as they had seemed. If they were drained and liberally manured they could be made to grow grass and crops.

Figure 1.2: Cutting turf by the breast slane method in the west of Ireland.

Estimates as to how much bogland has been cut away by hand down the centuries vary from a figure of around 750,000 acres to twice as much as that, but it is very difficult now to be accurate. By the time Bord na Móna took over the great Bog of Allen in the Midlands, almost half of it had already been cut away; most of the remainder has since been developed by the Bord. During the 18th and 19th centuries – indeed, down until the Second World War when turf was the only fuel most people had, something like 5 million tons were being cut every year. It was estimated that between 1814 and 1907 something like 800,000 acres of turf were cut away. Down to 1917 the official agricultural statistics included a separate heading for peat bog. In that year the area recorded as 'turf bog' was 766,353 acres, with an additional 463,297 acres of barren mountain and 339,297 of marsh, which probably included substantial areas of bog. In 1921 it was estimated that 6 million tons of turf were being cut for household purposes each year, even though the population was much less than it had been in the early 19th century. At this rate of consumption it was thought that there was enough fuel in the bogs of Ireland to last 700 years. The production of hand-cut turf by farmers peaked at well in excess of six million tons around 1926 [**Table 1.1**]. By the late 1920s there was a dramatic reduction to around three and a half million, and production continued at around this level until World War 2. In 1941 more than four and a half million tons of turf were cut by farmers, but the amount has steadily decreased since then.

During the Second World War, when no coal for household use was coming into Ireland from Great Britain, turf became a vitally strategic resource. But with the end of the war, hand-cutting began to decline. Oil was cheap and readily available, and with the coming of Bord na Móna and rising standards of living, the parochial self-sufficiency of earlier times was considered outmoded and unnecessary. By the 1970s annual production of hand-cut turf was down to about a million tonnes a year, harvested mainly from the blanket bogs of the west.

Two recent developments have reversed the downward trend in private turf-cutting: the invention of small, versatile turf harvesters, which operate profitably and efficiently on a small scale, and the passing in 1981 of the Turf Development Act to encourage the private development of smaller bogs. In the first six months of its operation 21 groups or co-ops applied for grants under this scheme.

TABLE 1.1. PEAT PRODUCTION BY FARMERS 1920-1950	
YEAR	**x 1,000 tons**
1920-26	**n.a.**
1926	**6397**
1927	**n.a.**
1928	**n.a.**
1929	**3567**
1930	**3259**
1931	**3529**
1932	**n.a.**
1933	**3494**
1934	**3310**
1935	**3658**
1936	**3623**
1937	**3589**
1938	**3339**
1939	**3866**
1940	**4235**
1941	**4522**
1942	**4245**
1943	**4377**
1944	**4344**
1945	**4300**
1946	**4007**
1948	**3574**
1949	**3775**
1950	**2848**

Central Statistics Office data

A short history

The traditional methods of winning turf by hand in Ireland are much the same as those that were in use in the extensive bogs of north-western Europe. The slane and the turf barrow are not Irish inventions; they are an adaptation to Irish conditions of ancient tools developed in northern Europe [**Figure 1.3**], in much the same way as the ingenious machinery of Bord na Móna which took the place of the slane in the Irish bog is an Irish adaptation of machinery developed for the bogs of northern Europe and Canada.

The earliest account of turf cutting among the Celtic peoples of Northern Europe is in Pliny's *Natural History,* which describes the harvesting of turf during the first century A.D. among the Germanic people between the Ems and the Elbe – the Chauce – on the North Sea coast of Germany:

> They weave nets of rushes and sedges to catch fish; and form mud with their hands, which, when dried in the wind rather than in the sun, is burned to cook their food, and warm their bodies chilled by the cold north wind.

Another classical writer described the Celtic Batavi as being so wretched that 'their drink is the drink of swine, and they burn their very earth for warmth' – in other words, they drank beer and burned turf: '*O miseram gentem quae cibum suum bibit, et terram suam urit'*. Latin writers often described turf as *'caespes bituminosum':* combustible soil. Cardinal Piccolomini, who later became Pope Pius II, wrote in 1458 how the inhabitants of Friesland 'make fires of combustible earth, since they lack firewood' *(ligna caret bituminoso caespite ignes fovet).* During the course of archaeological excavations in 1943 at a place on the German-Danish border called Norre Smedeby, turf cutting tools and even actual cut sods believed to date to the 2nd or 3rd centuries B.C. were found, and there is also archaeological evidence for Iron Age turf cutting in Scandinavia.

However, we do not need to look so far afield for hints of the antiquity of turf cutting in Ireland. Beneath the bog that is situated between the Hill of Goig and Castleconnel in County Limerick a togher was found at some time in the last century, and beside this, under at least 20 spit of turf, there were old bog holes and the remains of wooden slanes. Slanes have also been recovered deep in a bog in County Laois, and there are indications of old turf banks under the upper peat of Ardee Bog in County Louth. In 1833 half-burnt sods of turf were found beside a hearth excavated under 8m of peat at Drumkelin bog in County Donegal.

These tantalising archaeological glimpses are supported by occasional references to turf-cutting in the Old Irish law-texts. In the *Senchas Mar,* which dates from the 7th-8th centuries, turf cutting is described in terms that would be quite familiar to us today; however, for the few turf-cutting references the comments of the 12th century glossators are more informative. One seventh-century law-text includes 'the ditch of a turf-cutting' among the seven ditches that are exempt from liability in the case of accidental drowning. The fine for cutting turf illegally was very substantial: 5 *sets* (equivalent to two and a half milch cows). In the late 11th century tale *Aislinge Mheic Can Glinne* there is a reference to

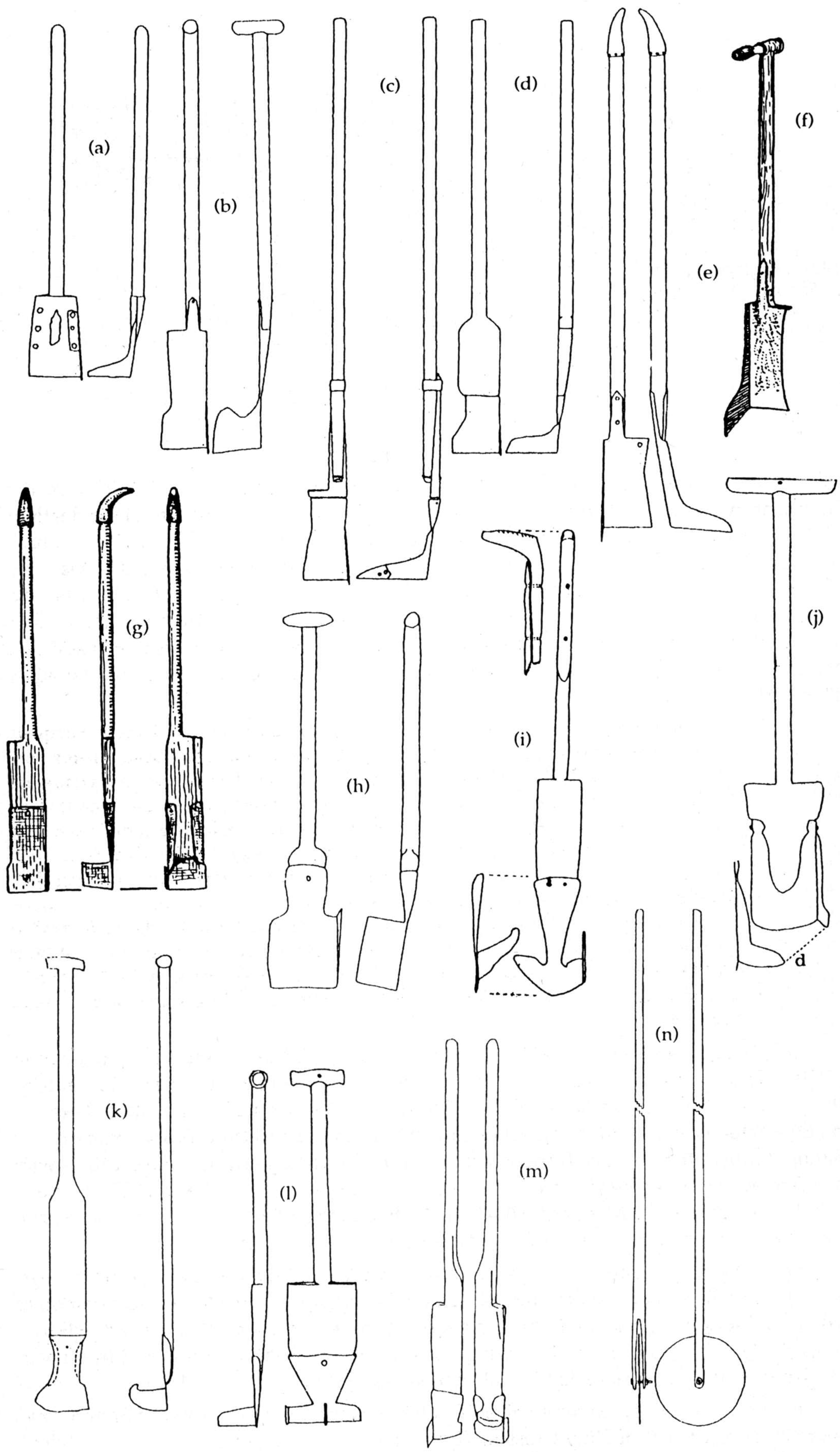
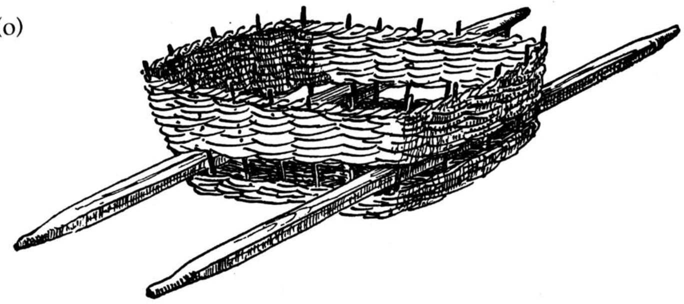
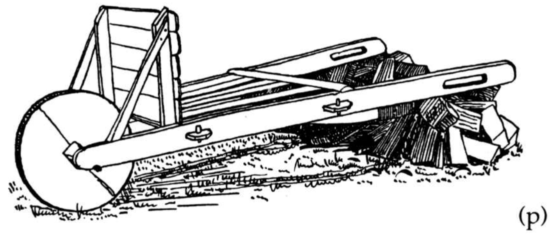


Figure 1.3: Tools for the bog

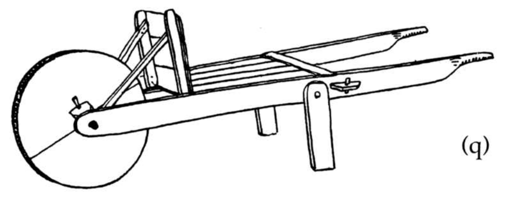
(a-n) Slanes and turf spades
Turf spades need to be as light as possible. Irish slanes were usually made from a light wood like elm or larch. In Norway pine was often used.
(a) Internal socket slane, Attymon, County Galway (NMI F.1961:24);
(b) Long open socket slane, Keady, County Armagh (UFM 272:1967).
(c) Short open socket slane, Derry, County Galway (NMI F.1963:222).
(d) Short open socket slane, Lackagh Beg, County Galway (NMI F.1961 :16).
(e) Strap socket slane, Kildare (NMI F.1963:216).
(f) Strap socket slane, County Derry (Evans, 1942).
(g) Open socket slane, Glendun, County Antrim (Evans, 1942).
(h) English peat spade from Rosedale Moor.
(i) Peat spade from southwest Scotland (NMAS).
(j) Scottish peat spade, Angus Folk Collection.
(k) Welsh peat spade, Tywyn, Merioneth (WFM 12.100/7).
(1) Danish two-winged peat spade, North Rangstrup county (DF 4599/1967).
(m) Norse peat spade, Sunnmore, More and Romsdal (De Heibergske Samlinger 12747).
(n) Danish implement for cutting mud turf, Baarse county (DF 411/1945).
(0) Turf cish from County Armagh (Evans, 1942).
(p) Turf barrow from County Meath (Evans, 1942).
(q) Turf barrow from County Antrim (Evans, 1942).
Drawings from *The Spade in Northern and Atlantic Europe*. Gailey and Fenton (Eds.), and *Irish Heritage* (Estyn Evans).

(o)





(p)



(q)

a fire made with two sods of turf and some oat chaff. A tale from the Fragmentary Annals in Standish O'Grady's *Silva Gadelica* gives an account of the death of a 7th century king of Connaught, Raghallach mac Fuatach, at the hands of a party of turfcutters. Although the incident is supposed to have taken place in 648 A.D., the tale is more recent by many centuries, and although it is full of mythological elements, the background detail of the turf-cutters describes a familiar may time *(Bealtaine)* activity that was certainly familiar to listeners of the story. By way of preface, it is necessary to add that Ragallach was a proper scoundrel, 'self-willed and full of malice', whose demise the saints have been prayerfully plotting.

> The saints prayed that before Beltane, and at the hands of mean folk, he by weapons of dishonour should perish in a foul pit. All which was fulfilled: for Beltane being now at hand, a wounded stag rushed upon Raghallach in the island where he watched. He seeing the deer approach took his spear, and with a thrust pierced him from the one side to the other; yet by swimming he escaped, and Raghallach getting into a boat pursued the deer, which from the loch went a great way and until he came upon certain churls that cut turf. These killed the stag and divided him. The king then coming up loudly threatened them by reason that they had broken up the deer, commanding them to yield him the venison. But among them the churls decreed to slay Raghallach the king before they would upon compulsion give up the flesh; and this their design they verily executed with the turf-spades that were in their hands, dealing him strokes on the head that left him lifeless, according to precise promise of the saints.

It is clear from these references that turf was regarded as an important resource in Gaelic Ireland, and that it was widely used as fuel. Later, from the end of the 12th century, the bog and its traditions were adopted by the Anglo-Norman colony, and there are frequent references to it in medieval documents. In the early 14th century Extent of the Manor of Moyaliff in County Tipperary the value of the *turbary* – the right to cut turf - with the road leading to the bog is valued at *iiijs* per annum – a considerable sum. The value of turbary on a bog in the Manor of Thurles in 1303 was ten shillings: *'una mora que vocator Loweny et extendunt turbarium eiusdem per annum ad xs'.*

Several 13th and 14th century entries in the *Calendar of Ormond Deeds* relate to bogs. One of the earliest, dated September 14, 1343, refers to a grant to a tenant of common of turbary of Morlogath; also the right to cut sods, stakes and trunks *(ad habendas et fodiendas glebas et 'stokys' et 'trunkes')* and carrying away *setum* (?rushes) wherever and as often as he wishes in his tenement of 'le Molrath' and Cradokestown.

In another deed, dated September 30, 1361, Thomas Stapiltun, Lord of Ferten, gave the abbot and convent of Holy Cross in Tipperary 'the right to go and return through all his land of Ferten with their horses, carts, carriages and cars *(bigis quadrigis et carhis),* to carry and take away sods, turf *(focalia)* and all other necessaries from the bog *(mora)* of the said abbot, etc., to their monastery and to all their townlands and granges as often as they wish, rendering nothing therefor to him or his heirs for ever'.

Later on, Shane Mac Dermot O Downey of Knocktopher, giving evidence to a Commission which sat between 1589 and 1594 to establish the bounds of the Earl of Ormond's ancient estates, describes how 'he took from tyme to tyme rent of such of the neighbours as took upp turf in the sd. moore [the turf moore of Lower Dirrenehenchy] and killed connyes [rabbits] uppon the lands of Ballaghetoore'.

An especially interesting entry in the Ormond Deeds relates to the area of Pollrone in Kilkenny. One of the witnesses who gave evidence of the Extent of Ormond at the end of the sixteenth century informed the tribunal how he

> sawe and knewe the tenants of Powlroan without disturbance ... quietly and frelly take and cutt turves uppin the said moore called Monekayne and take the said turves from thence quietly and frely. And also sa we and knewe the cattell of the said Powlroan quietly pasture upon that part of the said moore within the said meares without disturbance ...

Another witness, Nicholas Henebrie, a former sergeant to the constable Phillip Henebry, added that earlier in the century the constable had told him 'not to suffer any to take the profits of the said part of the moore ... but only the tenants of Powlroan':

> Also that when any of any other towne besides Powlroan did by licence take or cutt turves in the said parte of the said moure during the tyme of this deponent being sargeant to his said master Phillip Henebrye, this deponent tooke sargeant fee called 'arriged porte' of the said other Townsman.

From this it appears that each townland had its turbary rights on a particular bog; outsiders had to get permission, and if this was granted they had to pay a fee: *airgead portaigh:* – bog money. In early Ireland the bog was regarded as common to all members of the family who owned a territory, although a particular bank might belong for a time to a particular individual.

The right of the lord to demand a certain number of days' work on the bog each year from his tenants can also be found in the medieval documents; in the Extent of the Manor of Crenagh taken at the end of 1415 and recorded in the *Red Book of Ormond* we read:

Figure 1.4: Connemara women carrying turf home in baskets.

... *Item dicunt [iuratilquod quilibet tenens debet domino de custumis turbariae videlicet pro tractione* &c *j diem* ... (They also say it was customary for each tenant to give 5 days to his lord drawing turf and so on).

In the densely populated area of the Pale around Dublin, some raised bogs seem to have been cut away as early as the 13th century. Fingal Bog was cut away by the early 14th century, and Garristown Bog along the River Delvin in the north of the county ('the Redmore in Gariestown') was under cultivation in 1337, and was common pasture by 1348. Both upland and lowland bog often had the status of commonage in medieval times.

In earlier centuries, where deep bog had little value as land that could be used for other purposes, it seems to have been general practice that every family holding land around a particular turbary enjoyed the right to cut their annual supply of turf from it. The custom which allowed tenants to take their year's household supply of turf from the bog, but did not allow them to sell any of it, undoubtedly has its roots in the medieval tenant's right of turbary.

It appears likely that turf only came to be used widely as fuel in Ireland after wood became really scarce. The arrival of improved techniques with the new settlers of the sixteenth and seventeenth centuries may also have helped to accelerate the pace of incursion into the bogs:

> To judge from the bright red ashes one frequently sees in the excavated hearths of Dark Age habitations, peat was used as firing before history begins in upland areas and along wind-swept coasts. But we may accept the view that over most of the country turf cutting on its historic scale developed, probably under the stimulus of improved techniques brought in by English settlers after the major forest clearances of the sixteenth and seventeenth centuries. There is some evidence from some parts of the country, for the eighteenth century, that the cutting of peat for winter use was one of the occupations of transhumant herders who took their livestock to the bog pastures in summer. (Estyn Evans: *Irish Folk Ways).*

In most parts of Ireland turf had probably become the principal fuel for most people by the seventeenth century. When Fynes Moryson wrote his account of Ireland in 1605-17, people still burnt wood wherever it still grew, and he claimed that 'great woods or low shrubs and thickets' could still be found in most parts; in other parts, he claimed, they burnt turf and imported coal. By the time Gerald Boate came to write his view of Ireland's natural history in 1645, it was 'very much used throughout all the land', and in Petty's time in the late 18th century it was the main fuel everywhere, even where wood could be got, because it was easier to cut and carry:

> Their fewel is Turf in most places; and of late, even where Wood is most plentiful, and to be had for nothing, the cutting and carriage of the Turf being more easy than that of Wood.

The choice between wood and turf did not last for much longer. A little earlier, in 1681, Thomas Dineley described how

> The Warres and their rebellions, which have been so frequent here, having destroy'd almost all their woods both for timber and fireing; this want is supply'd by the boggs.

But in the beginning, the inroads made into the bog by small self-sufficient communities were relatively slight, little more than tentative nibbles at its vast fringes. Each townland and each household in the townland had its own carefully defined turbary rights.

> In towns [i.e. townlands] set to farmers, every house hath appropriated to itself a share or portion of the bog for turf cutting, by known measures and bounds, which whoever comes to that house is to enjoy so long as he lives in it.

But as the Irish population began to grow from the early 18th century, those nibbles became larger and larger bites. And it was not only the rural population which now depended on turf for fuel: so did the people in the growing cities and towns. In the bog areas, the turbary rights of earlier times survived; in some cases right of turbary was confined to the right to cut turf for your own use but not to sell it.

As the population grew, and as Dublin in particular began to grow, turf cutting on a large scale to supply the needs of the city began in those bogs that were within economical reach. This was greatly facilitated by the extension of the Grand Canal through the Bog of Allen as far as Monasterevan in 1786. In the early part of the 19th century 30,000 tons of turf were being shipped to Dublin from the Bog of Allen by canal every year. The price of turf 'on the canal bank' rose from 2/8d a ton in 1825 to 3/9d in 1844 and to 5/3d in 1866, but by the time it reached the consumer in Dublin it was very much higher – high enough at times to provoke riots against the avaricious boat-owners.

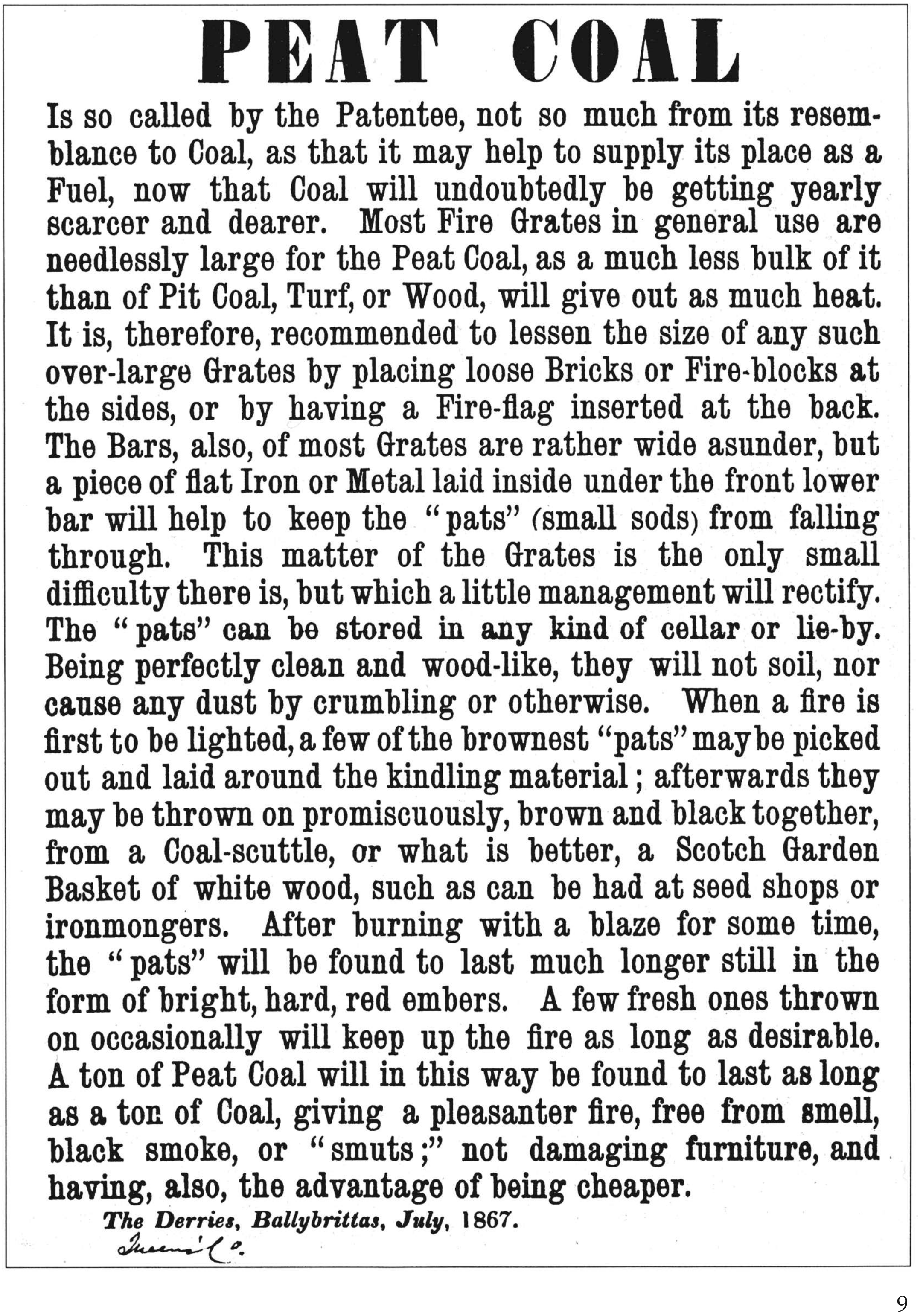
Figure 1.5: Turf carrier below Brandon Mountain on the Dingle Peninsula (Bord Fáilte).

The turf cutters themselves lived a wretched life, often in heather-covered caves hollowed out of a dry bank on the bog. In the 1640s labourers working on the bog in the earlier part of the year - when they would find it hard to get work – got 3d a day for men, and 2d a day for women besides their meals; later in the season the daily wage was 4d a day, and when labour was scarce, 5d.

One of the most successful turf-cutting enterprises of the 19th century was in Mona Bog along the Shannon, between O'Brien's Bridge and Castleconnel, which provided work for several hundred people from around 1825 until the end of the century. At the height of the enterprise, 5,000 tons of turf a year were ferried down the Shannon to Limerick. Unlike most other turf-cutting enterprises, this was a regular industry, not merely a seasonal occupation carried out when time could be taken off from other labour. A canal was cut from the Shannon into the bog, and branches from this served for drainage and transport. All the turf was destined for a distillery in Limerick to begin with, but when the distillery ceased operations around 1842, the turf went on sale to the general public. By 1875 around 200 acres of cutover had been reclaimed for cultivation.

One of the most remarkable hand turf enterprises of the 19th century was that set up by Robert M. Alloway in Laois around the 1860s and 1870s [**Figure 1.6**]. Alloway had a rather jaundiced view of mechanisation, and the failure of the many attempts by people like Jasper Rogers, Wye Williams, Rees Reece, Henry Gould, Henry Newton and Charles Hodgson (Chapter 3) gave some justification for his negative view. He was particularly scathing about attempts to use artificial heat to dry turf – 'so stupid a notion as to be scarcely worth alluding to'. He felt that the complicated machinery was too costly and unmanageable, and that earlier developers had an insufficient understanding of the nature of the material they were working with.

> I have, in consequence, discarded, as impracticable and unprofitable, Lord Willoughby d'Eresby's hydraulic presses, Cobbold's cylindrical churns, Glynn's steam rams, &c., &c., with all kinds of hot air blasts, heated tables, hot flues, kilns, &c., and simplified step by step, an economical, common-sense working plan, on plain,



PEAT COAL

Is so called by the Patentee, not so much from its resemblance to Coal, as that it may help to supply its place as a Fuel, now that Coal will undoubtedly be getting yearly scarcer and dearer. Most Fire Grates in general use are needlessly large for the Peat Coal, as a much less bulk of it than of Pit Coal, Turf, or Wood, will give out as much heat. It is, therefore, recommended to lessen the size of any such over-large Grates by placing loose Bricks or Fire-blocks at the sides, or by having a Fire-flag inserted at the back. The Bars, also, of most Grates are rather wide asunder, but a piece of flat Iron or Metal laid inside under the front lower bar will help to keep the "pats" (small sods) from falling through. This matter of the Grates is the only small difficulty there is, but which a little management will rectify. The "pats" can be stored in any kind of cellar or lie-by. Being perfectly clean and wood-like, they will not soil, nor cause any dust by crumbling or otherwise. When a fire is first to be lighted, a few of the brownest "pats" may be picked out and laid around the kindling material; afterwards they may be thrown on promiscuously, brown and black together, from a Coal-scuttle, or what is better, a Scotch Garden Basket of white wood, such as can be had at seed shops or ironmongers. After burning with a blaze for some time, the "pats" will be found to last much longer still in the form of bright, hard, red embers. A few fresh ones thrown on occasionally will keep up the fire as long as desirable. A ton of Peat Coal will in this way be found to last as long as a ton of Coal, giving a pleasanter fire, free from smell, black smoke, or "smuts;" not damaging furniture, and having, also, the advantage of being cheaper.

The Derries, Ballybrittas, July, 1867.

Figure 1.6: Poster produced by Alloway to advertise his 'peat coal'.

> but scientific principles, by which a dense portable, wood-like (rather than coal-like) substance, can be made at once from the soft, wet peat, consolidated without pressure and dried in a few days (generally three or four), by atmospheric evaporation alone'. In arriving at this desirable result, I always kept in mind the laws of capillary attraction, and atmospheric evaporation alone.
>
> In place of machinery and hot plates or flues, I have enlisted the services of three grand natural wonder-workers, who do what I want without cost, payment, or grumpling – viz., in summer, the sun and the wind; in winter, the rain. In winter the rain lends great help to the mashing or pulping; in summer the sun and wind dry my product, in much less time than any artificial heat or wind machine ever did, and at a twentieth part of the cost.

Alloway was thus very keenly aware of the greatest problem presented by peat as a fuel: its very high moisture content and the difficulty of drying it economically. To get rid of the 9kg of water contained in 10kg of fresh peat takes 5,760 kcal of nature's energy. The remaining 1kg of dry peat has only 5,100 kcal of energy. This shows very clearly the inefficiency of trying to dry peat artificially.

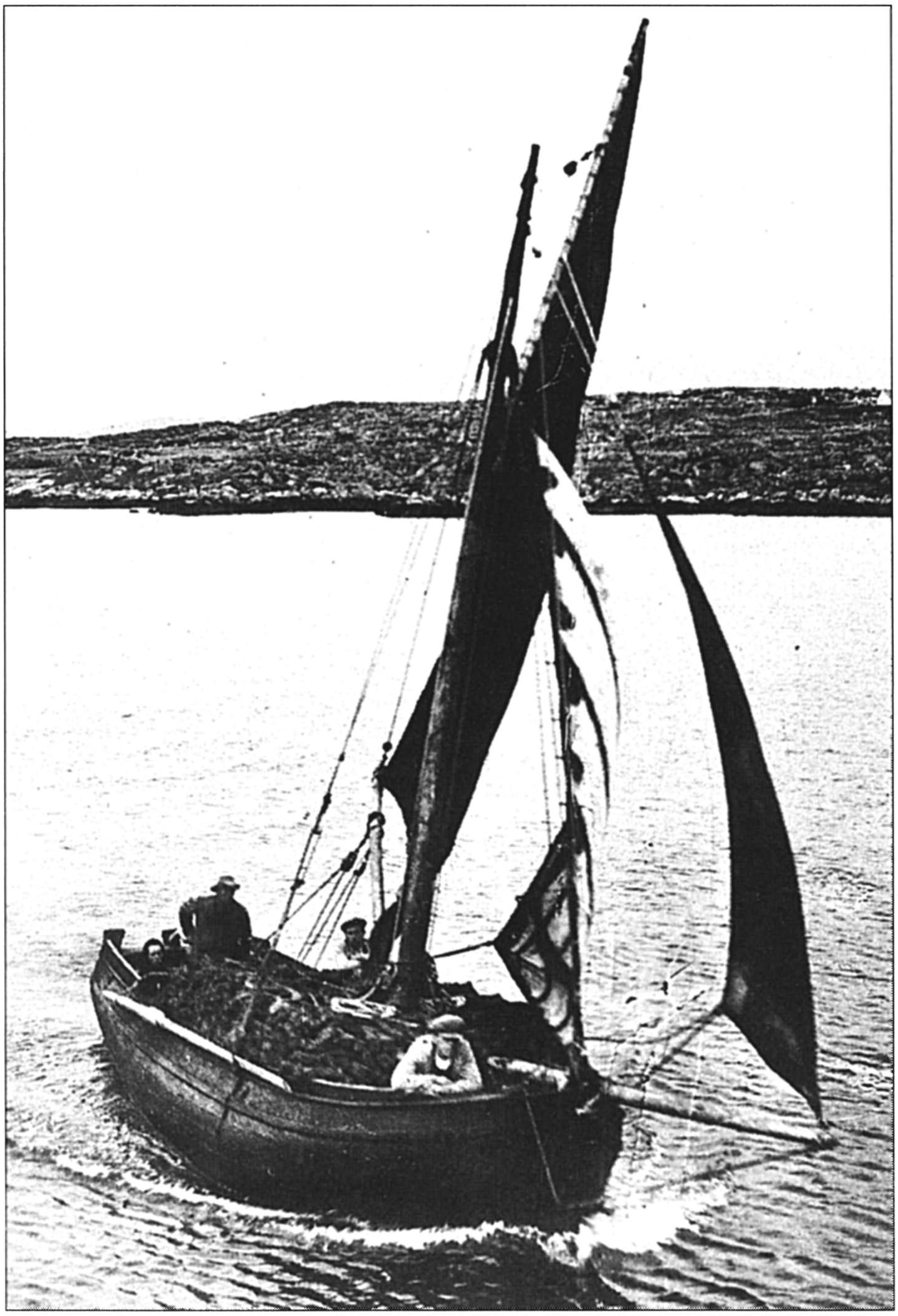
Alloway looked on his operation as a specialised kind of farming. The raw material was dug out and prepared during the winter months, using a macerating machine that he had himself invented to mince it up. As soon as – and if – the weather became dry enough in April, this mush was wheeled in barrows from the peat tank where it had been stored over the winter to the moulders, who were for the most part women, boys and girls, one barrow-man supplying between four and six moulders. The moulders shaped the sods by hand at an average rate of about 200 pats a day with the help of four-foot plastering laths on long moulding tables 36′ long by 4′ wide. Skilled hands could however make as many as 2,000 a day; the rate of pay was 3d a table, so skilled workers could earn what was good money for the time. The sods of condensed peat took a few days to dry on the tables, after which they were raked into wheelbarrows. They were then ready for the market, and the tables were ready for the next batch of turf mush. In this way 30 to 40 crops of condensed peat could be produced in the same space and without any waste – as long as the weather was dry enough, which in some years was not very often.

One of Alloway's working bogs had 150 moulding tables, which gave an annual output of 750 tons of peat, but he envisaged that a full-sized 'manufactory' would have 10,000 tables. He claimed that he had produced as much condensed peat in one year as Hodgson's recently-closed factory had managed to produce in six, without machinery and drying costs, and with only a third of the work force.

Alloway was particularly enthusiastic about the possibility of extending 'this healthful employment of young children from 10 to 15 years of age', considering that 'it would prove an admirable industrial school for the flocks of young boys and girls now rearing up in idleness and worthlessness in our poor-houses'. To his way of thinking, hand turf was so superior that all turf should be made this way, and his approach to large-scale production was based on this conviction.

Alloway was not alone in his scepticism about the advantages of machines for cutting turf. Another advocate of hand-won turf was R. Going, C.E., who penned his arguments in its favour in various newspapers in the early 1870s. The colourful account of the arrival of the machinery for the new Banagher Peat Works at Birr in 1873 in *The King's County Chronicle* (See page 85) has a sober letter from Going in the adjoining column arguing the superiority of the slane.

In the 18th and 19th centuries in particular, large amounts of turf were cut in Connemara and transported by traditional Irish sailing craft – hookers, *gleoiteoga* and *leabhaidi* – across to the bog-free Aran Islands and the Burren in Clare **[Figure 1.7]**. These boats linked a large network of little harbours in Connemara with the port of Kinvara, the main point of entry on the opposite side of Galway Bay. Farmers from south Galway and north Clare would buy the turf, and carry it home by cart. The trade continued until the end of World War 2, when it quickly gave way to transport by lorry; the annual Cruinniu na mBad festival at Kinvara in August commemorates this forgotten chapter in Irish maritime



history. A considerable quantity of turf was also shipped from Poulanishery in Clare to Limerick Bay, a distance by sea of forty miles, 'for the supply of which trade, immense ricks are always ready on the shore; and sometimes the boats return laden with limestone from Askeaton and Aughinish' (Lewis' *Topographical Dictionary* entry for County Clare).

In the later 19th century turf was not only a vital, but at times a strategic resource. People had to have their annual supply of turf; indeed, sometimes in the days of the Land League people took care to pay their turbary dues even though they withheld payment of rent. Landlords were occasionally known to refuse turbary rights in order to punish tenants who had offended them: for example, Bernard Fitzpatrick, son of Lord Castletown, was accused of refusing to set turf banks to one Thomas Carroll or to any of his friends because he had opposed Fitzpatrick's wish to have soldiers quartered in Donaghmore Workhouse in 1881.

By 1912, 15,000 tons of turf were making their way along the Grand Canal every year to Dublin on boats which could carry turf loads of between 30 and 60 tons; by 1920 this had fallen to 6,500 tons. But the turf that reached the city tended to be of poorer quality, partly because the better black turf was kept for use by the turf cutters and their local customers. The wholesale turf dealers could buy turf from the cutters for as little as 7/ 6d a ton before the First World War; it rose to 18/= during the war. In Dublin however, this turf was sold at a penny for two, three or four sods, which worked out at about 40/= a ton – not that much cheaper than coal, which was 47/= a ton.

Figure 1.7: Transporting turf by hooker from Connemara to the Aran Islands.

The cost of overland transport had always been one of the great obstacles to turf as an economic fuel; the canals brought about a considerable reduction in this cost. One of the great advantages the Dutch had enjoyed in the exploitation of their vast peat deposits was the dense network of waterways in the Netherlands. The Dutch agronomist J.W. de Zeeuw believes that the ready availability of peat fuel played a large part in the flowering of the Dutch urban economy and culture in the 17th century.

Turf and the co-operative movement

In 1904 the *Journal of the Department of Agriculture* published three communications on the subject of 'the manufacture of peat fuel in Ireland', which reported the findings of the German peat expert J. Tissington Tatlow. Tatlow had come over from Schleswig on Horace Plunkett's invitation, at the instigation of Arthur Steel Lough of Killeshandra CoOperative Society in County Cavan, to explore the prospects for mechanised turf production on a co-operative basis. The first experiments were tried at Killybandrick Bog near Killeshandra – a mud turf bog – in June 1903, arousing great local interest. The machinery consisted of a gravity-driven bucket excavator and a horse-powered macerator. A team of ten men and boys and two horses produced 14,000 sods a day (6.5 tons when dry). The sods were ready for footing in a week, in a year when the summer was so wet that the Killeshandra turf was 'the only dry turf in the country'. In spite of the weather, and difficulties arising from the use of horses on a wet bog and separation of the excavation and maceration processes, the turf was produced at a cost of 6/4d a ton compared with 10/- for hand-won turf. Encouraged by this, the Cavan Co-operative Turf Making and Peat Moss Litter Company was formed in 1903. However, the initial enthusiasm faded in the face of problems due to capital costs, transport charges, organisational difficulties and a reluctance to persist with the new methods, especially when it meant relying on foreign expertise.

In 1933, co-operative turf societies were established on a county basis by C. S. Andrews in order to promote the production and harvesting of hand-cut turf, and to facilitate its direct sale by the producers. The organisation of the societies was done by the Irish Agricultural Organisation Society on behalf of the Peat Development Section of the Department of Industry and Commerce, which organised the sales of the turf in bags. The Department set a standard of 30% moisture, 6% ash and a density of 0.9 for the turf produced. The scheme was operated at county level by County Council surveyors and engineers. 33 societies registered in the first year (1933) and 124 in 1934. In that year the Turf Development Board Ltd was established to take charge of the societies, which between them produced 200,000 tons of turf, to be sold at a fixed price of 11/6 a ton. Transport was a major cost, even in the early years when turf was transported by rail at a concessionary rate of 6/ - a ton. The societies met with varying degrees of success. Those within reach of the Dublin market were well-organised and profitable, whereas in Connemara, where there was no tradition of organised cutting and selling on a regular basis, they were more or less a failure. In 1940, 134 societies failed to make their returns to the Registrar and were cancelled, but by this time the Board was losing confidence in the societies in any case because they often reneged on contracts to supply turf if they could sell it themselves locally at a higher price, and because of arguments over drainage and road construction works.

The provisions of the Turf (Use and Development) Bill of 1935 were largely designed to promote the use of turf. Under this bill, whenever a coal merchant sold a quantity of coal, he had to dispose of an equivalent weight of turf. A scheme of a different kind to promote awareness of turf as a fuel was the National Turf Cutting Championship, which was organised for the first time at Allenwood in 1934. This became an important and popular annual spectacle in the years before the War, with hundreds of contestants and thousands of supporters. At the 1939 event the Dutch Consul General promised to bring over a Dutch team to contest the championship the following year, but the outbreak of war smothered this plan.

Although almost all the turf cut by hand was used as domestic fuel, there were instances where it was used for industrial purposes. Between 1906 and 1922 the Marconi trans-Atlantic wireless station at Clifden was powered by turf-fuelled steam engines, using some 8,000 tonnes of hand-won turf a year; the station was destroyed during the Civil War. Between 1911 and 1920 the 500-loom Robb Linen Factory at Portadown was powered by peat gas produced from 3,500 tonnes of hand-won turf a year.

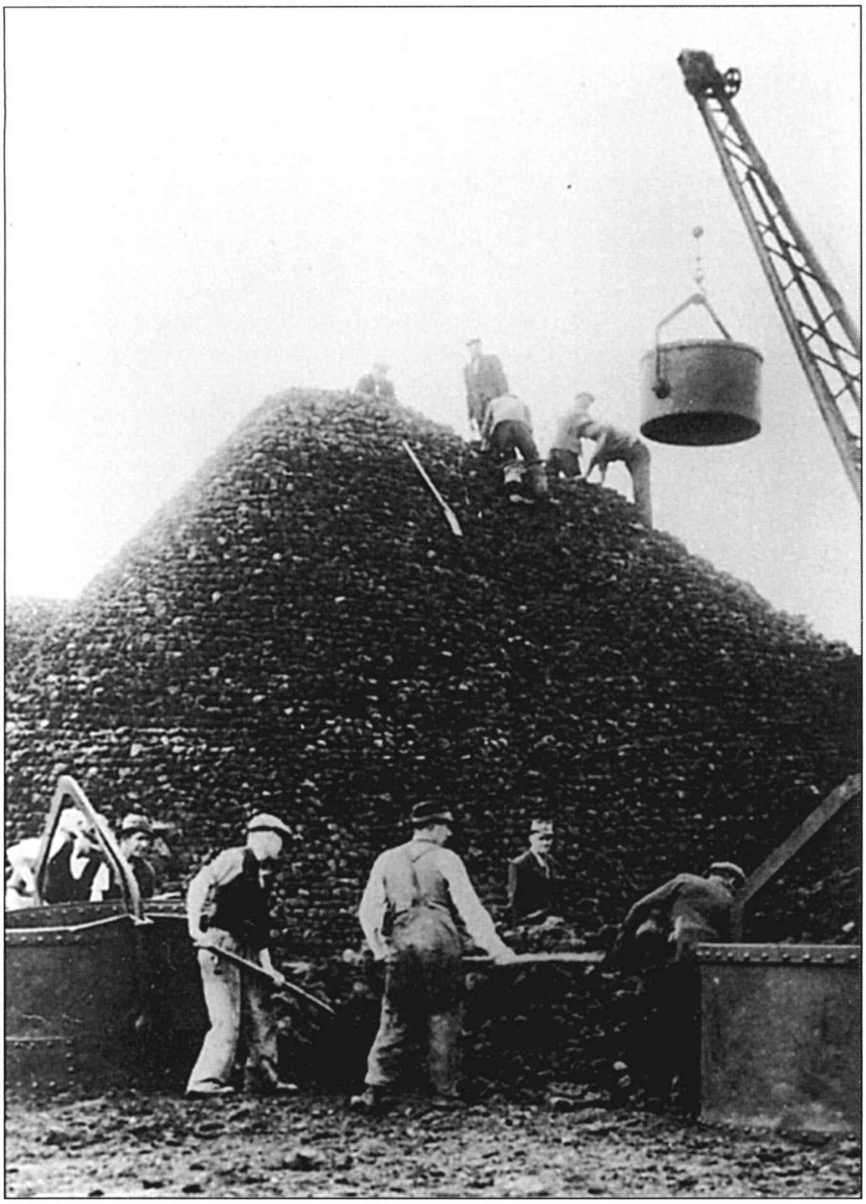


Figure 1.8: Hand-won turf in Phoenix Park.

During the harvesting season in the late 1940s a fleet of 200 lorries was engaged in the transport of 10,000 tons of turf a week to Dublin. Annual production on the scheme was about 130,000 tons. Between 1942 and 1947 over half a million tons of turf were delivered to the Park in this way.

The turf campaign of the war years 1940-1946

The greatest concerted attempt to utilise the resources of the bog took place during the Second World War [**Figure 1.8**]. After the spring of 1941 coal supplies for domestic use dried up, and the bogs were called upon to provide the entire fuel needs of the country, replacing the two million tons of imported coal. The Government appointed the Cork TD, Hugo Flinn, as Turf Controller, a job that he threw himself into heart and soul; the credit for keeping the country supplied with fuel during the War was due largely to his energy, inventiveness and organising ability. Because such a vast enterprise could not be organised efficiently from Dublin, the Government (at Flinn's instigation) empowered the County Councils to take over and work bogs, using compulsory purchase if necessary. The Councils responded with enthusiasm and efficiency; their workforce had little else to do because of wartime shortages of materials, and under the direction of the County Surveyors and Engineers bogs in every county were worked as never before through a series of 'Council Direct Labour Bog Development and Turf Production Schemes'. To help him with the organisation and management of the task, Flinn appointed a Turf Executive with himself as chairman. The Land Commission and the Special Employment Schemes Office were also enlisted for the campaign, and the Office of Public Works was put in overall charge of transport. The Turf Development Board was given the task of organising an efficient marketing system. Parish Councils had the task of ensuring local self-sufficiency in rural areas; this often led to genuine co-operative effort, but there were organisational difficulties due largely to the lack of a tradition of real participative democracy.

Mile after mile of new bog face was opened up, and already by 1941 around 1,000 bogs were being worked, in every county in the Republic. Even bogless Wexford, which had used up all the accessible turf from its bogs on the Blackstairs in the 19th century, did its best, cutting away the blanket peat from Moneer Bog, 2,000' above sea level on Mount Leinster. A new 3.5 mile road was built to give access to this remote bog in 1941; in the summer of 1943, 160 men, boys and girls were busily at work on top of the mountain. Along the County Clare seashore at Seafield and Kilkee, and in several other places even sand-covered intertidal peat deposits were exploited during the War – a particularly laborious task since the rising tide filled the excavated trenches anew with water every day.

The County Council teams saved something like a million tons in 1941 (the first season of the scheme), and by the time the scheme ended in 1947 it had harvested a total of over three million tons. Family production accounted for a further million tons a year. By the summer of 1941 some 30,000 workers were employed in the Government turf schemes, with an output of around 100,000 tons a week; a bank 50 yards long and two yards wide by 7.5 feet deep would yield 25 tons of dry turf (dry means 25% moisture), with about 1,500 sods to the ton. As many as 15,000 people were at work under various other schemes organised by Parish Councils, institutions, industries and thousands of households and individual entrepreneurs.

There were considerable difficulties with the campaign. Transporting such vast volumes of turf to the cities was one. This was especially so with Dublin; it was difficult to get large amounts of turf into the city from the bogs of Kildare by road, so attempts were made to promote cutting in the Dublin-Wicklow mountains and to get turf from the bogs along the Grand Canal. Thousands of Dubliners made their way into the Dublin Mountains to save their own turf, and there was extensive harvesting in areas like the Sally Gap and Glencree. Another problem was the cost of turf and its unreliable quality; the price of turf had to be comparable with coal, and the cost of transport made this very difficult. Turf which could be bought for 10/ - a ton by the roadside in Connaught might cost at least four times as much – and often considerably more – in Dublin. In 1944 the price of turf in Dublin was 94/10d a ton, whereas the cost of production was only 39/7.5d. Much of the turf delivered to the city was of inferior quality, especially in relation to water content, which was a cause of especial aggravation to city dwellers since it was sold by weight rather than volume. On the other hand when turf was sold by volume – as it had been in the past – there was a tendency for the less scrupulous supplier to put as much voluminous but light turf in a load as he could get away with. The Government put a stop to this in 1942 when it came to an agreement with the Turf Development Board that turf should in future be sold by weight rather than volume. Finally, there were labour problems; in parts of the country it was difficult to get enough experienced hands to work the bogs, so there was considerable migration, especially from the west and in some cases out of the cities. Conditions were often very hard. Annaholty Bog supplied Limerick City, and the workforce here included 200 city men, who went on strike in July 1941 for a 50%

Figure 1.9: Submarine turf being saved at Carnsore in County Wexford (Bord Fáilte).

increase in pay (from 30/- to 45/- a week), and the provision of transport, free rubber boots and shelter.

A new element in the campaign for self-sufficiency in fuel in 1941-42 was the introduction of what was known as the 'Kildare Scheme', which set out to supply Dublin from an area of 250 square miles situated between Enfield, Edenderry and Newbridge. 24,000 acres of bog were acquired and drained, and a network of roads constructed. To work these new bogs, men had to be brought in from outside the area of the bogs, many of which had small populations, so fourteen special residential camps, each with room for 500 men, were erected and equipped with the basic facilities. The first five of these hostel blocks were built by the Office of Public Works in 1942 – Ballinderry, Enfield, Timahoe, Rathangan and Lullymore - to house 1,000 men from the west. The workers were paid mainly on a piece-work basis, and might earn up to £6-£7 a week in this way, with a time rate of £1/13/4; board and bed were free. Most of these camps closed for the winter.

In a short time the camps began to resemble refugee camps rather than the 'villages' of which newspapers of the time rather euphemistically spoke. A radical re-organisation soon took place however, under the direction of Bill Stapleton, who had managed the camp site on the Ardnacrusha hydroelectric scheme. By 1943, as many as 4,000 volunteers were at work in the turf camps in County Kildare, and by the time the scheme came to an end in 1947, it had added nearly 600,000 tons of fuel to the national supply. In 1938-39 turf production in the Free State had been 3,339,000 tons; by 1943-44 it was 4,377,000 tons, an increase of 31%. These camps were tough places, run on semi-military lines; the telling of their story deserves a volume of its own.

Work continued during the war at the Turf Development Board's three machine turf works. The war years gave the Board a lot of valuable experience in the production of machine turf; the relatively small amount of high grade fuel produced was devoted to special cheap turf schemes organised for the urban poor. Lullymore produced briquettes right through the War Years, reaching full capacity by 1945. The briquettes were invaluable, because they kept high-priority industries going; they helped to keep the trains running on occasion, and at times of special difficulty the dry turf dust of which they are made even fuelled a whiskey distillery and kept a cement factory in operation. Several European countries, including Ireland, had experimented with the use of turf for raising steam in railway engines in the 19th century, but although the results were impressive, transport costs and bulk always outweighed other considerations. However, wartime conditions tipped the balance the other way. Turf was also used for making gas in several towns and cities. Hugo Flinn died suddenly in 1943, but by this time the Turf Campaign was in top gear. Todd Andrews was appointed Fuel Controller in his stead, but as Andrews readily admitted, Flinn really had no successor.

This whole episode is an area in which there is much scope for timely research at local level: to record first-hand oral tradition before it is too late, to trace and secure the documentary record, and to identify the turbaries and elucidate their subsequent ecological development. Peat World at Lullymore is an important starting point for studies of this kind. It is the main repository for non-corporate documentation on peat development in Ireland.

In 1957 the Irish Sugar Company made a modified Lilliput machine available for hire to farmers in the Tuam area of County Galway; so successful was this that within two years they had five machines on hire, one working as far afield as Killasser, 50 miles away in County Mayo. General Costello (general manager of the Sugar Company) had hoped that this initiative might encourage co-ops and syndicates to buy machines of their own, but this idea was a victim of the success of the hire system, which farmers found much easier. The first modern independent operators were not farmers, but skilled operators with experience in Bord na Móna. However, a number of turf co-operatives were set up and operated successfully in the '60s and early 70s.

SAVING THE TURF

Preparing the bog

In the 19th century the preparation of a bog for turf-cutting was often carried out by Government organisations such as the Congested Districts Board or the Land Commission, or by enlightened and improving landlords, applying approaches to drainage techniques, the making of access roads and tracks, and the layout of facebanks, which experiments here and on the continent had shown to be best. Drainage was the first prerequisite. Experience had shown that the best way to do this was to open a main drain across the bog, deepening it year by year until eventually the bog was bottomed by the drain. Sub-drains were opened parallel to this, cross-connected to the main. To obviate the risk of a bog burst, it was recommended that turf breasts should only be opened parallel to the sub-drains. On mountain bogs it was recommended that bog holes and breasts should always be opened up and down slopes rather than across them.

Cutting the turf

Turf cutters recognised four different layers in a raised bog. On top there was the *clearing* or 'top scraw'. Under this was a variable depth of *white turf,* which gave way quite abruptly as a rule to the underlying *brown turf.* As the bottom was approached this gave way in turn to the *black turf* of the fen peat. White and brown turf, Boate reported, 'costeth but little paines in the making: for being digged, and having lyen some dayes a drying (first spread out thin and single upon the ground, and afterwards piled up in little heaps) it is brought into the barn'. The traditional method of cutting and saving turf by hand hardly changed between Boate's time and our own.

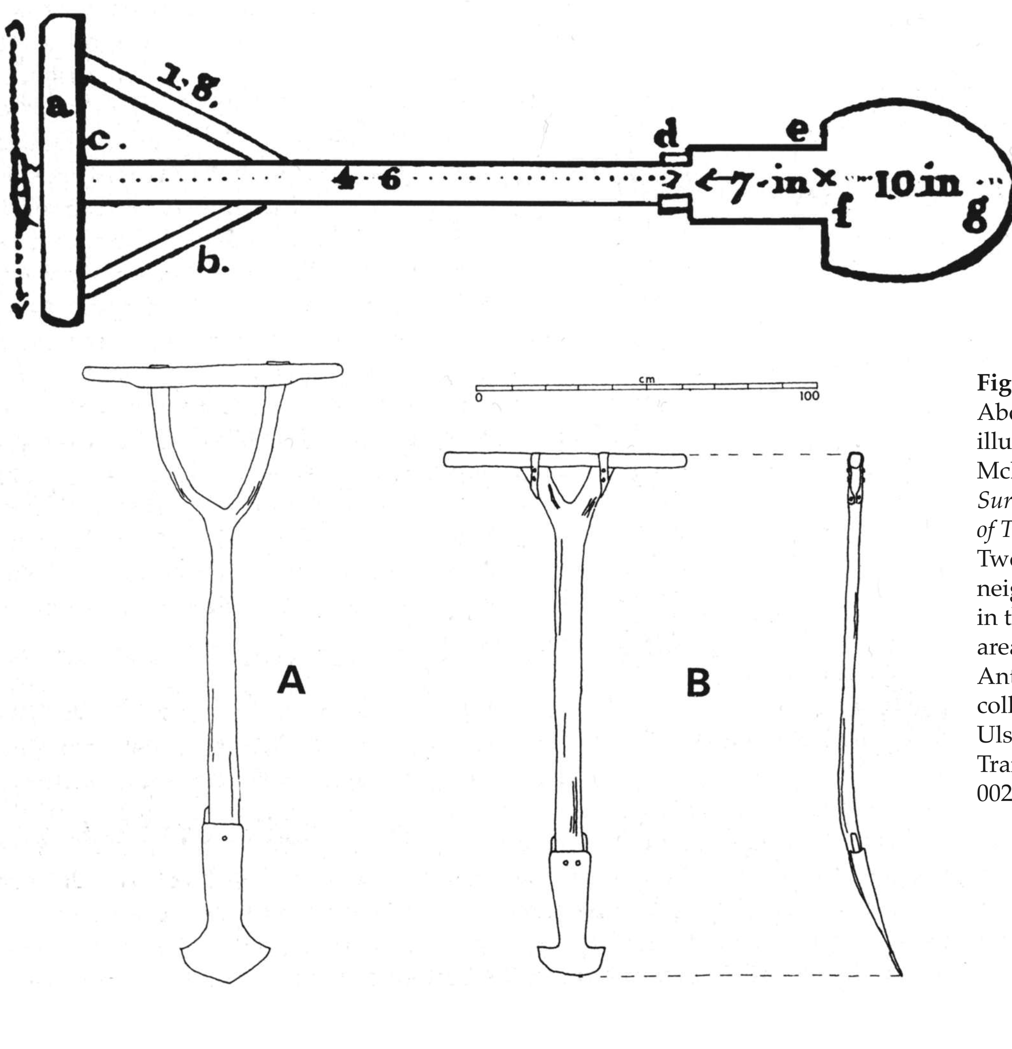


Figure 1.10: Above: '*Shroghoge*' illustrated in J. McEvoy, *Statistical Survey of the County of Tyrone*. Below: Two flachters from neighbouring farms in the Cushendall area of the Glens of Antrim; B is in the collection of the Ulster Folk and Transport Museum 0020.1978).

A special implement called a flachter **[Figure 1.10]** – also known as a skroghoge *(scraitheóg)* or scraw-cutter – was used in the north of the country to cut away the heathery scraw from the bog in preparation for cutting. It was an import from Scotland, and is also found in many other parts of northern Europe, but it does not seem to have been used over much of Ireland. The flachter was a very individual tool, crafted by the local blacksmith from pliable wood such as ash or sally, and with a blade made from scrap metal. The wide handle enabled the operator to push and undercut the scraw with thighs and hands. In some bogs, an upper zone of turf – as much as 2m or so – might be cut away from the entire bog before going on to harvest the lower layers. Where the cutting of the turf was done with method and foresight, the cut scraws were sometimes reserved and replaced on the cutover 'low bank' after cutting. But in most areas much less efficient arrangements were favoured.

An extensive and specialised Irish vocabulary surrounded the saving of turf, and each part of the country had its own variants. Some of the terminology connected with turf-cutting in the western isles of Scotland (whose Gaelic tradition was derived from north-east Ireland) is of Norse origin. A turf bank in Scottish Gaelic is *bac móna (bakki* = bank in Old Norse); the word for a turf spade in Scottish Gaelic is *tréisgeir,* which is simply till' Old Norse word *torf-sccir,* a turf-cutter. It is possible that the Scandinavian tradition of turf-cutting influenced that of north-east Ireland through its close connections with Scotland.

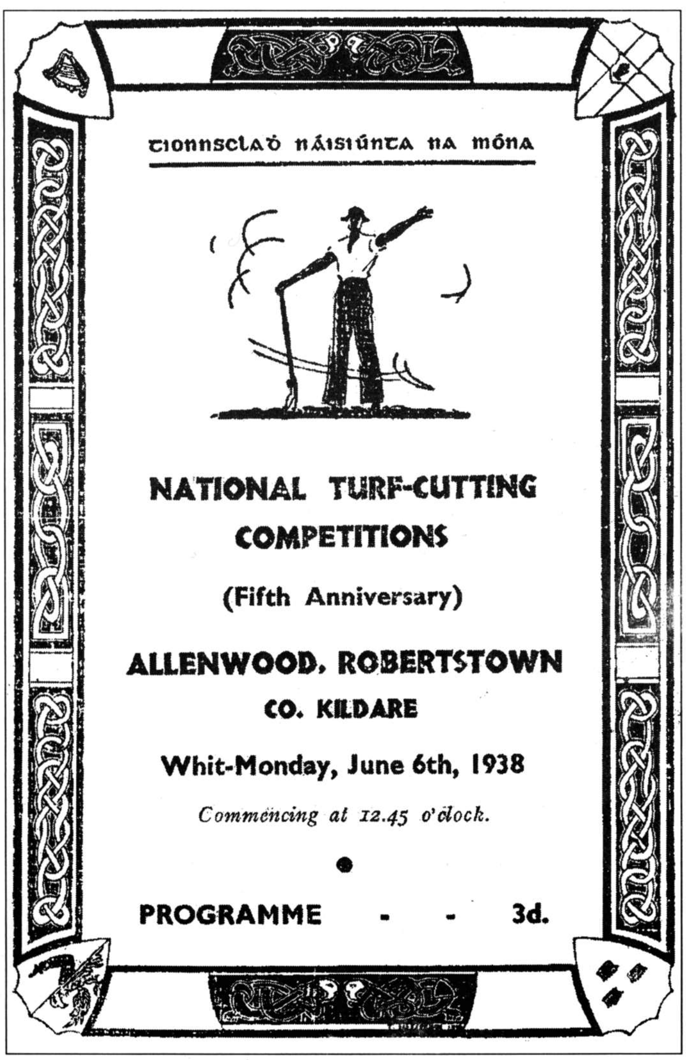


Figure 1.11: Cover of the programme for the 1938 National Turf-Cutting Competitions.

The turf was cut with a turf spade or slane (*sleaghán*). The *becket* that was used to cut turf in the East Anglian fens down to the 1940s was essentially the same as the slane, and similar tools were in use throughout Great Britain and in other parts of Europe, so this is not a uniquely Irish tool; it was also used in other countries, where turf was cut in basically the same way as in Ireland, although the design varied considerably between different countries and indeed between regions in the same country [**Figure 1.3**]. A variety of more specialised turf spades and knives was also employed. In many ways saving the turf was a more organised affair in Great Britain; the Ulster turf tradition is closer to it than the rest of Ireland. Long-handled all-wooden scoops or shovels were used in the Somerset levels for 'lecking' out the water that seeped into the boghole overnight. These resembled the *dydal* used in Medieval times in England for shovelling out peat underwater, and this in turn is very similar to the longhandled shovels from Clonaslee described in the section on ochre (See page 100).

The first operation in cutting the turf was 'clearing': the removal of the healthy 'scraw' (the upper living layers of stems and roots: from the Irish *scraith,* a green sod) and the underlying weakly humified material. This was sometimes used to provide a firm surface on the cutover. The slane consists of an iron head and a long wooden shaft. The head has a flat blade, generally with a wing on one side, so that the sods can be cut on two sides and detached with a single twist of the implement. The head has a socket for the shaft; in most slanes this is an 'open' socket formed by bending back the upper part of the blade to form two triangular flanges which wrap around the bottom of the shaft. In the north-east of

Ireland the open socket is generally longer than in other areas, and is generally found only in breast slanes, whereas the most common type of foot slane has a double 'strap' socket which may be a relatively recent introduction from Britain. Apart from these broad differences, each district had its own distinctive style of slane; these were made either by local blacksmiths or in spade mills. In the National Museum there is an extensive collection of slanes that were made in the mills, whereas the Ulster Museum has an extensive collection of slanes that are mainly of local origin. There are basically two kinds of slane and two correspondingly different approaches to cutting. The *breast slane* is used where the turf-cutter can stand facing the turf bank; it may or may not be winged. It can only be used where conditions underfoot remain relatively dry as cutting proceeds, so it is the method most widely used in blanket bogs. The sods are cut by horizontal strokes into the facebank, before being cut vertically by another man standing on top of the bank. The cut sods are usually spread on the uncut bog surface; 16 'boxes' of turf a day was the average level of productivity. The size of the sod cut with the foot slane was around 10″ x 5″ x 5″, compared with 14″ x 6″ x 6″ for the breast slane sod; in the Turf-Cutting Championships of the '30s however, the 'perfect sod' measured 12″ x 4.5″ x 4.5″.

Figure 1.12: Christopher Daly.

Deep bogs are cut with the *foot slane*. The sods are cut on two sides by vertical strokes of a winged slane; the bottom of the sod is broken by the lifting action of the slane as the sod is raised and thrown to the waiting barrow-men, who take it away to spread on the dry cutaway (the 'low bank') in front of the turf breast (the 'high bank'). Output was estimated at around 20 boxes a day. Fenland turf cutters in the 1870s would expect to cut 8 - 10,000 sods (or cesses as they were called there) in a good 14 hour working day. An American observer calculated that the rate of hand cutting per day by a team of 5 working fairly hard was 12,000 sods (85m^3). Mallet quoted a cutting rate of 400 ft^3 per day (which he doubted) but some of the feats recorded during the National Turf Cutting Championships in the pre-War years dearly show that it could be achieved **[Figure 1.11]**. The Lullymore turf-cutter Christie Daly **[Figure 1.12]**(who came from Bourard, Rathmore, County Kerry, where he was born in 1924) was reputed to be the fastest slanesman of all time. During the week ending 12th July 1945 Daly cut 598.5m^3 of turf in the 48 working hours. It took six wheelers to catch and take away the turf, which he cut at a rate of up to a hundred sods a minute. In the words of Paddy Kavanagh (who won the national title that year), he cut the turf so quickly as to produce 'an unending series of sods touching each other as they left the bog hole'. Richard quotes a figure of 3m^3 (106 ft^3) as a slanesman's average hourly output in Germany, where the day's work would produce an estimated 12,255 sods (each 43 x 12 x 12cm).

The sods thrown up by the slanesmen were loaded onto special bog barrows by two men who wheeled them away from the bank and tipped them onto the spreading ground. Slanesman and wheelers worked as a co-ordinated team. In the Turf Cutting Championships marks were awarded not only for output, but also for the condition in which the bog hole was maintained by the slanesman, for the size and shape of the sods, and for neatness **[Figure 1.13]**.

As cutting proceeded, the cutter had to work at an ever greater depth in the bog hole. This meant that as the day wore on, and he became progressively more tired, he was having to throw the sods – which became heavier as the bottom approached, the sods of wet fen peat being particularly heavy – from a greater depth. To add to the problem, the deeper he went the more water seeped into the hole, and there was always the danger of a surge of water if preliminary drainage had been insufficient. This was not only the danger that the turf would not be saved in time, but the physical danger of being trapped at the bottom of a hole three or more metres deep. To obviate this danger the bog was often bottomed in stages by constructing a series of steps.

In some lowland bogs the upper part of the bog would be cut with the breast slane, but a foot slane had to be used for the bottom. Compression of the turf by the feet of the slanesmen above was considered to make the cut turf less 'tender'.

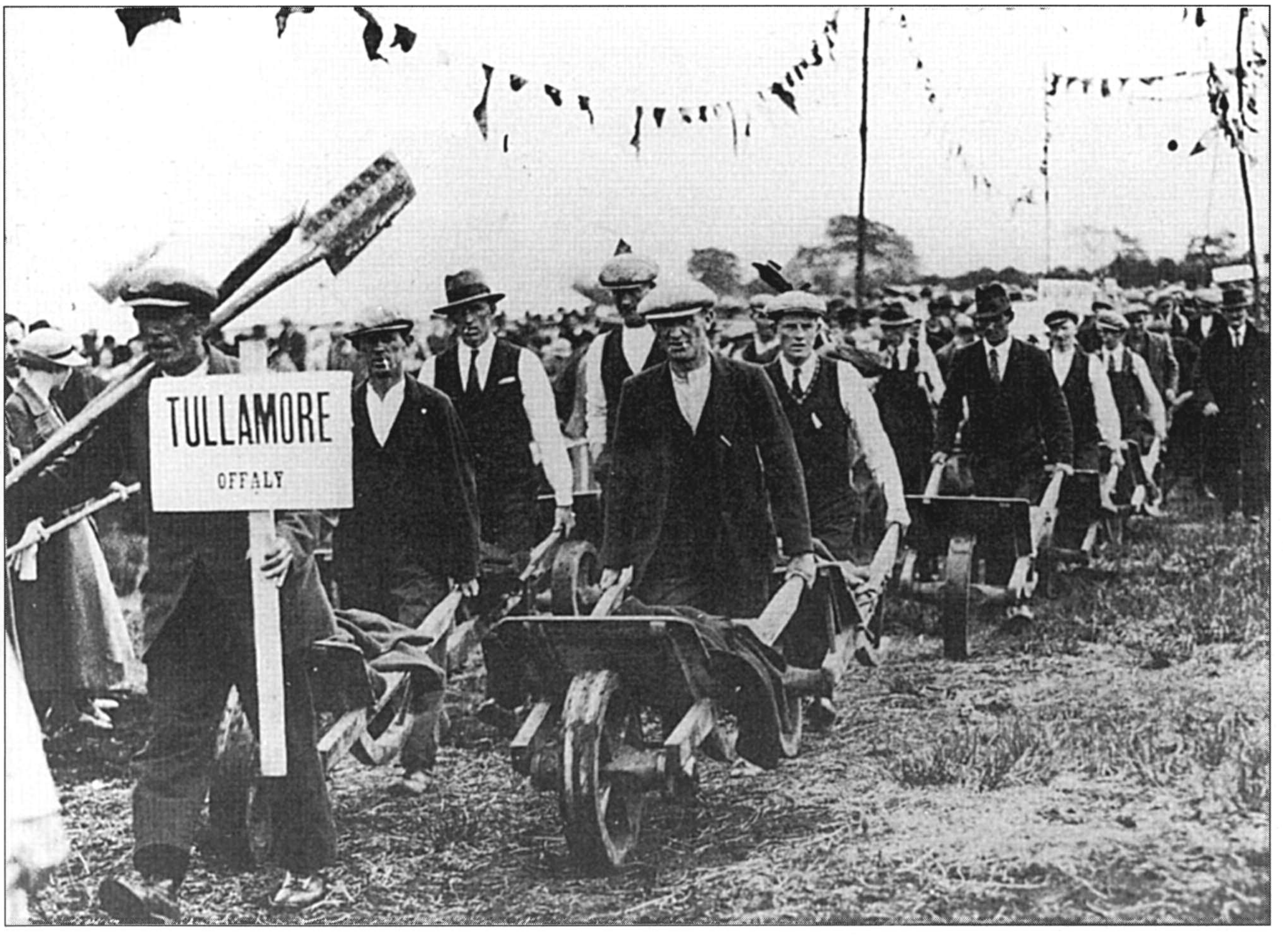


Figure 1.13: Scenes at the National Turf-Cutting Championships.

The preferred method of turf-cutting over the country as a whole however was the foot slane method. This is reflected in the relative numbers of entries for the two competitions in the National Turf Cutting Championships; in 1933 for instance, there were 71 entries for the foot slane competition compared with 21 for the breast slane event. However, on the Kildare Scheme during the War Years the wing breast slane was used almost exclusively, and the long sods produced by this method were for this reason those most familiar on the streets of Dublin during the War. These sods could be stacked in pyramids of seven or eight which dried easily; with foot slane turf four sods are set on end, leaning against each other, with two further sods on top. The arguments advanced in favour of the wing breast slane were (1) it cut sods with the grain of the peat, and so the sods were less inclined to break and there was less waste; (2) it reduced the amount of trampling of the peat floor: when cutting in this way the cutter trampled on one floor in every six; when using the foot slane every floor is walked; (3) it made for more efficient footing. Another (unstated) reason was the fact that the use of the breast slane method had been perfected in these Kildare bogs over several centuries. Another (unstated) reason was the fact that the breast slane method had been perfected by the professional turf-cutting men over the centuries in the Bog of Allen, who carried their turf by horse and cart for sale in Dublin and the nearby towns. The loading of the cart with the perfectly-shaped sods was a day's work in itself; after loading the cart the turfman would start his journey in the evening, arriving in Dublin in time for breakfast, where he sold the turf from door to door by the dozen sods.

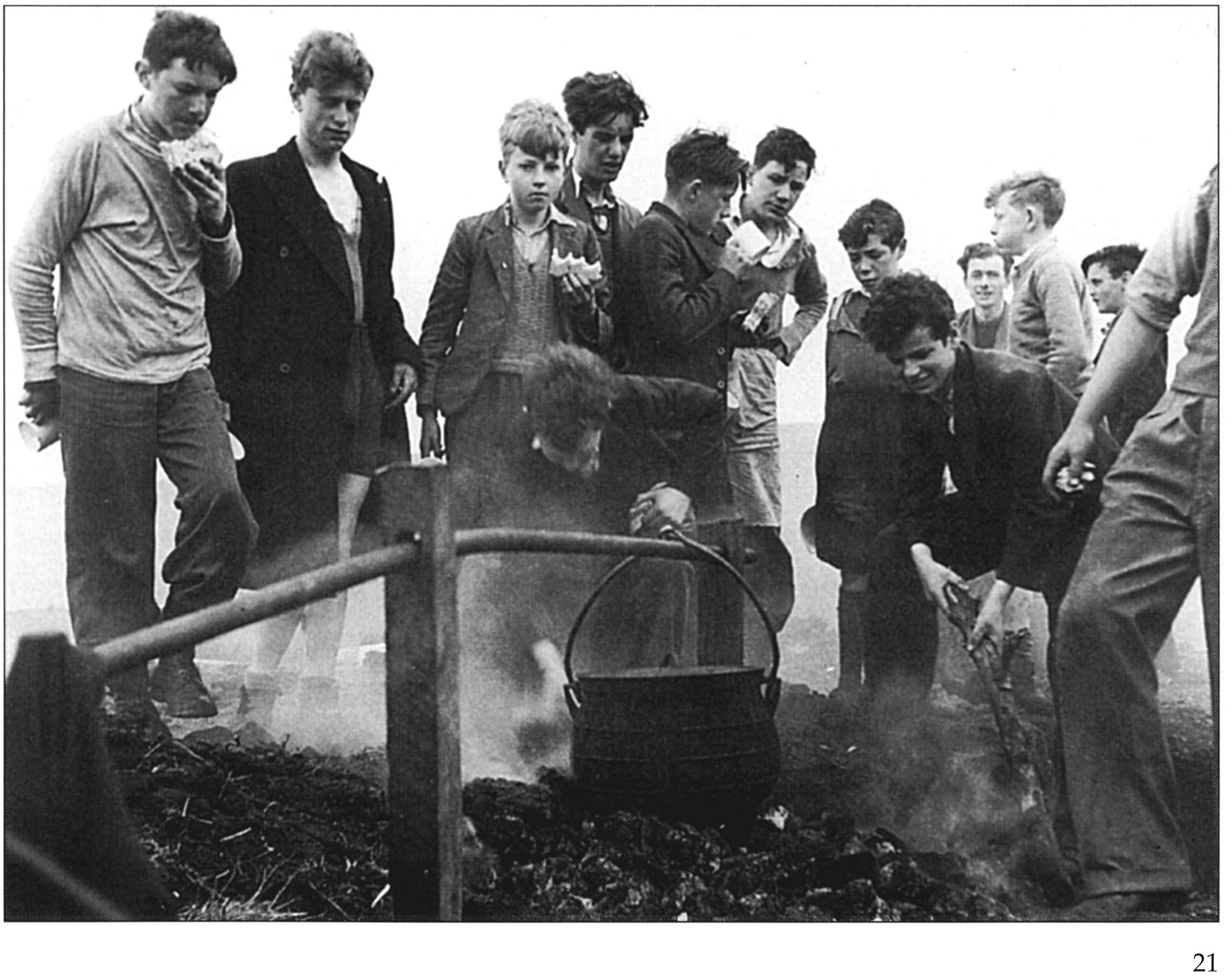
Figure 1.14: The chairman of the Organising Committee of the Turf Cutting Champinships was Major de Courcy Wheeler, seen here (left of centre) with Eamon de Valera. This is a picture which echoes a changing Ireland, for Major de Courcy Wheeler was the army officer who accepted de Valera's surrender at Boland's Mills at the end of the 1916 Rising just over twenty years before.

The moisture content of the turf when it is cut is around 95%; as it dries on the spreading ground this is reduced to 25 or 30%. After a week or ten days, depending on the weather, the turf is turned and then *footed* (Irish *cróigeadh, gruaigeadh),* which entails placing groups of five or six sods on their ends (with maybe a few on top) to facilitate circulation of air around them; after a further week or so the footings are built into *clamps.* Traditionally the clamped turf was taken home by donkey and cart and stored for winter use in sheds, or outdoors in thatched ricks. The architecture of windrow and other turf heap construction varies across northern Europe, and in each country it has produced its own specialised nomenclature. The drying period was the critical time, and it generally takes a month for slane-cut turf to become fully air-dry under favourable weather conditions. In very bad years the turf would simply fail to dry at all and have to be abandoned.

With slane turf one man could cut enough peat to give three tons of air-dry peat in a 10-hour day; a second man could wheel and spread this amount up to 40 yards or so from the turf bank and a third would generally be required to catch and load the cut sods. At Ticknevin in Kildare the catcher would wheel his barrow of 20 or so sods up to 20 yards from the bank, where the wheeler would take over, taking it up to 50 yards further before tipping the sods on the drying ground. As for the later operations, it was reckoned that three men/four women/six youths could foot or clamp 36 tons in a day, and finally that eight men could collect and stack 36 tons of turf on a rampart in a day. On the peat moss bog at Maghery in County Derry the Dutch method of cutting was employed early this century to produce very large sods (20″ x 6″ x 6″). This involved the use of two different cutting implements: an 18″ x 6″ breast slane and a tool called a 'sticker', which measured 20″ x 9″; with these two tools one man working on his own could cut three tons of moss peat or four tons of fuel peat in a day. One of the advantages of the method was that there was no need of a catcher or wheeler: there was enough space on the ramparts beside the bank to spread the large sods. Another advantage was the greatly reduced space needed for spreading. The same method (using a long hay knife instead of the sticker) was used on the peat moss bog at Portglenone. Around Ballinrobe in County Mayo – where spreading ground on the bogs was limited – very large sods, famous for their hardness, were made using a similar method in which the vertical and horizontal cuts were separate operations.

The chemistry of what happens as peat dries is not fully understood, but it seems to be caused by alteration of the pectin in wet peat to pectose. *Pectin* is the gelatinous substance in ripe fruit that causes jam to set, but it is also found in other parts of plants. When it alters to anhydrous *pectase,* the peat loses its somewhat gelatinous consistency. Machine turf dries much more quickly than natural sods, but the more important difference is that – unlike slane turf – it is not easily re-wetted by rain. The calorific value of hand-won peat is around 3,300 kcal/kg (6,000 BThU) – half the value for coal but much more than wood. White turf was not greatly favoured as fuel because of its high volume, though it was used all over the country in lime kilns; it burned brightly and warmly, but very quickly. However, advantage was taken of the fact that, although white turf of itself has little heating power, great heat is produced when it is burned with limestone, which led to its use in a patent method for heating greenhouses in the last century. The ash that remained was known as Roche Ash, and made an excellent fertiliser.

Figure 1.15: Young turf-footers break for lunch. Footing turf was a common summer job for teenage boys in the turf-cutting areas during the labour-intensive days of the 1950s.



Black turf made a long-burning fuel, but it had a high ash content and (more critically) it was very hard to keep the sods in one piece as they dried. It could be cut into beautifully coherent, very heavy sods, but unless exceptional care was taken in drying these, they fragmented into small pieces of rock-hard consistency. Black turf had one very important specialised use, and that was by blacksmiths: peat charcoal was also widely used in the forge until about 1850. The traditional use of turf in iron smelting is dealt with in Chapter 3.

Mud turf (hand turf)

Turf cut in the traditional manner consists simply of slices of the bog, and its composition and value as fuel varies with its location in the bog profile. In some bogs however, the peat was first *macerated;* water was even added on occasion to help the mixing. Mud turf was only made in some districts, generally where the turf was too wet to cut into coherent sods. It seems to have been particularly common in the bogs of Cavan, Leitrim, Down and Sligo. It was a very old method, and Boate's description of how it was made in the sixteenth century is not much different from the way it was made in our own century and probably not very different from what Pliny was talking about:

> On that dry place where the mud is poured forth, sit certain women upon their knees, who mold the turf, using nothing else to it but their hands.

It was also the method universally adopted in the wet bogs of Holland, in the general area of which Pliny was writing. Exactly the same process was still taking place in Kilkenny in the early 19th century. Here is how Humphrey O'Sullivan described the cutting of turf in his diary (*Cín Lae Amhlaoibh)* for 12 July 1827:

> Gearrtar ansin é le sleán ucthta má bhíonn an súsán gan dreo go forlíonta, nó le sleàn binne má bhíonn se dreoite go hiomlán. Agus cuirtar ar an bport dá thriomú é. Ach ní hé seo an mhóin is fearr ach an gar fuinte le cosa duine, d' éis é a shluaisteáil suas as an bpoll ar an bport, agus é a dhéanamh ina bhfóid le lámha ban ...

> [The turf] is then cut with a breast slane if the sphagnum is not decomposed completely, but with a foot slane if it is. Then it is put on the bank to dry. However, this is not the best turf: the best turf is that which is kneaded by foot, after the peat has been shovelled up out of the boghole onto the bank, and made into sods by womens' hands ...

Figure 1.16: (below and right): Saving mud turf in Ulster. [© Ulster Folk & Transport Museum; WAG 1913/4].

Mud turf was still being made on Ardee Bog in County Louth in the 1980s, and floated in cots on the River Dee down to the town of Ardee. Its main drawback from a commercial point of view was the relatively low output; three men could only cut, mix and spread enough peat mud for two tons of air-dry turf per day.

One of the most succinct descriptions of the making of mud turf comes from the pen of Michael J. Murphy, writing at a time when it was still being made in the bogs on Slieve Gullion:

> The men, stripped to shirt and old trousers cut like modern shorts, to make "mud britches" worked knee-deep in rank, lusty mud trembling in a black mass in a bog-hole.
>
> The "bank" is prepared first, shorn clean of bog-grass and heather, and battened down till the surface is fairly level; this "bank" is made near the spot where the bog-hole will be sunk. The hole is usually convenient to a supply of water from a stream; this is dammed and a channel cut to carry the water when required to the hole. Often, water has to be carried. However, the top sod is dug from the hole and thrown well back.
>
> At a depth of a spade, this surface is dug up, chopped with the spades and graips [four-pronged forks] and clearned of bits of wood, bog-fir and grass. The water is then let in. The pulverised turf is again mixed up with the water with graips, and by puddling and trampling with the bare feet. All are in bare feet, of course, and in this part of the work, women and children are delighted to help.
>
> After it has been mixed the men take up positions at one end of the hole, and working with a rhythmic unison, shovel the mud on to the prepared "bank". This is skilful work, hard and swift, and the rhythm is essential if mid-air clashes of laden shovels are to be avoided. There must be speed, and little leisure, for a hole must be finished on the day on which it was started, as underground seepage oozes in and renders it useless and unworkable. Such holes are said to be "lost".
>
> Each depth of a spade is known as a "floor". These must be dug at a uniform depth to ensure swift, rhythmical shoveling, which, though hard and difficult, is learned by sweating practice. Water is let into each succeeding "floor", mixed and shovelled out, until a "floor" is reached of a turfy material entwined with white roots and which is known as "lake". Like grass and wood, the roots prevent the solid manufacture of mud turf.
>
> Meanwhile the "bank" of mud on the brow has been gradually heaping up. This is levelled and then raked. With the two thumbs touching, and the fingers held perpendicular at right-angles, to the alignment of the thumbs, the bakers mark off the

> mud, drawing their hands towards them through the mass, and cutting it into squares or oblong pieces by a dividing cut or stroke of the hand. The bakers work backwards over the mud, filling and levelling the tracks of their bare feet as they go. Many women were adept at this and earned worthy reputations as bakers. And that finished one day's work. And though bog-mud is good for corns and aching feet, the workers are now dog-tired exhausted beyond belief, and glad to get home through the night.
>
> When the squares dry and set they are cut clean to the bottom with a sharp spade or with a hay-knife; these are lifted singly with a swift, energetic snatch. If badly baked, or if wood or grass lie within each turf, they break under this snatch but the force is necessary to whisk each off the adhering bank. Each sod of turf is then placed in an upright position which is known as "footing turf" .... Later, about eight sods or cakes of turf are built in small, lattice-like heaps known as "wind-rows", a term which explains itself. When properly dry in these, the turf is built into stacks or ricks known as "clamps".

The surface onto which the mud was thrown was sometimes enclosed by boards. The Slieve Gullion account suggests that the shaping of the sods took place immediately, but this was generally done a few days after the mud was dug out and spread. Two kinds of fuel were made from this *puddled* turf; Barrow loads of turf mud were spread to a thickness of 10-12" on the spreading ground; after a day or two this was trampled and left to soak. Then the drying mud was cut into squares 10-12" by 18" thick, and either compressed by hand into more compact and superior sods ('hand turf') or left to dry a while before footing ('foot turf'). Two of the most perceptive of the 19th century bog developers, Robert Alloway and Robert Mallet, believed mud turf to be so superior that all turf should be made in this way. Mallet felt it required only one-third of the labour needed by the normal method. The method allowed peat of different densities from different depths to be thoroughly mixed; mud turf was also much denser than ordinary turf – for the same reason that machine turf is. Experiments carried out by Mallet showed that kiln-dried turf weighed 31 lbs/ft^3 when it was cut in sod form, whereas if it was dug out and mixed before being made into sods and then kiln dried, it weighed 64.6 lbs/ ft^3 [**Figure 1.16**].

The new machines

The story of the harvesting of peat by machine is told in later chapters, but it is more appropriate to discuss the impact of the small new machines here because of the way in which they have so completely replaced the hand-cutting of turf in the last fifteen years or so.

Largely because of the increasing use of oil for domestic heating, there was a dramatic decline in the hand cutting of turf during the 1960s. In the early 1970s the main solid fuel used (in the Republic) was Bord na Móna machine turf – twice the volume of native coal and hand-won turf combined, and 25% more than imported coal. Oil was 60% cheaper than peat fuel in 1960, but by 1974 (as a result of the increases in the price of oil which followed the crisis of the previous year) the price of peat was 65% less than oil. Since the 1980s machine peat harvested by private producers has steadily increased in importance and that produced by Bord na Móna has declined.

Machines suitable for the manufacture of macerated turf on a small scale have been available since the 1840s. Towards the end of the last century several small macerating machines were imported by a number of entrepreneurs interested in developing peat production. In 1874 for instance, following the recommendations of the Purdon Commission, McDonnell imported machines to produce peat for use on the GSR locomotives at Inchicore (See page 87). In the early 1920s four or five different kinds of machines for excavating peat and spreading it as sods were available in Germany. Their output was between 90 and 220 tons of peat per day (a day consisting of three 8-hour shifts). They needed between four and eight men to run them, and it was felt at the time that the way to achieve maximum efficiency was to incorporate the best features of each

TABLE 1.2. PRIVATE TURF PRODUCTION (1992)

COUNTY	1991 TONNES	1992 TONNES
Galway	278,000	286,500
Clare	25,000	32,300
Cork	26,000	28,100
Limerick	24,200	29,300
Kerry	150,000	153,200
Tipperary	98,000	91,500
Donegal	110,000	90,520
Mayo	125,000	120,050
Roscommon	92,000	92,860
Sligo	50,000	38,000
Cavan	13,850	15,300
Kildare	71,400	68,500
Laois	26,700	30,200
Leitrim	31,600	32,100
Longford	48,920	49,300
Meath	29,500	26,400
Monaghan	4,600	4,600
Offaly	113,400	109,560
Westmeath	75,200	70,400
Wicklow	4,800	3,800
Total Tonnes	1,398,170	1,372,690

The breakdown of the 1,372,690 tonnes is as follows:-

Tiphead Turf:		99,880 tonnes
Sale on Spread:	–	484,200 tonnes
Cut on Owners' own Plot	–	788,610 tonnes

1993	1 to 2m
1994	1.3 to 1.35m
1995	1.4 to l.5m (Estimate)

<u>Types of Machine Turf Produced</u>

(a)	Chainsaw Turf	–	479,100 tonnes
(b)	Hopper Turf	–	752,290 tonnes
(c)	Miniput Turf		141,300 tonnes

design in one machine. The new machines available today are of several different kinds. Some of them excavate peat only from the upper layer below the scraw; these have the advantage that the tractor can travel across a firm surface while harvesting, and have only modest visual impact; on the other hand there is little mixing of peats of different composition. The *field press* method does not have this disadvantage; it excavates peat from a face-bank, macerates it and extrudes the sods as continuous strings. It requires less power than other small-scale production methods and has a comparable or better output (three to five tonnes per hour per extruder). Most of the fuel peat machines used today are made in Ireland. The only machines imported from Germany in the last fifteen years are probably a few moss peat block cutting machines manufactured by Herman Becker. Some machines (such as Merri) have been imported from Finland; the Finnish expertise in peat harvesting was acquired in large part from Bord na Móna, then further refined and exported round the world.

The use of these new sod peat machines has made the systematic commercial exploitation of small bogs a very profitable enterprise. The focus on small bogs arises partly because few if any large bogs remain in single ownership, but also because these machines are much more flexible then the large machines used by Bord na Móna for the very large bogs, and earlier drainage greatly facilitates their operation. Mainly because the large sod peat bogs worked by Bord na Móna over a period of 40 years have been exhausted, more sod peat is now being harvested from smaller bogs by private operators using small machines than by Bord na Móna [**Table 1.2**]. The smaller scale of the development has allowed the return of the bog meitheal in a limited form, because although the peat is harvested and spread by machine, the sods still have to be turned, footed and drawn home by the user.

Although there was some private development of peat before 1981 (e.g. fuel peat at Maam Cross in County Galway, Redwood and Sharragh in North Tipperary, horticultural peat by Erin Peat near Birr) the mechanical harvesting of small bogs received a big boost with the passing of the Turf Development Act of June 1981, which superseded the various earlier Acts passed between 1946 and 1980, and enabled Bord na Móna to make grants available for the development of privately-owned bogs. Grant aid was available for bog development and the purchase of turf cutting and harvesting machinery. The first operating season for the new scheme was 1982; private production at this time amounted to 300-350,000 tons, and the number of machines (mainly sausage machines working cutover bog) stood at around 80. The scheme lasted until 1987, by which the output had soared to some 1.4 million tons harvested by 700-750 machines. The expenditure on the scheme on machinery and drainage totalled nearly £8M over the period [**Table 1.3**].

The aim of the scheme was (1) to bring home to private producers the fundamental importance of bog drainage and (2) to introduce a range of turf machinery suitable for small house plots of one to two acres with a face bank width of 20 - 40 yards, as well as for larger bog areas. Up to 1981 bog drainage, and in particular high bog drainage, was practically non-existent. To encourage private drainage Bord na Móna initially hired out ditcher units to carry the work out in several counties. Subsequently, with the help of grant aid, full-track and half-track units for tractors to pull ditchers were introduced to the private sector. Screw-levellers and harvesters were also introduced as well as widetracked excavators to construct main outfalls and to load hopper/field press machines.

Figure 1.17: The Lilliput machine in action.

The machine most in favour for the harvesting of fuel peat prior to 1981 was the Lilliput. This had a bucket drive surrounding the macerator and extrusion spout, with a spreader that was freely suspended behind the chassis. This facilitated rapid turning, and the long spreading time made for turf with particularly high density. In the early 1980s Lilliput machines with trailing spread arms suitable for small plots were introduced. The Herbst-Difco and KHChainsaw (or sausage) tractor drawn machines appeared around the same time. The Lilliput was invented either by Flugger or Heiner – a court case failed to decide which. Most of their machines were supplied to the countries of Eastern Europe, but Bord na Móna purchased thirteen, and General Costello's sugar company purchased ten machines from Flugger.

Most of the Lilliput (and related Miniput) machines were manufactured by Schnittger's Shamrock Machine Turf Company at Edenderry – Schnittger came to Ireland as an employee of Flugger and remained to manufacture turf machinery on his own. The Lilliput was the larger of the two (100-120kW engine) and was designed for use on fully developed bogs; the Miniput had a 60-80kW engine, and was recommended for use in partly drained bogs. These machines were suitable for cutting large areas of 100 to 200 acres and upwards but were not very successful on the smaller Land Commission plots of 20 to 30 yards in width as the machine was wider than the plot and some of the turf was dropped on neighbouring plots outside the owner's boundary. These 'sausage' or 'chain-saw' machines widely were based on the design of a machine used by Bord na

TABLE 1.3.
Private Bog Development funded under the Turf Development Act, 1981

No. of Schemes	Type of Application	Area (Ac)	No. of Owners	Cost IR£	Grant IR£
-					
540	Groups & Co-ops	35,558	18,614	4,969,820	2,976,488
31	Companies	6,262	31	2,760,835	1,222,862
849	Individuals	28,277	849	8,381,241	3,639,224
1420		70,097	19,494	16,111,896	7,838,574

Total paid out in grants IR£6.8 m.

Annual production of sod peat during the Scheme

Year	Tonnes
1981/82	350,000
1983	463,700
1984	680.279
1985	607.094
1986	663,840
1987	1,037,000
1988	1,255,600
1989	1,389,600
1990	1,410,000
Total	7,857,113 tonnes

Breakdown of the 1.41 m tonnes of privately produced sod peat during 1990:

49% cut and harvested on individuals' own house plots (lR£7 to IR£I0/tonne cutting cost)

12% sold at tiphead (lR£28 to IR£34/ton incl. V.A.T.)

39% sold direct from bog spread ground (lR£14 to IR£18/ton incl. V.A.T.).

Source: 1990/91 Annual Report of Bord na Móna.

Móna in the 1970s for draining headlands etc. The first Difco machine was manufactured by Ballintubber Enterprises in County Roscommon. However, the company felt a German label would improve the machine's image, so Herbst of Wicklow was brought in as selling agent so that the machine could be sold under the name of Herbst-Difco.

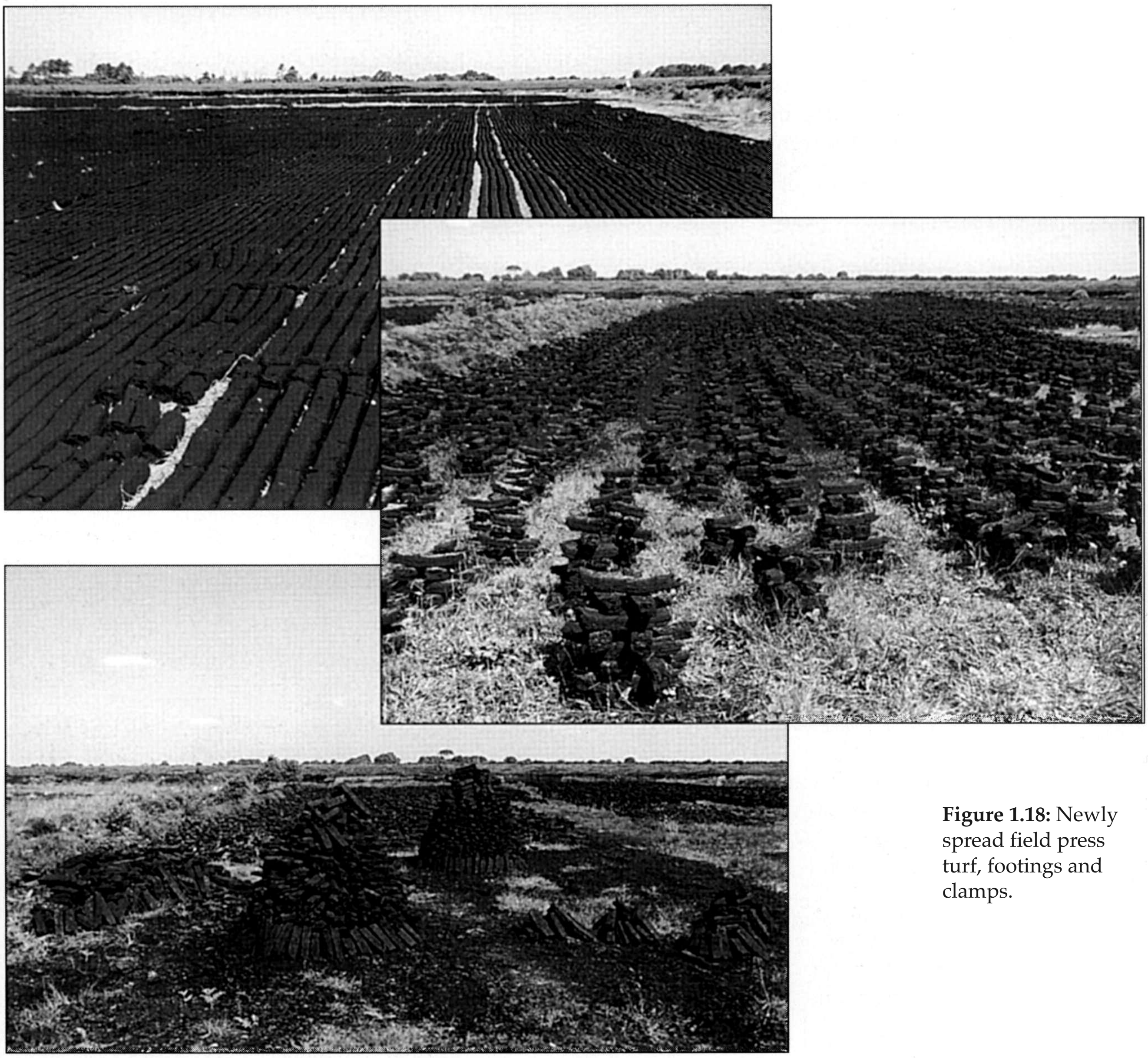


Figure 1.18: Newly spread field press turf, footings and clamps.

Tractor-drawn field press (hopper) turf machines fitted with wide-tracked excavators were introduced around 1983-4. In time, these were replaced by large self-propelled hopper units. Although field presses had been used extensively in Sweden during and after the War, it was only when it became apparent here in Ireland that continual use of the sausage machine was destroying spreading areas that they were seriously considered. Prior to this the use of the field press was considered uneconomical: as long as suitable spreading ground was available, why pay for two machines to do what one machine could do in half the time?

Field press or hopper machines generally operate from a face bank and deposit the turf on the cutaway. The method has replaced many of the chainsaw / sausage machines as the spread ground used, once it had been initially developed, requires little maintenance from year to year. The cutting areas for the chainsaw machines on the other hand require much more maintenance (screw-levelling and ditching at 100ft intervals every three to four years); if this is not done, the area is liable to flooding. Furthermore the cutaway areas best suited to the operation of these chainsaw machines were cut out after four or five years, and contractors were forced to operate from the high bog face with hopper machines. The quality of hopper / field press turf is of much better quality as the full profile of peat from the face-bank is macerated before the sods are spread. Sausage/ chainsaw machines were unsuitable generally for high bog (especially in the Midlands) where the short cutting blade produced a moss peat type sod. In addition, sausage turf from many cutaway areas contained moss strip pings from the high bog and produced poor quality sod peat. On the other hand chainsaw turf was cheap to produce (it is a one-man operation) and the machine is relatively cheap (around £7,000), whereas hopper turf was a two-man operation requiring the use of both a turf machine and an expensive excavator. Damien Martin compared the costs of the two methods in the early 1980s and found that sausage turf cut with a Herbst machine cost just under £9/tonne dried to produce whereas hopper turf using a Keigher AIU machine cost £13/tonne. In quality however, the hopper turf is superior.

The earliest of the 'mini-bagger' type machines (with 25-30m long spread) was the 'mini' Strenge, which had a light single-sod scraper / tube-spreader. The machine used by Bord na Móna in its ill-starred Fóidín experiment was modelled on a Rohr-Madl design. This used milled peat, which it compressed and macerated and then extruded as small sods that were descriptively referred to as 'elephant droppings'. The idea was to make use of milled peat that had failed to dry properly because of bad weather. However, the partially dry condition of the milled peat made it much less amenable to maceration, and meant that an unacceptably large amount of energy had to be expended on the process, which was soon abandoned.

Small machines have also been busily at work on the bogs of Northern Ireland over the last fifteen years or so. It has been estimated that in 1991 turf was being cut from 3,769ha of blanket bog in the North; most of this was machine turf, harvested from 1,020 sites.

To a very real extent, the new machines have been responsible for the revival of the bog meitheal; in the two decades after 1960 or so the bog margin had grown increasingly deserted, no longer re-awakening each May to the chorus of voices of all ages come to reap the annual fuel harvest. With the spread of the new cutting machines all this has changed.

The cut turf is spread in continuous, regular lines on the spreading ground, so all the labour of cutting and wheeling out has gone. But as it dries it still has to be turned and then footed in much the same way as it always had, and this is work that is as backbreaking as ever, more so maybe since most of those working on the bog nowadays are inured no longer by the labour of regular manual work on the farm or elsewhere.

The spreading ground is a special place, a new type of bogland ecosystem, which the much drier conditions make suitable for a whole galaxy of invading creatures. Rooks hawk the spreading grounds. Larks and warblers, buntings and cuckoo still call as they always have on the edge of the bog. Decomposition of the peat is much more rapid here, and this establishes the foundation for a complex of food webs in the area between farm or woodland and the margin of the uncut bog. The activities of turning and footing the turf provide a splendid opportunity to explore this world – taking your mind off your back – because lifting the sods is like taking the lid off, and you can see many of the creatures who have so quickly moved in to colonise this empty land. These are mostly creatures who normally spend their day hiding out of the sun under stones or logs, and the flat, damp sods provide the perfect conditions for them, until they are so systematically evicted when the turf is turned and footed. Among the commonest creatures under the sods are several species of worms, slugs, millipedes, ground beetles and the grubs of craneflies. These are all creatures that will also be found in heathy grassland, but conditions here allow us to actually see how abundant they may be. We will meet many of them in Chapters 10 and 11.

Turbary

By the beginning of the 18th century most bogs belonged in law to individual landowners, and most of the large bogs were part of great estates. However, longstanding customary rights survived from earlier times. Residents in a particular parish or community, or on a landlord's estate would often have a customary right of turbary in a particular bog. Rights such as this can be invoked by anybody coming within the custom of the locality, even if they have no other land rights. To qualify as 'customary' in law, such rights must satisfy four basic requirements: they must be 'ancient, certain, reasonable and continuous'. In practice, if the right has been exercised for 20 to 40 years without anybody objecting, it is generally accepted as of ancient origin. Customary rights like this can often be traced back to Crown grants resulting from the resettlement of confiscated land. A right of turbary can also be acquired by prescription ('profit-a-prendre'), where a claimant can demonstrate that he has cut turf without secrecy, without permission and without force continuously for a period of 30 years; if he has cut turf continuously for 60 years under the same conditions he can claim an absolute right to the turbary.

Tenants generally enjoyed the right to cut turf from a particular bit of the landlord's bog. People could also lease turbary on con-acre (i.e. for 11 months, seasonal on a year-by-year basis). This had the advantage from the landlord's point of view that the lessee acquired no rights over the bog. In the 18th-19th centuries turbary rights were largely controlled by the great estates. In the late 19th and early 20th centuries many of these were bought by the Estates Commissioners under the Land Acts; tenants bought their holdings from the Commissioners, and continued to enjoy their turbary rights even if the bog itself remained in the freehold of the old landlord. Turbary Trusts were sometimes set up. The break-up of the estates accelerated after the establishment of the Irish Free State in 1922 under the Land Commission (1923 Act and subsequent Acts), which divided bogs into individual strips – often very numerous and narrow, the average width being 20-30 yards – and assigned these to individual tenants. Sometimes (on smaller bogs generally) the fee simple went with the turbary. In other cases, the fee simple to blocks of turbary was assigned to one tenant [**Figures 1.19 and 1.20**]. The idea here was that in the long term the reclaimed cutaway would augment his holding, and it simplified the registration of title at the Land Registry. The Commission leased turbary rights to 5,000 users in 1931, and built many roads to improve access. In the west many bogs are held in common rather than divided up into individual plots and rights. Before the demise of the Land Commission, most of the bogs not in common ownership had been divided up and the ownership given to farmers.

In north Armagh, which had very extensive bogs, areas of turbary were called rood-mosses, although individual banks didn't necessarily have to be a rood (which is a quarter of an acre) in area. In the Midlands, con-acre bog was usually rented for the year in small banks measured by the perch; a perch is five and a half yards.

With this complex history behind it, it is hardly surprising that complicated questions of title over bog are frequent, especially where there was extensive division by the Land Commission, or where the right to graze a bog is held by one party, the turf underlying the grazing by a second, and the residual cutaway or fee simple by a third not to mention the sporting rights. Where Bord na Móna took over bogs for development, each of these interests had to be purchased to give clear title. The complexity and frequent uncertainty also facilitate trespass at the present time, and have sometimes led to the development of bogs without proper legal title.

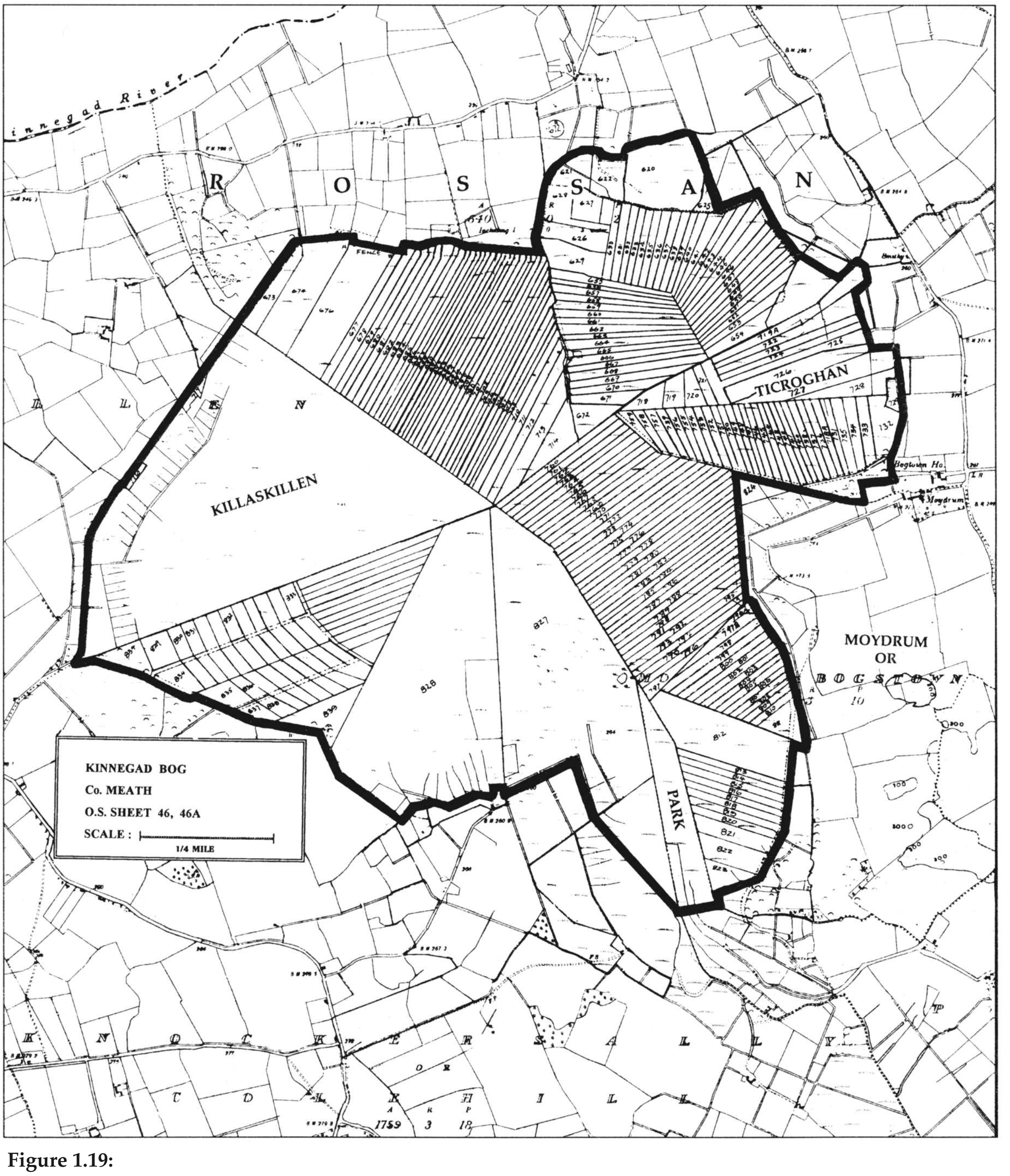


Figure 1.19:

Kinnegad bog, County Meath.

An area of some 330ha; boundary of bog shown edged by heavy black line. Another typical example of the intricate web of ownership which characterises many bogs. The ownership was primarily unencumbered registered freehold, belonging formerly to the Toppin Estate (lLC Estate Record No. E.C. 7127), Rossan townland: except for a block of plots in Bogtown townland on the eastern side of the bog, whose title is a registered fee simple to one landholder subject to turbary rights for around 60 tenants. The large triangular plot on the western side of the bog in Killaskillen townland was a Trust property, with undefined turbary rights for tenants of the Trust. This was originally part of the Estate of the Marquis of Lansdowne (lLC Record No. E.c. 823, c. 1900).

The centre of the bog is the meeting point for several townlands which radiate outwards from this point. Other old estates with land on the bog included:

(i) Estate of John H. Nicholson (lLC Estate Record No. E.C. 7587), townland of Ticroghan.

(ij) Estate of Auchmuty (lLC Estate Record No. S. 3304), townland of Knockersalley or Colehill.

(iii) Estate of R. H. Sheridan (lLC Estate Record No. S. 133/29), townland of Knockersalley or Colehill. (iv) Estate of Kingston, Franklin and Handy (a minor record, No. S.711), townland of Park.

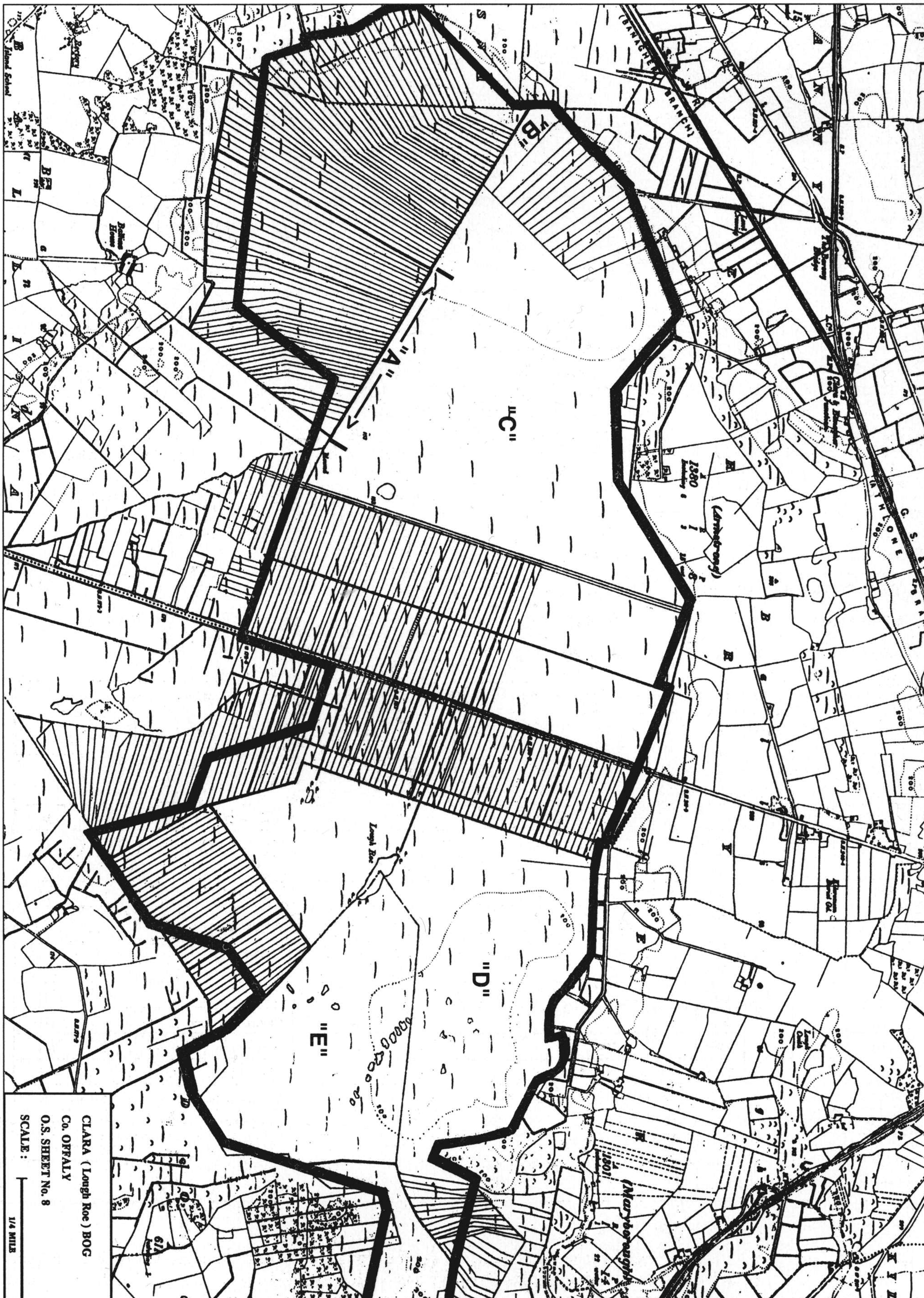


Figure 1.20: Clara Bog, county Offaly.

Clara (Lough Roe) Bog, County Offaly

Clara bog was compulsorily acquired by Bord na Móna for the production of milled peat for Ferbane power station in 1980 (under Order No.217 of the General Board Meeting of 5 December). Ownership details for this area were collated in Book of Reference No. 258, which contains the names of all persons or bodies – some 200 in all – holding a title interest in the bog. Because of its ecological importance, it was transferred to the Office of Public Works (Wildlife Service) in 1987. The boundary of the area of bog currently owned by the OPW is edged with a heavy black line.

The map illustrates the intricate patchwork of ownership in this 464ha of bogland, providing a good demonstration of the various forms of title and ownership which can exist within one area, some overlying or subsisting on each other, such as: (i) 'A' is a block of 36 plots in Ballina townland, on which there was one registered fee simple owner and 36 tenants with turbary rights.

(ii) 'B' is a plot whose title is held as unencumbered registered freehold by one owner, in the townland of Erry (Armstrong).

(iii) 'C' – also in the townland of Erry (Armstrong) – is unregistered freehold land held by Trustees under a Trust. These lands were originally part of the Estate of Henry Ward Bailey, deceased Irish Land Commission [ILC] Estate Record No. 5.4180). Under order of the High Court some time around 1921 the Bailey Estate was sold in the Land Judges Chancery Division; the judge was William Evelyn Wylie. Trustees for some of the tenants appear to have purchased untenanted land and the bog marked 'C' on the map. However, there is no trace of documents or orders relating to the setting up of this Trust, its terms, or subsequent conveyances of the lands to the respective tenant purchasers – if any. The Trustees were James Rogers, Solicitor (Tullamore) and Rev. Michael Bracken (Clara). All the documents of title, together with all records relating to title, were in the Four Courts at the time of the fire of 1922, and were presumably destroyed.

(iv) '0' is a plot of around 80ha in the townland of Erry (Maryborough) which was transferred to Bord na Móna by the Land Commission in 1963. It was part of the Goodbody Estate ILC Record No. 5.4958).

(v) 'E' is a plot of c. 65ha in the townland of Doory that was transferred to Bord na Mona in 1977; it was part of the Kemmis Estate ILC Record No. E.C. 7177). 33

Figure 1.21: Page from the Book of Reference for Clara Bog.

TURF DEVELOPMENT ACT 1946 | **BOOK OF REFERENCE NO. 258**

TOWNLAND OF BALLINA | **ACQUISITION OF LAND NO. 49** | **COUNTY** OFFALY | **O.S.** 8

BARONY OF BALLYCOWAN | **BOG** BOORA - LOUGH ROE

Ref. No. or Nos. and/or Folio Nos. on Deposited Plan of Lands Specified in Column 2 1.					Description of Lands 2.	Owner or Reputed Owner 3.	Lessee or Reputed Lessee 4.	Occupier 5.	Area Acres 6.	
Plot No.	Folio	Map Reference								
		L.R.	L.C.	V.O.						
517		29	$33R^2$	1A	Land (Bog) (	Fee Simple of Plots	) -	Henry Rourke	1	056
518		"	$33Q^2$	"	" (	517 - 529	) -	Daniel Fogarty	1	175
519		"	$33P^2$	"	" (	Raymond Minnock	) -	Richard Heaton	1	281
520		"	$33O^2$	"	" (	Folio 17708	) -	John Grinnan	1	194
521		"	$33N^2$	"	" (	"	) -	John Butler	1	476
522		"	$33M^2$	"	" (	"	) -	Thomas Duffy	1	570
523		"	$33L^2$	"	" (	"	) -	Mary Cornally	1	750
524		"	$33K^2$	"	" (	"	) -	John Hanlon	2	204
525		"	$33J^2$	"	" (	"	) -	Thomas Minnock	2	471
526		"	$33H^2$	"	" (	"	) -	Mary Lynan	2	744
527		"	$33G^2$	"	" (	"	) -	Michael Larkin	2	619
528		"	$33F^2$	"	" (	"	) -	Thomas Daly	2	739
529		"	$33E^2$	"	" (	"	) -	Margaret Colgan	2	745
									25	024

Stencil No. A/5 | **Page No.** 2.

Figure 1.22: Kilmacshane Bog in Co. Galway.

Kilmacshane bog lies between the River Suck and the Grand Canal. The larger numbers indicate the various freehold plots, and the smaller numbers refer to defined turbary rights. '4A' is an area with 1;1ndefined grazing rights. Note. the way roads were put in to allow access to each turbary plot. Turbary schemes of this kind were put in place as part of the land re-allocation of the ILC from the 1920s right down to the late 1970s.

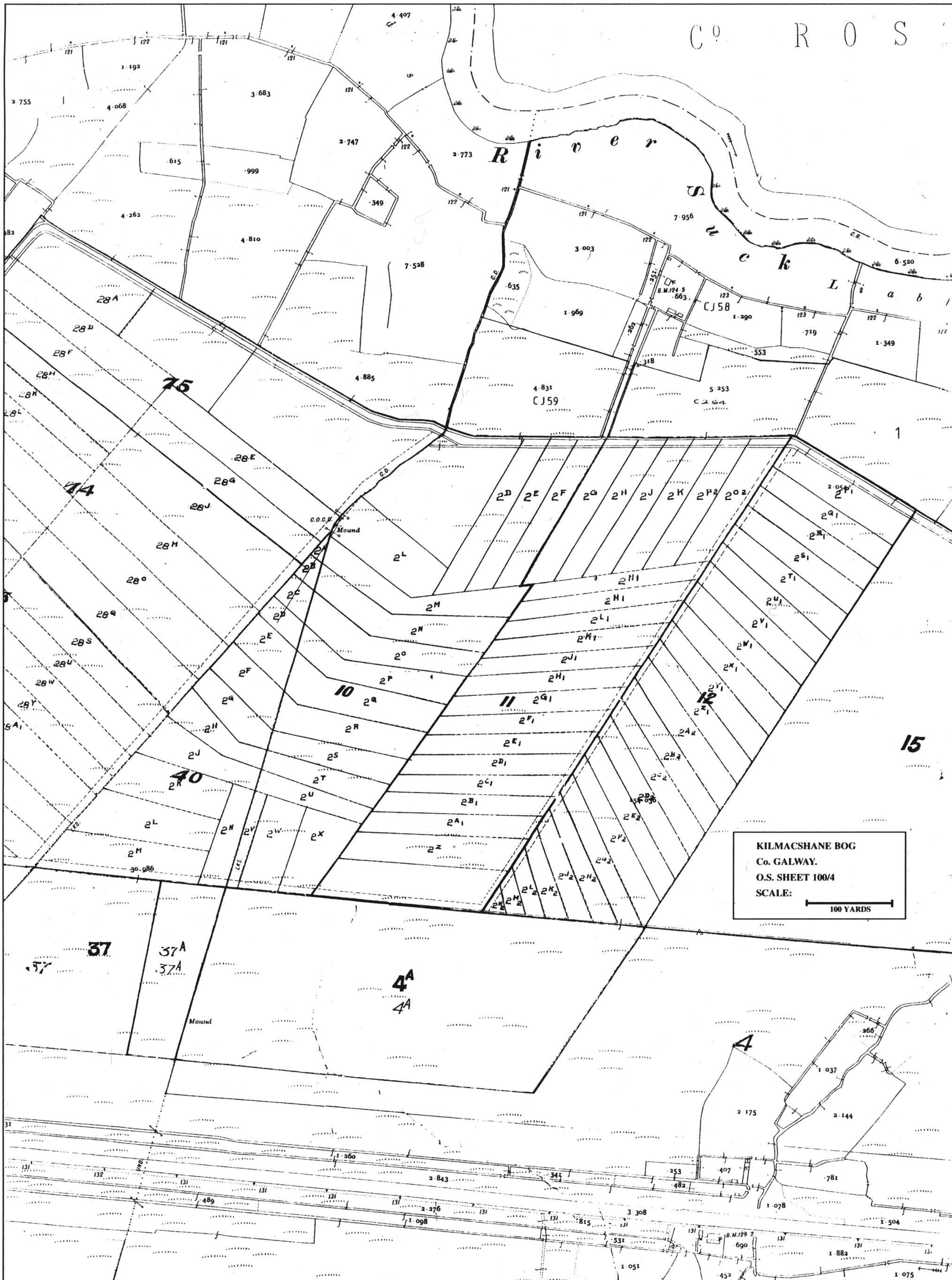

KILMACSHANE BOG
Co. GALWAY.
O.S. SHEET 100/4
SCALE:
100 YARDS
River Suck
Co ROS
CJ58
CJ59
Mound
75
74
40
10
11
12
15
37
4

Figure 1.22.

Figure 1.23: Footing turf in a peat bog let in con-acre in County Mayo early in the century.

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Chapter Two

Reclaiming the bogs

The perseverance of many of the poor Irish is wonderful. Allow one to settle on a wild bog, and apparently without any means, he contrives to live. At first his lodging will be a hole cut in the turf; alongside which he will have a little patch of tillage, a few fowl, and perhaps a goat; then by degrees the tillage increases in extent, and a pig and heifer-calf is added to the stock. Afterwards the heifer grows into a cow, and the boghole into a cabin, and the man is put under rent.

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Introduction

Thousands of years ago the bog extended its domain into the world of the farm, locking away tens of thousands of potentially productive hectares under a blanket of inhospitable peat. But as the population of the country began to grow in recent centuries, attempts were made to reclaim some of this land for farming. By the 16th century certainly, bogs were being used as rough pasture, and there are indications that reclamation on a limited scale was taking place in more densely settled areas. A late sixteenth century inquisition on the extent of Ormond tells us that the tenants of Cottrels Bowly (Cotterellsbooly) in Kilkenny pastured their animals on the 'moore or medowe called Mane roman', and some of the tenants had sown crops on a part of the moor. One of these enterprising tenants, Edmond Mortell, 'did eare a litle croft, parcell of the said medowe or moore and sowed the same with wheat and beare'. However, in the Middle Ages both mountain and lowland bog often had the status of commonage, so that the use of the edges of the bogs for rough grazing was probably widespread.

The use of bog margins for grazing may go back very much further than medieval times. The occurrence of fulachta fiadh on reclaimed fen along the edges of bogs in the Midlands raises the interesting possibility that these ancient cooking places mark the seasonal camps of Bronze Age herders accompanying their cattle in late winter and spring, at a time when the bog surface was much drier, and when the fringing fens would have provided valuable early grazing.

In the eastern part of the country, in the lands of the Pale, the demand for turf resulting from the high population and the great pressure in the 13th and early 14th centuries to create as much productive arable land as possible, led to the removal of many of the raised bogs close to Dublin. Finglas bog would seem to have been cut away by the early 14th century. Garristown bog – 'the Redmore in Gariestown' – on the River Delvin in North County Dublin, was under cultivation in 1337, but it had reverted to common pasture by 1348. The bog at Newlands near Tallaght may also have disappeared in medieval times.

Bog reclamation had already begun before Gerald Boate wrote in 1645 that he knew 'Gentlemen, who turned into firm land three or four hundred acres of Bog, and in case that this detestable rebellion had not come between, in a few years there would scarce have been left one acre of Bog of what was in the lands and possession of the English '.

Boate also describes the way bogs were drained in his time:

> On that side of the bog where the ground is somewhat sloping, they cut a broad, deep trench, beginning it in the firm ground and advancing it unto the entrance of the bog, into which trench the water would sink out of the next part of the bog in great

> abundance ... Some part of the bog being by this means grown reasonable dry within a short space of time, opportunity thereby was ministered to advance the trench further into the bog; and so by little and little they went on with it untill at last they carryed it quite across the bog from one side to the other; and having done this they made a great many lesser trenches out of the main one on both sides of the same; the which bringing the water from all parts of the bog unto the main trench, did in a little while empty the bog of all its superfluous moysture, and turn it unto good and firm ground.

This in some ways resembles the way bogs were drained in Holland. The Dutch probably had more experience than anybody of systematic bogland drainage and reclamation, and the story is told (unfortunately it rests on rather slender evidence) that an offer was made during the reign of William III by a group of would-be Dutch colonists to settle in the Queen's County and to transform the Bog of Allen into meadow – on condition that they be allowed to administer their own laws of empoldering. The remarkable achievements of the Dutch in peatland reclamation in the 17th century show that this was not an idle boast, and access to efficient and cheap energy was an important ingredient in the growth of the Dutch economy and power at the time. Dutch engineers were active not only in the Netherlands, but further afield – in the drainage of the East Anglian fens, for example.

The agricultural attack on Ireland's last wilderness which took place in the 18th and early 19th centuries was probably influenced to some extent by successful reclamation projects at this time in the vast bogs of north-west Europe. As early as 1425 in Holland the Groningen Fen Edict resulted in a steady annual turf output of 10^6 m^3, and yielded 1,400 ha of cutaway suitable for tillage. The Reclamation Edict of Frederick the Great in 1765 was the beginning of steady, purposeful reclamation in Prussia. J.C. Findorff's bog colony in Bremish-Verden (1750-92) served as the model for other similar ventures in subsequent decades. The reclamation of the vast Burtang Bog, which originally occupied 50,000 ha on the German-Dutch border, took a century to reclaim, and must have served as a constant inspiration to would-be bog developers of the 19th century.

However, there were two more immediate reasons for the growing interest in bogland reclamation in the 18th century: firstly there was a new confidence among the landed gentry, and the new landowners were anxious to make their estates as productive as possible; the more productive land one had the greater the amount of rent one could expect. Secondly, the burgeoning population put an unprecedented pressure on land; all these millions of people lived in a self-sufficient economy, in most cases depending on the land alone for their livelihood. Land which had lain semi-derelict and underused in the 16th and 17th centuries was brought back into production. The growing population provided landowners with an endless supply of hungry, cheap labour on the one hand, and on the other hand increased the numbers of people desperate for land. In these circumstances attention focused increasingly on the vast, barren tracts of land beyond the productive fringes.

Many observers looked to the bogs with great optimism; some, among them Sir Robert Kane, (writing in 1844) believed that virtually *all* the bogs could be reclaimed for cultivation:

> The uncultivated land includes bogs and mountains. It has been already shewn, that the area of bog is 2,833,000 acres, of which almost all is capable of reclamation, and of being adapted to productive husbandry, if not required as repositories of fuel. Of the mountainy land also, comparatively little is beyond the domain of agricultural enterprize ... there is no district in Ireland sufficiently elevated to thereby present serious impediments to cultivation, and scarcely an acre to which the name of incapable of cultivation can be applied. It has been calculated that of the land at present waste, 4,600,000 acres are really available for agriculture, and from my own investigations, I am inclined to consider that estimate as certainly not exaggerated.

At this time, prior removal of the peat was not, considered to be essential for reclamation. Although dozens of different techniques and variants were recommended by different experts, two things were basically needed to make a bog productive; firstly the waterlogged peat had to be drained, and secondly its low nutrient status had to be increased and maintained by the addition of fertiliser, followed by cultivation and manuring, and subsequent upkeep and maintenance. Estimates of the cost of reclamation varied. In 1820 the costs of reclamation were reckoned to be between £5 and £15 an acre; the value of the bog rose after reclamation from next to nothing in some cases to anything between 10 and 40/= an acre or more. There was a difference of opinion as to whether it was more remunerative to reclaim red or black bog.

Draining was the first and most important thing. The difficulties and techniques of bog drainage were well appreciated in the 17th century; they are discussed in some detail in Gerald Boate's *Naturall History of Ireland* (1647), and since this book was written before Boate ever visited Ireland, it must reflect thinking in the country at the time. Moreover, anybody familiar with what was happening in Holland at the time would have appreciated the problems and techniques involved. The healed scars of the drains dug by the early reclaimers can still be seen in parts of the country. Henry Kinahan, writing at the end of the 19th century, describes how one sometimes came upon a 'Sassenach's Cut' in the middle of an extensive bog, evidently the remains of what was once a canal across the bog, or how beds or seams of clay, which could only be interpreted as the surfaces of land cultivated by these early pioneers in bog reclamation, were sometimes encountered while cutting peat at different levels.

The basic principle in the effective drainage of a large bog is that the exit of the main drain should be at the lowest point of the circumference of the area, and that this drain should gradually be pushed back towards the centre of the bog. Smaller side-drains branch from the main drain at right angles, and these in turn are assisted by shallow surface drains. The depth of these drains should be increased gradually from year to year to prevent collapse. In the 19th century, main drains some 6′ deep and 8′ wide were sunk along the edges of the bog, and then cross drains 3′ deep and 4′ wide were made across the bog at intervals of five to ten perches during the first year. In year two the drains were deepened and the surface gravelled or limed, and manured. Potatoes would usually be planted for the first few years, yielding on average around 30 barrels at 8/= each, equal to £12 an acre – or it could be let in its newly-reclaimed state at three to four guineas to the land hungry poor. Barley usually followed this, and then the land was let out to meadow. A similar rotation might be started again after say seven years – but there were as many permutations on the best rotation as there were experts. Other rotations were commonly dominated by such plants as rye and rape.

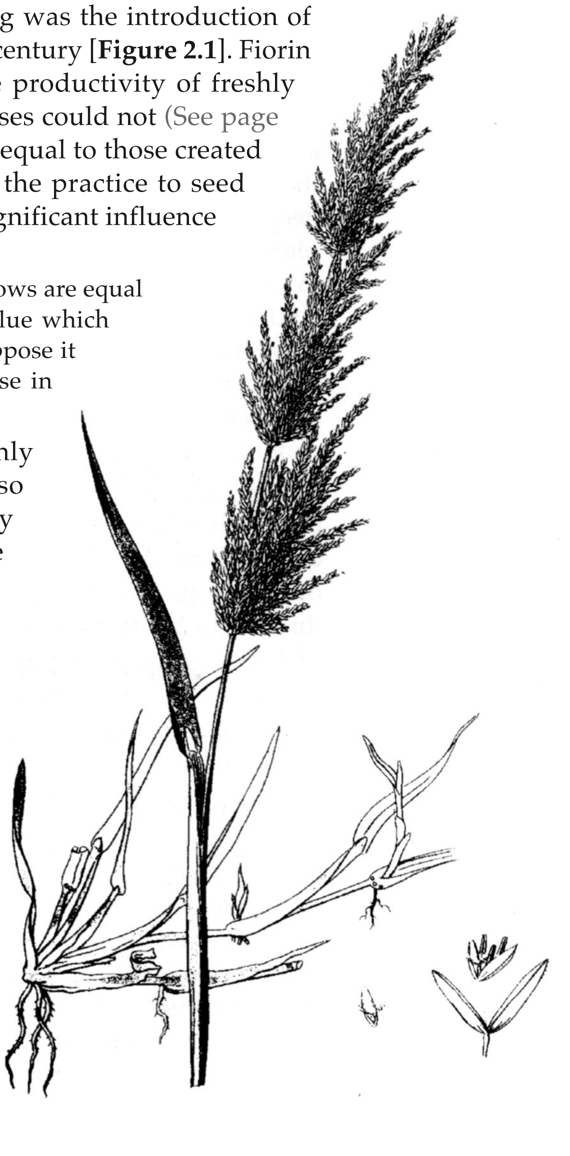
In reclaiming 30-40 acres at Ballyegan Bog near Birr, B. Mullins had sunk main drains which were 14′ wide at the top, 8′ wide at the bottom, and 8-12′ deep, which were used as navigable canals to convey manure. Mullins' method – and he had the advantage of having constructed 40 miles of canals across the Midlands bogs – resulted in a lowering of the bog surface by over seven feet in two years, and he ended up with 'excellent pasture for live stock, but particularly well suited to the grazing of young horned cattle'.

The surface of well-drained bogs fell at times by 15-20′ in 30 years. During the construction of the Grand Canal in the early 18th century, Edenderry Bog sank by 43′ and Ballinasloe Bog by 20′; part of the canal which appears on the engineers' drawings as deep cutting through Edenderry Bog ended up on a high embankment (See page 65).

In parts of the north-east (North Armagh for instance) bogland was often reclaimed by first of all encircling it with a deep drain, then removing the surface heather scraw, and digging holes at regular intervals 30-45 cm deep across the bog. Masses of red, burning peat were then put into these holes to smoulder away. After a week or so the entire surface of the bog would be burnt, and could be dug over in readiness for planting. Potatoes did best on cutaway bog, with oats second-best, though the yield with oats was less than on better mineral soils. Another disadvantage was that crops often ripened two to three weeks later on reclaimed peat soils than on warmer soils, which increased the danger from early frosts. Areas of reclaimed cutaway were often used as hay meadows, and in good years under good management might give two crops a year, the first in June and the other in early September, and, weather permitting, the after-grass might then be grazed until late October. Fields in newly reclaimed bog were usually separated from each other by banks and drains, though in Kildare C. Nangle had planted hawthorn hedges in turf bog by digging foot-deep trenches which he filled with earth.

As the peat dries, decomposition by microrganisms makes its nutrients available, but in those days, long before the development of the modern science of plant nutrition, the productivity of bogs was estimated by practical rules of thumb. So, for instance, if the bog produced red or yellow ashes on burning – which we would expect nowadays from peat with a higher mineral content – one could expect a good return from potatoes, rape or other crops the first year, whereas if the bog was a red bog producing only white ashes, one would have to wait several years for a return. In his Statistical Surveys of various counties (and especially Offaly), Coote frequently assesses the productivity of bogs on the basis of the colour of the ashes when burnt. Thus, in the Barony of Garrycastle 'burning does not answer, as the ashes are but light and white', whereas in Coolestown 'they always burn, and their bogs produce heavy red ashes'. Coote describes the bogs of Cavan as yielding 'the strong red ashes, which are so particularly good and lasting a manure'. Turf ashes were also widely used as a manure in their own right, especially in the north of the country, but again only red or yellow ashes were valued. The ashes were either applied directly to the fields, or peat was spread on the ground at a rate of as much as 150 car loads to the acre and allowed to dry before being burnt and spread, still hot, to be ploughed in later.

Figure 2.1: Bog supergrass. In the early 19th century, creeping bent was so popular that G. V. Sampson could describe it as 'the grass which predominates' in County Londonderry. 'In the low meadows of Aghanloo, it grows above three feet in length, and is so thickly matted, that it can scarcely be winnowed and saved in the space, on which it grows' (*Statistical Survey of the County of Londonderry*, 1814).

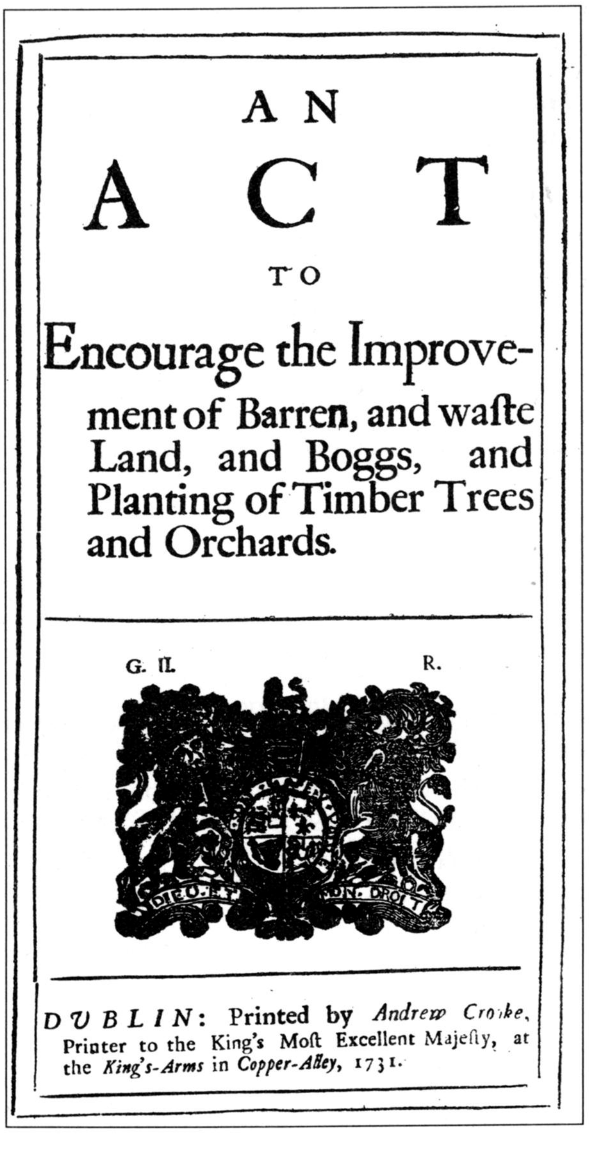


A significant factor in the reclamation of bog for grazing was the introduction of creeping bent or fiorin *(Agrostis stolonifera)* in the eighteenth century [**Figure 2.1**]. Fiorin is a very variable and adaptable grass, and can harness the productivity of freshly reclaimed bogland soils in a way which more productive grasses could not (See page 234). Arthur Young was of the opinion that no meadows were equal to those created by improving a bog, even though in his time it was not yet the practice to seed reclaimed bogland with fiorin; his opinion must have had a significant influence on go-ahead farmers:

> Whatever be the means used, certain it is that no meadows are equal to those gained by improving a bog: they are of a value which scarcely any other lands rise to; in Ireland I should suppose it would not fall short of forty shillings an acre, and rise in many cases to three pounds.

The principal fertiliser used was lime, which not only supplied one of the major macronutrients required, but also neutralised the acidity of the peat. There were many readily accessible sources of abundant lime, esker gravel, limestone and bog or lake marl being the most important. Marl or calcareous blue clay from the Shannon and its lakes was widely used as fertiliser. 'Bog stuff' was widely used as a manure by farmers large and small. Sometimes it was mixed to a compost with dung or, as near Clonmacnois, with marl from the Shannon callows for raising potatoes or oats. Occasionally, so much was used that it turned the soil itself moory. In some places (like the Knockmealdowns) turves were cut from mountain sides and used to make compost which was then sold. If farmyard manure could be procured it was used, and until the introduction of guano and artificial fertilisers there was a large trade in 'scavenger's manure', which consisted of the sweepings of Dublin, carried along the canals by the empty turf boats into the Midlands; this trade ended around 1850. Seaweed and sea-sand were widely used in the reclamation of low-level blanket bog in the west of Ireland. Shell sand dredged from the bays of Cork and Kerry was widely used in Munster in the late 19th century, sometimes being carted for miles over the mountains to wherever it was needed. Even seedling mussels were sometimes collected and used as manure. Occasionally, attempts were made to 'warp' mountain streams – deflect their course in flood so that they might spread mineral debris on top of the bog.

Centuries of cutting turf by hand have removed many bogs altogether, but even where the land has been fully reclaimed for agriculture there are sometimes clues to its bogland ancestry. Around Belmullet for instance, and in the north-west corner of County Kerry, the farmland is divided into regular fields by high banks of undisturbed peat, and in places the roads are several metres above the level of the land, at the same height as the boundaries separating the fields. In North Armagh, extensive areas of fen and reed swamp bordering Lough Neagh – similar in many ways to the Norfolk Broads in England – are divided up by heather-capped peat ramparts, the last skeletal fragments of the vast raised bogs which formerly covered the area.


AN

ACT

TO

Encourage the Improvement of Barren, and wafte Land, and Boggs, and Planting of Timber Trees and Orchards.

G. II. R.

DUBLIN: Printed by Andrew Crooke, Printer to the King's Moft Excellent Majefty, at the King's-Arms in Copper-Alley, 1731.

Figure 2.2: Title page of the Act of Parliament passed in 1731 to encourage the reclamation of bog and other 'barren and waste land'.

Incentives to reclaim: legislation and premiums in the eighteenth century

A number of Acts of Parliament passed in the early part of the 18th century mark the beginning of a serious interest in peatland reclamation. The earliest of these, passed in 1716 to promote 'the draining and improving of unprofitable bogs and low ground', was concerned mainly with developing navigation on the Shannon and other large rivers. This was followed in 1728 by an Act appointing Commissioners to oversee the execution of drainage works and recommended the setting up of a public fund; this was provided for in a further Act in 1729. The impact of these measures appears to have been very limited, as least in regard to the reclamation of bogs. The first land reclamation act proper was passed in 1731, largely due to the efforts of Arthur Dobbs, who was an active member of the Dublin Society, 'to Encourage the Improvement of Barren and waste Land, and Boggs, and Planting of Timber Trees and Orchards [**Figure 2.2**]. Among other incentives it offered remission for seven years from the payment of tithes on flax, hemp and rape sown on land which had been reclaimed. Under this Act it became compulsory for landowners around a bog to establish boundaries on the bog, and to co-operate in drainage

> ... where any Person or Persons shall be Seized or Possessed of any Lands Contiguous, or Adjoyning to any Bogg, Moss or Lough, or to Ground between the Flux and Reflux

> of the Sea, and shall be Desirous to Settle and Ascertain the mears and Bounds thereof ... Regard being had to the Length of the Profitable Land Adjoyning to such Bogg, Moss, Lough or Ground belonging to such Several Proprietors ... And where a Drain shall be Necessary to Carry off the Water from such Bogg, Moss or Lough, the said Commissioners [appointed to oversee the division] or the Major Part of them, shall and may Lay Out and Ascertain the same, and the Length, Breadth and Depth of such Drain, and likewise Order and Appoint what Part or Proportion thereof shall be Made or Done by the said several Proprietors, with Regard to the Benefit that each of them may Receive thereby.

It was the parliamentary measures enacted later in the century which underlay much of the reclamation which took place towards the end of the 18th and in the early 19th centuries. In 1771 the first Act directed specifically at bogland reclamation was passed. This 'Act to encourage the reclaiming of unprofitable bogs' made it lawful for Catholics to lease substantial areas of bogland:

> Whereas there are large tracts of bogs ... and it hath been proved by experience such bogs are capable of being converted into arable or pasture if encouragement were given to the lower class of people to apply their industry ... be it enacted that every papist or person professing the popish religion who shall be desirous to employ his industry and money for the improvement of the Kingdom by reclaiming unprofitable bog shall be at liberty to take a lease of any tract not exceeding 50 acres and 1/2 acre arable land as a site for an house ... and to hold same at such rent as shall be agreed upon ... for any term not exceeding 61 years.

To qualify as 'unprofitable', the bog had to be at least four feet deep after reclamation, and the tenant had to reclaim a minimum of ten acres, the bog had to be at least a mile from the nearest town, and half of the reclamation work had to be carried out within 21 years. In return, the tenant would be free from 'all tithes, cesses, or applotment' for the first seven years after the bog was reclaimed.

The second Act was the Catholic Relief Act of 1793, which gave the elective franchise to Catholics. At this time the population of Ireland was somewhere over four million, and three million of these were Catholics. To qualify for the vote, a tenant had to be a '40-shilling freeholder'. Because the number of votes in the landlord's control was an important political asset, it suited landlords to maximise the number of such freeholders they had on their land~ As a result, landlords were quite happy to lease otherwise useless bog to people desperate for land of any kind. The 40-shilling franchise was withdrawn by the Relief Bill of 1829, but the tenants kept their land, though with less enthusiastic landlord support.

The formation of the Dublin Society in 1731 (after 1820 the Royal Dublin Society) led to the provision of new incentives to reclamation. Among its activities was the award of premiums and medals for drainage of bogland. The value of, and the conditions attached to, these premiums varied with time, but those offered for 1769 are fairly typical:

For effectually reclaiming the greatest Quantity of unprofitable Bog (not less than 30 Acres) so that in the Year 1769, it shall be in Tillage or Meadow	£50
For the next Quantity, not less than 25 Acres	£35
For the next Quantity, not less than 20 Acres	£25
For the next Quantity, not less than 15 Acres	£18
For the next Quantity, not less than 10 Acres·	£12

> Every Claimant is to lay before the Society, the Quality of the Bog before reclaiming, the several Methods he shall have taken to reclaim the same, and the Depth and Breadth of the Drains he shall have made: No Person shall be entitled to the above Premiums, unless the Depth of the Bog before reclaiming shall have been at least four Feet from the Surface to the Bottom of the Bog, or two Feet after reclaiming, nor shall any Person receive more than one Premium for the same Ground; every thing else alike, Renters of Land shall have the Preference.

To every Renter of Land, not holding above 20 Acres, who shall effectually reclaim one Acre of unprofitable Bog, so that in the Year 1770, it shall be in Tillage or Meadow, the Society will give a Premium of £2.10s. The Sum of £50 will be appropriated in these Premiums to each Province, and if more than twenty Claimants, entitled to the said Premium, should appear from anyone Province, then the sum of £50 will be divided among such claimants.

To the Person or Persons who shall bring in, improve, and effectually manure to the Satisfaction of the Society, the greatest Quantity of unprofitable Mountain (not less than 15 Acres) so that in the Year 1769, it shall be in Tillage
£12/10s

For the next Quantity, not less than 10 Acres	£15
For the next Quantity, not less than 5 Acres	£7 /10s

Every Claimant must lay before the Society, the Nature of his Mountain Land before reclaiming, and the several Methods he shall have taken to reclaim it.

To every Renter of Land, not holding above 25 Acres, who shall effectually reclaim and have in Tillage in the Year 1769, any Quantity of unprofitable Mountain (not less than one Acre, and no one Person to receive a higher Premium than forty Shillings), the Society will give an Encouragement at the Rate of twenty Shillings for every such Acre of reclaimed Mountain. The Sum of £50 will be appropriated in these Premiums to each of the Provinces; and if more than 50 Acres shall appear to have been reclaimed among such Claimants from anyone Province, then the sum of £50 will be divided among them proportionably to the Quantity of Mountain which each shall have reclaimed; not no one Claimant is to receive a higher Premium than forty Shillings.

For each of the Provinces	£50

An additional premium was on offer for 'effectually reclaiming the greatest Quantity (not less than 18 Acres) of wet moory Ground, not properly coming under the Denomination of Bog or Mountain'. In the absence of a detailed study of the RDS records, it is difficult to estimate the overall influence of this stimulus, but the indications are that the response greatly exceeded the expectations of the Society. The published awards for the years 1774 and 1775 give an indication of the widespread effect of the scheme at this time. In 1774, 923 'Poor Renters of Land' received premiums for reclaiming bog, 1,461 for reclaiming mountain, and 620 for reclaiming moor. The amount each farmer received varied in Lotto-like fashion, because a fixed amount was allocated to each province, so how much each received depended on the number of successful applicants. In Leinster there were only 50 successful applicants, who received £3 each; the 236 in Ulster got £1.0.4d each, the 247 Connaught Renters got £1 apiece, and the enthusiastic response of the 390 successful applicants from Munster merited only 16.3d apiece. The total of the 'Poor Renters of Land' premiums for each of these years was £2,080.

For the year 1775, 855 Poor Renters received bog reclamation premiums, 1,231 received premiums for the reclamation of mountain, and 1,040 for moorland; 20 went to Leinster, 3.09 to Ulster, 342 to Munster and 184 to Connaught. The small number for Leinster in both years suggests that there was little reclamation of raised bog, but the same pattern is evident in the breakdown for reclamation of mountain. In 1774, 151 mountain premiums went to Leinster, 310 to Ulster, 227 to Connaught and 773 to Munster. In 1775, 66 premiums went to Leinster, 420 to Ulster, 534 to Munster and 211 to Connaught. The pattern is apparent also in the awards for the reclamation of 'moore'. In 1775 the premium for reclaiming the greatest quantity of mountain in Leinster went to Rev. Robert Greene of Kildare for 30 acres, in Munster to Edmund Roche of Cork for 142 acres, in Ulster to Henry Charters of Monaghan for 17 acres, and in Connaught to Peter Kelly of Galway for 30 acres. In the National Museum there is a fine silver cake basket made in Dublin by Iohn Locker which was presented to Lancelot Sandes of Kilcavan in Laois 'for having reclaimed in the year 1769, 20 acres of bog, in the Queen's County, and for reclaiming 25 acres of bog in the year 1765 he was honoured with a gold medal, and for reclaiming 30 acres of bog in the year 1766 he got a premium of Thirty-five pounds' [**Figure 2.3**].

Figure 2.3: Silver cake basket awarded to Lancelot Sandes of Kilcavan in Laois for the reclamation of bogland (National Museum of Ireland).

These incentives led to a new concentration of tiny farms on the fringes of the bogs. Sir Charles Coote describes one of these settlements in Geashill in County Offaly, as it was in the late 18th century:

> The habitations of the poor are miserable towards the bogs, which cover an immense tract of this country, consequently turf fuel is very cheap and abundant; but the dangerous custom of incautiously burning the bog, was like to have had the most fatal consequence to a great tract of this country, which melancholy scene I witnessed: on the very edge of the bog some beatin was on fire, and a very strong breeze springing up, the whole face of it caught the blaze, being in a most combustible state from the excessive drought of the season: the poor peasants, whose miserable habitations were thickly scattered here, with difficulty escaped from the flames, but the whole of their effects were burnt with their huts; and, what was still more melancholy, the potatoes and corn, which they had with much difficulty been able to rear in the last scarce year, and just seemed to promise a fine crop at the ensuing season, whose approach they anxiously looked for, were in a few minutes destroyed, and with them seemed to perish the hopes of again enjoying the blessings of plenty.

Like everybody else, Coote was optimistic about the prospect for reclaiming bogs for meadow-land – although his optimism referred mainly to the fens and marshy land on the extensive fringes of the deep red bogs which were, be felt, 'capable of being made the best meadow'. He was greatly impressed by the providential arrangement that right in the middle of the bogs themselves there was such a superabundance of the very fertiliser which was most necessary in the reclamation of bogland: lime, in the form of the limestone gravel in the Midland eskers. Indeed, he saw in this the beneficent hand of Providence:

> The great and universal remedy for it, which is limestone gravel, nature has kindly thrown small heaps of, at convenient distances, in the midst of the moors, and these tufted mounds, so conspicuously scattered on the surface, seem as if they had been purposely deposited there to reclaim them; if we deduct the quantity of this valuable soil; from what appears to be the bogs, in this country, an immense tract of valuable land is acquired, fit for all the purposes of husbandry, and will be found more productive either in pasture or tillage, than the general run of the best lands in the county.

Many other observers were equally optimistic. Dutton, writing about County Galway around 1826, felt there was very little of that county that could not be improved by burning the surface and then manuring with seaweed or lime; he claimed to have 'scarcely ever seen a bog that could not be reclaimed at a remunerating expense'.

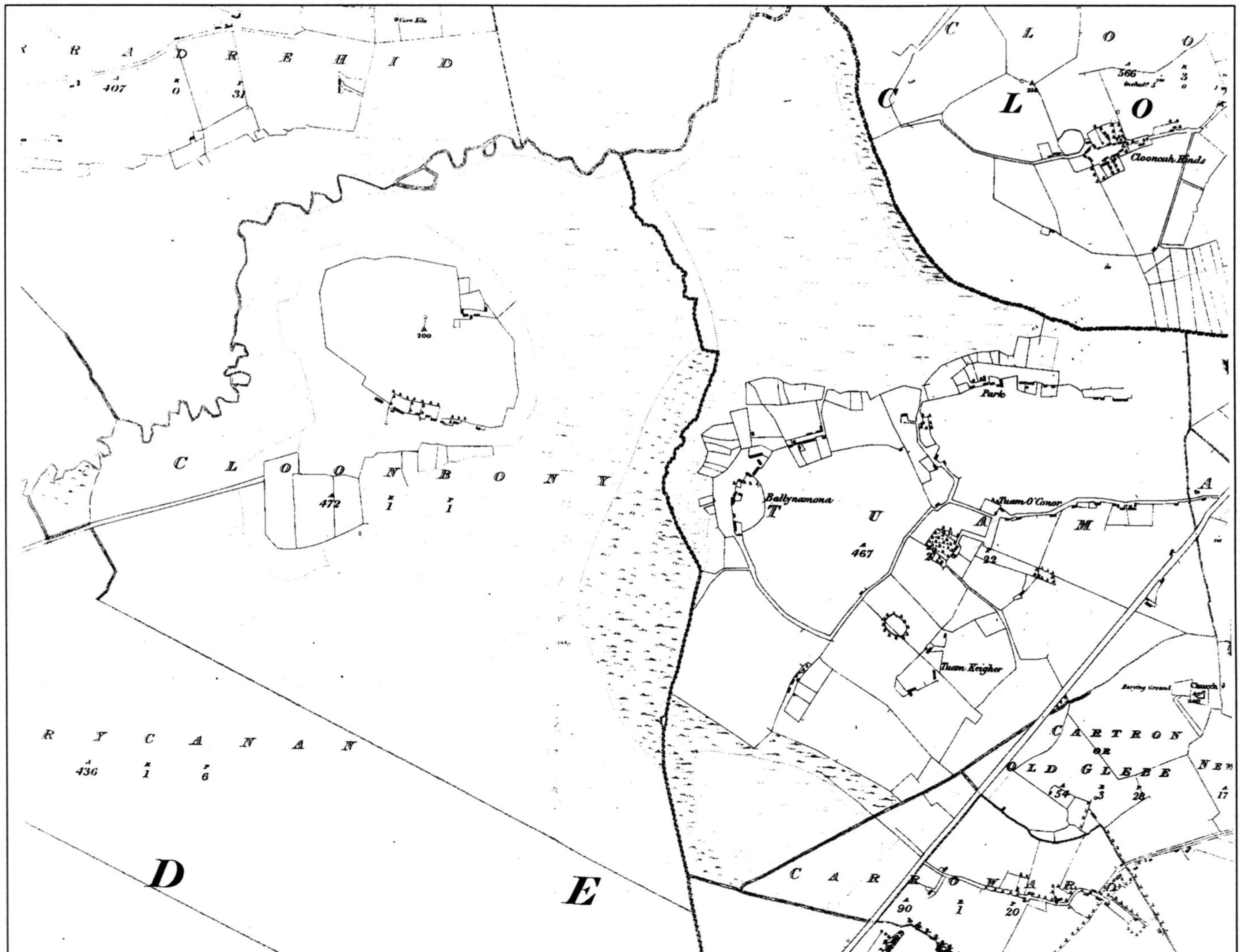
One of the most dramatic reclamation schemes undertaken in the 18th century was the drainage of the bogs around Monivea Castle in County Galway, the home of the French family. The castle was surrounded by two deep and. virtually impassable bogs, which had grown so much since the castle was built that they blocked the view from the ground floor. Robert French diverted the river which flowed between the castle and the bog, and he cut wide, deep drains through the bog – wide enough for boats to ferry manure and limestone in to the castle farmyard, and out to where they were needed on the bog. Several years on, the bog had subsided by 15 to 20', and the view from the ground floor was restored.

Another early success story was the reclamation of 100 acres of very wet red bog at Woodlawn in County Galway around 1760 by Frederick Trench. So wet was this bog that at first he could only cut drains four feet wide and two 'spit' deep, but there was very severe frost in the winter of 1765, and he took advantage of this to cart clayey gravel out onto the frozen bog, the icy surface of which he covered with two inches of this material. By the following May the bog had dried out so much that he was able to use horses and men to carry manure out across the surface. He then planted potatoes which gave a good return of 40 44-stone barrels to the acre (worth 8/ = a barrel). He then levelled the trenches and sowed barley, which yielded ten barrels an acre at 8/= a barrel. The reclaimed bog was subsequently turned over to good meadow.

The spectacular growth in population which was the outstanding feature of Irish history in the half century before the Famine probably began around 1780; between then and the Famine the population doubled. In the 30 years between 1791 and 1821 it grew from just under five million to nearly seven million. On the one hand, this rapidly growing population gave new urgency to the need for more agricultural land; on the other, such a rapid expansion would probably not have been possible without the bogs. But there were other factors at work as well: the shift from pasture to arable, and the almost exclusive dependence by the vast majority of the population on the potato for food. The explosive growth in the population forced the peasants to reclaim as much of the bog as could be reclaimed. The great reclamation period began around the same time as the rapid expansion in population, but it could not have occurred without the potato, because it was the only crop which was productive on such land: acre for acre, the potato could provide four times as much food as any other crop. When Arthur Young visited Ireland on his celebrated Tour between 1776 and 1779, he saw the first fruits of these two Acts. Almost everywhere he went, he found that for at least nine months of the year potatoes with milk were the food of the people – except for parts of Ulster, where they had oatbread and some meat. The yield seems to have ranged between 40 and 150 barrels to the Irish acre; a barrel contained 22 stones. Bog reclamation accelerated from the 1780s onward, driven by the unprecedented pressure on land brought about by the burgeoning population, and the desire on the part of landlords to maximise their profits.

There were many variations and permutations of method when it came to actually setting about the drainage and cultivation of the bogs, but County Kildare, where the fringes of the vast expanse of the Bog of Allen were being won for farming, mainly by piecemeal reclamation, from the late 18th century at least, was fairly typical. After it was drained, the surface was ploughed or dug up, gathered into heaps, and the heaps mixed with limestone gravel or clay; when they were dry enough the heaps were burnt, and the ashes spread on the surface before it was ploughed or dug again, more deeply this time.

Another approach, which did not involve drainage was described by Richard Gratten of Carbury in his evidence to the Devon Commission. The bog was ridged at a cost of 40/= an acre to take off surface water; when it was firm enough manure and gravel were brought onto the bog in barrows and spread. Potatoes were grown for two years, followed by oats, clover and grass seed, but Gratten observed that this was practicable only where the bog was within 25 perches of a road.



Figures 2.4 - 2.6: Pre-Famine agricultural incursion on the margins of raised bog.

Figure 2.4:
Settlement on the bog fringes at Cloonbony and Tuam in County Roscommon (6" sheet 36). Note especially the aptly-named Ballynamona (bog village) and the 'derry' settlement of Cloonbony.

In Galway Lord Clonbrock had 200 men at work on drainage and reclamation projects on his vast estate. In Cork the Earl of Mountcashel had leased a tract of mountain 'to poor people, who have built houses upon it, and I let it so exceedingly cheap that they contrived by degrees to bring in one acre in one year and another in another'. On one Crown property in Cork, 298 acres had been reclaimed in five years – one or two acres was all the ordinary farmer could reclaim in a year. These are examples selected almost at random, but everywhere the story was the same: in Tipperary the population was 'coming to live on the mountains'; hundreds of acres of mountain in County Waterford were reclaimed – and so on. Other noteworthy examples from the 18th century included Bland's reclamation of part of the Kenmare River bog in 1753, and the reclamation in the 1770s of thousands of acres of bog around Westport belonging to the Marquis of Sligo. A dramatic example noted by the Bogs Commissioners was the bog at Bullahindley (presumably Bunnahinly in Westmeath), where the Down Survey showed 1,173 acres of bog in 1655; by 1811 half of it had been reclaimed.

By the end of the 18th century, bogs were being drained and fertilised all over the country, and many of those who wrote about Ireland and its problems in the early decades of the new century commented on the phenomenon. These observers tended to concentrate on the more spectacular examples, but most of the reclamation was done not by the great landowners, but by cohorts of nameless peasants who were forced by the system to squeeze from the bog whatever it could add to their very limited resources.

The 19th century

By the early years of the new century, patches of land were being reclaimed around the periphery of most of the raised bogs of the Midlands; in the case of one parish in County Laois, for instance, the amount of farmland grew from 1,551 acres to 2,618 acres between 1794 and 1812. The bogs retreated steadily in the decades which followed. Even in the ten years between 1831 and 1841, when the enthusiasm of landlords for reclamation had cooled, some 2% is believed to have been added to the country's productive farmland. In the decade between 1841 and 1851 alone, the amount of agricultural land increased by well over 6%, most of this taking place in the years up to 1845, the final burst in an expansion which had continued steadily over the half century preceding.

Bogland reclamation took place in nearly every county, but it was most intensive in the poorer counties where population increase was greatest, and where extensive areas of bog were available. Writing in 1816, the Rev. James Neligan noted how 'countries consisting chiefly of mountainous and coarse tracts of land are those which produce the greatest increase in population, whilst those that are fertile and accessible contain the fewest inhabitants'. Giving evidence before the Devon Commission (a major repository of information on 19th century reclamation), Richard Gratten of Kildare claimed that 'the population of Ireland is found to increase the nearer you get to the neighbourhood of bogs'. In other words, rural population was often at its densest where settlement was recent.

Most of this reclamation was done by the peasants themselves, and with little hope that there would be any long-term return on the investment of their labour, because the need to use their good land to grow crops that could be sold to pay the rent forced them to find new ground to plant their potatoes: on the fringes of the raised bogs – especially the marginal fens – and the slopes of the mountains. The general opinion at the time was that crops could be successfully grown as far uphill as 800' where conditions were favourable. But this brought about little improvement in their lot, because after a few years under potatoes, the new land was capable of grazing or corn, and became subject to rent as well, forcing the whole process a stage further.

Another reason was the anxiety of progressive landlords to consolidate the tiny holdings on their estate, or to turn arable land over to grazing. In the 1820s and 1830s there was a move to convert good land on the lowlands from arable to pasture to meet the growing demand for livestock products. One effect of this was to reduce the demand for labour on the lowland farms and to reduce somewhat the importance of marginal land for grazing. It also tried to put a stop to further subdivision of already small holdings. Progressive farmers began to feel that money and resources would be more profitably invested in making good land better than in reclaiming waste land of low productivity. One of the few ways to achieve this was to evict tenants and force them to settle on bogland or 'up the mountain'. Many landlords must have felt that this policy was at the very least an investment, because these new fringe settlements must gradually but inevitably improve the land. So even after subdivision was being discouraged on lowland farms it was sometimes encouraged on the mountains, where numbers alone could win the land for agriculture. The land was unsuited to the use of horses or farm machinery, which these displaced people could not afford anyway, and its productivity could best be unlocked by the key crop of the potato. This was a critical factor, because no other crop could produce such an abundance of food under these conditions. Without the potato, the bogs could never have been called on to accommodate the explosive growth in population which occurred after 1780.

The outlines of the new fields carved out on the fringes of cultivation were determined not by the requirements of the horse-drawn plough, but by a compromise struck between the constraints of the local landscape and the limitations of unaided human effort. It was estimated at the time that ploughland needed five times as much labour as pasture, but land cultivated with the spade needed four times as much again as ploughland.

These nuclei of new settlement, both on the mountain bogs and on the lowland wastes, had room to expand by subdivision of holdings or simply by extending further into the bog or up the mountain. One contemporary observer (Pim, 1848) noted the way these pioneers sometimes began by settling at the foot of a mountain, and ending up many years later at the top:

> It is well known that much waste land has been brought under culture for several years past. This has been effected, chiefly by allowing cottiers to take in a portion of the mountain side; and when they had tilled it for a few years, and partially reclaimed it, calling on them either to give it up to the landlord, or to pay a rent. In some cases, they probably retained it, and became permanent tenants: but in others, they gave it up, and commenced anew; not unfrequently ending near the top of the mountain, at the bottom of which they commenced many years before. Thus cultivation crept up the mountain sides, or encroached on the secluded valleys heretofore untilled. This mode of reclamation required no capital on the part of the landlord. The cottier or tenant was the sale agent. He obtained a bare subsistence by very severe labour, and rarely effected any improvement in his own condition. It was practicable, on account of the facility with which the potato was cultivated; and it is very doubtful whether it be practicable with any other crop.

But the new fields could also be managed in quite a different way, one which had its roots in the older Gaelic and Anglo-Norman ways of managing land, but which developed in its modern form with the rapid expansion of population and the opening up of the new frontier in the bogs beyond the fringe of the old farmland. They could be cultivated in common by several families living close together in the cluster villages known as clachans, going out each day to work large openfield holdings in which each family was allocated separate strips. It was a system which in many ways allowed a more efficient use of resources, but of course was not at all in keeping with progressive ideas on farming, or modern ideas on property.

Displacement or banishment onto the bog did have one blessing: there was unlimited fuel – no small blessing when one considers the great expense this was to poor families remote from the bogs, especially in the cities.

But there were circumstances in which this settlement of the mountains could backfire. In some cases turf mould was exported in such quantity to distant farms for use in manure as to give cause for concern. There were also cases where overcropping and undermanuring led to the destruction of fragile, vulnerable hill soils. In some of the mountain bogs in Iveragh in Kerry potatoes were grown for the first two years after

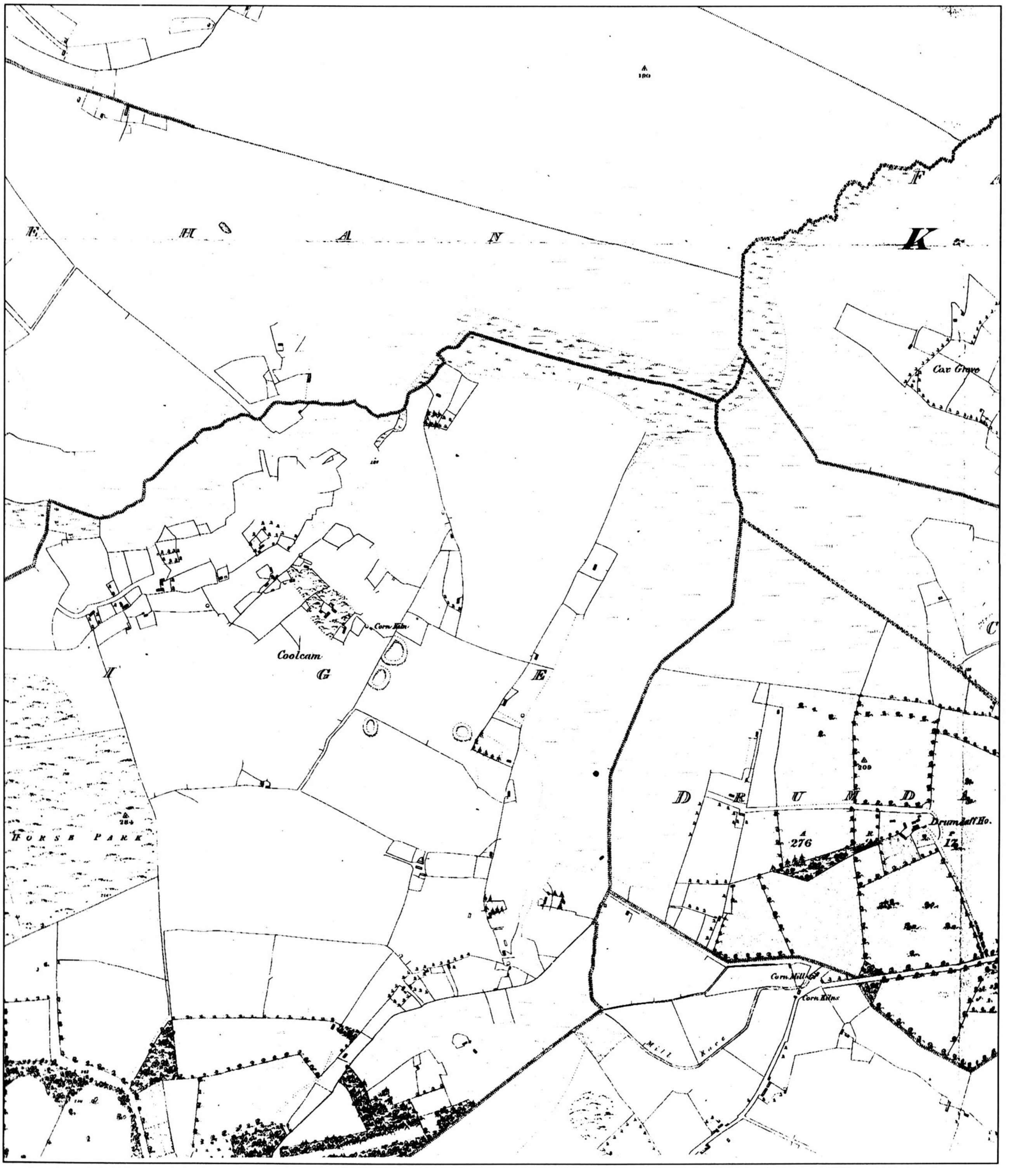


Figure 2.5:
Bog settlement at Coolteige in County Roscommon (6" sheet 36). The cluster of ringforts shows that medieval settlement had extended right to the edge of the bog. Encroachment onto the bog itself came later.

reclamation; after that it was sown with oats or wheat for three or four years without manuring, until the already impoverished soil was exhausted: but the reason for this approach was that the exemption from tithes on the newly reclaimed land only lasted for seven years. The tithes amounted to £1 or £2 an acre, which was very considerable to the poor tenant, so rather than pay it he moved on to reclaim a new piece of bog.

There is a somewhat lighter side to this dark picture. In spite of the enormous pressures under which they lived, some did undertake reclamation with enormous enthusiasm and energy. John Gannon may have been exceptional, but he was certainly not unique. Gannon took on the challenge of reclaiming red sphagnum bog in County Kildare – the most difficult and unpromising kind – with what can only be described as ferocious enthusiasm. His method of preparation was enormously laborious: he dug out the limestone gravel he needed as manure from under seven or eight feet of bog. The result of his labour, besides 'large and numerous clamps of turf' was 'large plantations of fine corn, great gardens affording prolific crops of potatoes, and fine grass, all upon the same black bog, so lately under water'; he had a garden of cabbage and a bed of garlic, which he shared with his poor neighbours. The Royal Dublin Society's referee, John Wynn Baker, recounted how Gannon told him that if by some miracle money ever came his way he would buy a bog with it, 'for that he had rather occupy bog, than "the best land in the nation"'.

The improvement in the roads from the late 18th century, and especially after 1817, greatly facilitated reclamation, not only because roads made it possible to get crops to market, but they allowed manure and fertilisers to be brought into the bog, and turf to be brought to the lime kilns which were so busily at work throughout this period. Back in 1769 no attempt could be made to reclaim the moorlands of south Clare because there were no roads to bring in lime. Arthur Young painted a graphic picture of the early attempts to reclaim these hills, with lime being 'carried by little miserable mountaineers thirty miles on horse's back to the foot of their hills, and up the steeps on their own'. At this rate it took a whole day to get a single load of lime to where it was needed in the heart of the mountains – and the standard rate of application was something like 40 loads to the acre.

The Anglesey Road from Newport to Thurles in County Tipperary, completed in 1828-30, provides a good illustration of the effects of the new roads on mountain reclamation in particular. Richard Griffith, who was really the driving force behind the building of the turnpike roads, described the effect of this particular road on mountain reclamation in a letter to the Commissioners of Public Works in 1831:

> The Thurles to Newport road though completed but one year has already produced a considerable improvement in the Country. Formerly there was no road passable for wheel carriages into the mountains or even for horses in winter; consequently there was no industry in the area, which, when I commenced the work in the spring of 1828 was the den for Kirby and other notorious outlaws and murderers, who lived in these mountains in defiance of the law. But during the last year from the limestone quarries of Ballycahill alone upwards of nine thousand horse-loads of lime have been drawn into the mountains and used for manure. Lime was also brought from the quarries near Newport and I can venture to say that more than ten times the quantity of land has been manured with lime in the interior of the mountains than during the previous year. As might be expected new buildings and inclosures have kept pace with the indraft of lime and I have no doubt that the agricultural industry will supplant that system of lawless outrage which has hitherto been the disgraceful characteristic of the population of the Slieve Felim Mountains.

Extensive reclamation was taking place on other mountain ranges too. Vast quantities of marl were dredged from the Shannon near Killaloe, dried in heaps on the shore, and then hauled into the mountains between there and Broadford, where it was spread on the bog at a rate of 50 loads to the acre, bringing about astonishing improvements.

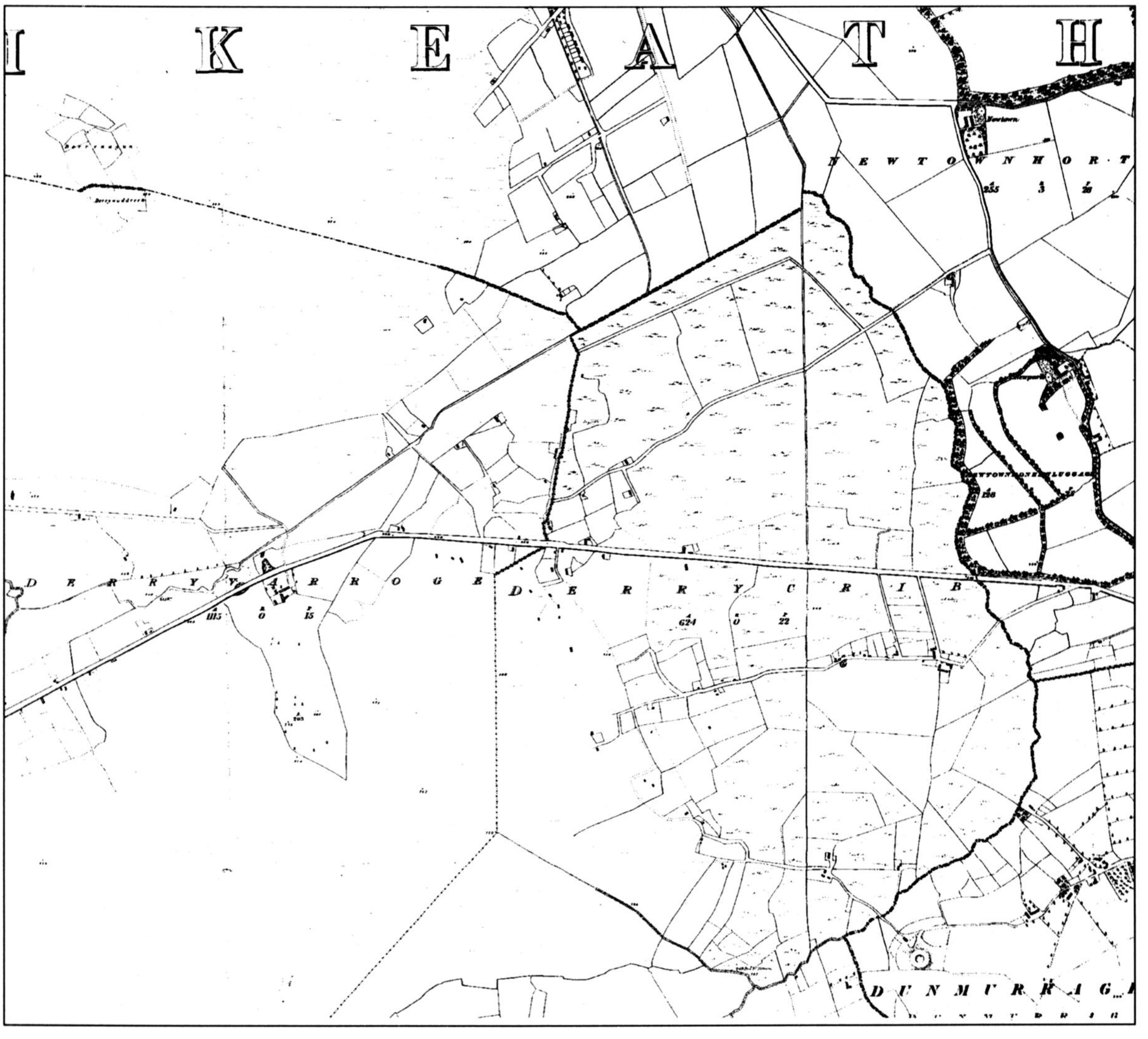


Figure 2.6: Agricultural land advancing westwards onto raised bog in north Kildare (6" Sheet 9). As in many bogland areas, 'derry' is a frequent epithet in placenemes, in this context meaning a cultivated area surrounded by bog.

At the same time, there were forces working against reclamation. In certain areas bogs were too valuable to reclaim for agriculture – in Armagh, for instance, where large quantities of turf were needed every year to fuel the numerous bleach mills; the bogs in the valleys of county Down, next door to Armagh, were virtually exhausted – and reclaimed – by the early 19th century. Apart from this though, in some areas the unwillingness of landowners to co-operate in large-scale drainage schemes sometimes made reclamation of large areas of bogland impossible, even though legislative provision had been made for the solving of such problems in the 1731 bogland reclamation act. There were also some big landlords, less pressed for money than average, who preferred to keep their vast tracts of mountain for shooting and sport – and it was often the case that the landlords who owned the largest tracts of bogland were those least in need of the financial incentives offered by reclamation. On the other hand, the tenants themselves often resisted encroachment on their rights of grazing and turbary.

The process was encouraged by the considerable number of books and pamphlets on various aspects of wasteland reclamation which appeared during the 18th and 19th centuries. An early perceptive pamphlet appeared anonymously in 1757; significant pamphlets by Parsons Persse (1800), Robert Fraser (1802) and Thomas Newenham (1809) were followed by the reports of the Bogs Commissioners in 1814 and numerous less ambitious reports, booklets and parliamentary bills at intervals thereafter. Much of this was summarised in a book by Kinahan and McHenry at the end of the century.

The climax to all of the growing interest in the reclamation of peatlands was the establishment of a Commission on Bogs in 1809. This was set up at the instigation of Sir Arthur Wellesley, Chief Secretary of Ireland in 1807-8, whose particular interest was the expansion of flax-growing, for which the bogs of Ireland, if drained, 'would answer better than any other for its successful cultivation'. The Bill to set up the Commission was enthusiastically introduced by J. Leslie Foster, who was interested in more than the possibilities for flax, on May 5th 1809, and became law on June 15th. The Commission was a remarkable institution, and its achievement was no less remarkable. The Bogs Commissioners, who were unpaid, and had to take an oath to perform their duties faithfully, were General Charles Vallancey, Richard Griffith Snr., Henry Hamilton, J. Leslie Foster, William Gore and Hans Blackwood. The engineers who did the work, assisted by their teams of surveyors, were Richard Griffith, Alexander Nimmo, William Bald, Thomas Townshend, James Alexander Jones, John Longfield, David Aher, Thomas Colbourne, Richard Brassington and Richard Lovell Edgeworth. These men carried out the first detailed survey of Ireland's bogs at a cost of £41,565 between 1810 and 1814 – a most remarkable achievement. The country was divided into four areas, and further subdived into 25 districts [**Figures 2.7-2.9**]. The Commissioners produced four reports, together with maps and general observations. The engineers estimated that the total area of bogland in Ireland was over 2,830,000 acres, half of which was lowland bog, half upland. The Commissioners confined their attention to bogs of over 500 acres, and detailed surveys and maps were prepared for more than a million acres of these 'low champaign bogs' in 25 districts. For this reason there is little or no mention of areas like Cavan, which Larkin's county map of around the same period shows to contain about 90 bogs, none of them as large as 500 acres, but totalling 17,600 acres between them. In addition to the 25 surveyed bogs there were less detailed reports on the mountain districts of Wicklow, Erris and Connemara. The Commissioners did make some attempt to calculate the areas of smaller raised bog and unsurveyed blanket bog areas (like Donegal, Tyrone and Fermanagh) in order to arrive at a total for the country as a whole.

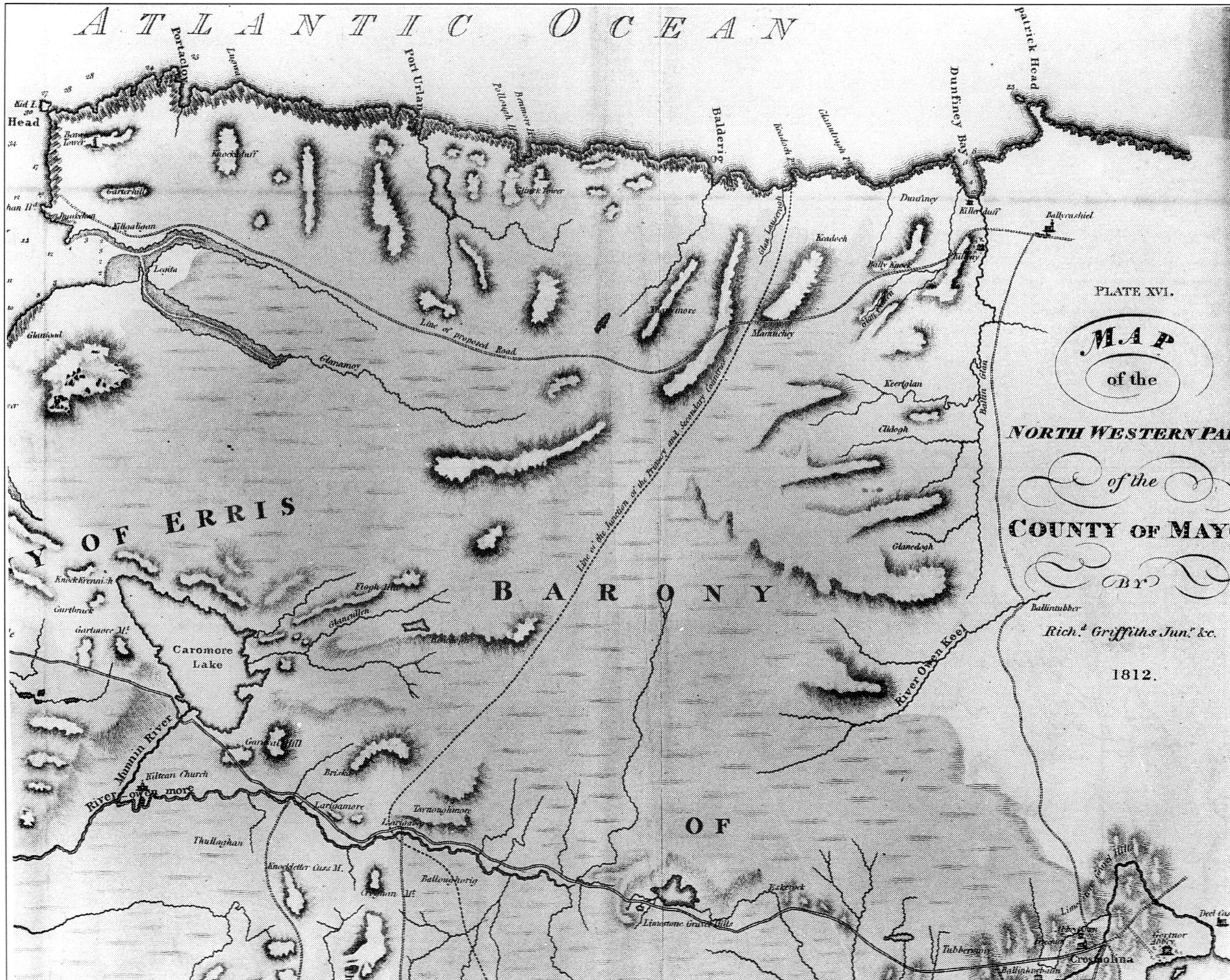
> From all the above data, we can confidently pronounce that the extent of Peat Soil in Ireland exceeds two millions eight hundred and thirty thousand English acres, of which we have shewn at least 1,576,000 to consist of flat red Bog, all of which according to the opinions above detailed, might be converted to the general purposes of agriculture; the remaining 1,255,000 acres form the covering of Mountains, of which a very large proportion might be improved at a small expense, for pasture, or still more beneficially applied to the purposes of plantation.
>
> *Fourth Report of the Commissioners.*

For the bogs surveyed in detail lines of drainage were laid out, estimates made of how much it would cost to reclaim them, and proposals were put forward on how this might be done. Their optimistic conclusion was that most could be reclaimed at a cost of between £1 and £20 an acre, and would yield a permanent rental of 10-15% on outlay; half would be suitable for tillage, the remainder for pasture and tree-planting. Under very favourable circumstances, reclamation might produce land worth £4 an acre. Reclamation costs might be much higher – as high as £50 an acre for four years – but the value of the crops produced was little less than this.

The Reports of the Bogs Commissioners contain a wealth of detailed information on reclamation practices in different parts of the country in the early 19th century. There was considerable variation in reclamation procedures and crop rotations, but Griffith's recommendations give an idea of the general approach. The bog should be left for a year or two after initial drainage to shrink or subside. Then gravel should be spread at a rate of six loads to the perch (about 350 tons – 1,000 loads – to the acre), with a top dressing of ashes of quicklime. Potatoes might then be grown for two years, followed by oats, and then the land could be laid down with hay seed, bringing the value of the land up to £1/10s an Irish acre (18/6d an English acre). Another popular rotation was to plant rape in the first year, and follow this with potatoes, oats and meadow. A further application of clay or gravel followed (250 loads to the acre), leaving the land 'in a state of great power and vigour '.

Figures 2.7 - 2.9: Extracts from some of the Maps in the Reports of the Bogs Commissioners.

Figure 2.7:
Part of Richard Griffith's 1812 map of the bogs in the 'wild and dreary country' of the Baronies of Erris and Tyrawley in north-western Mayo (Plate XVI in the Fourth Report). Note in particular the utterly remote location of Balderrig (Belderg); **Figure X <Chapter X)** shows how very different this part of the country looked in the Neolithic. Note also the location of Glenamoy, on which so much research on peatland reclamation has been centred this century.



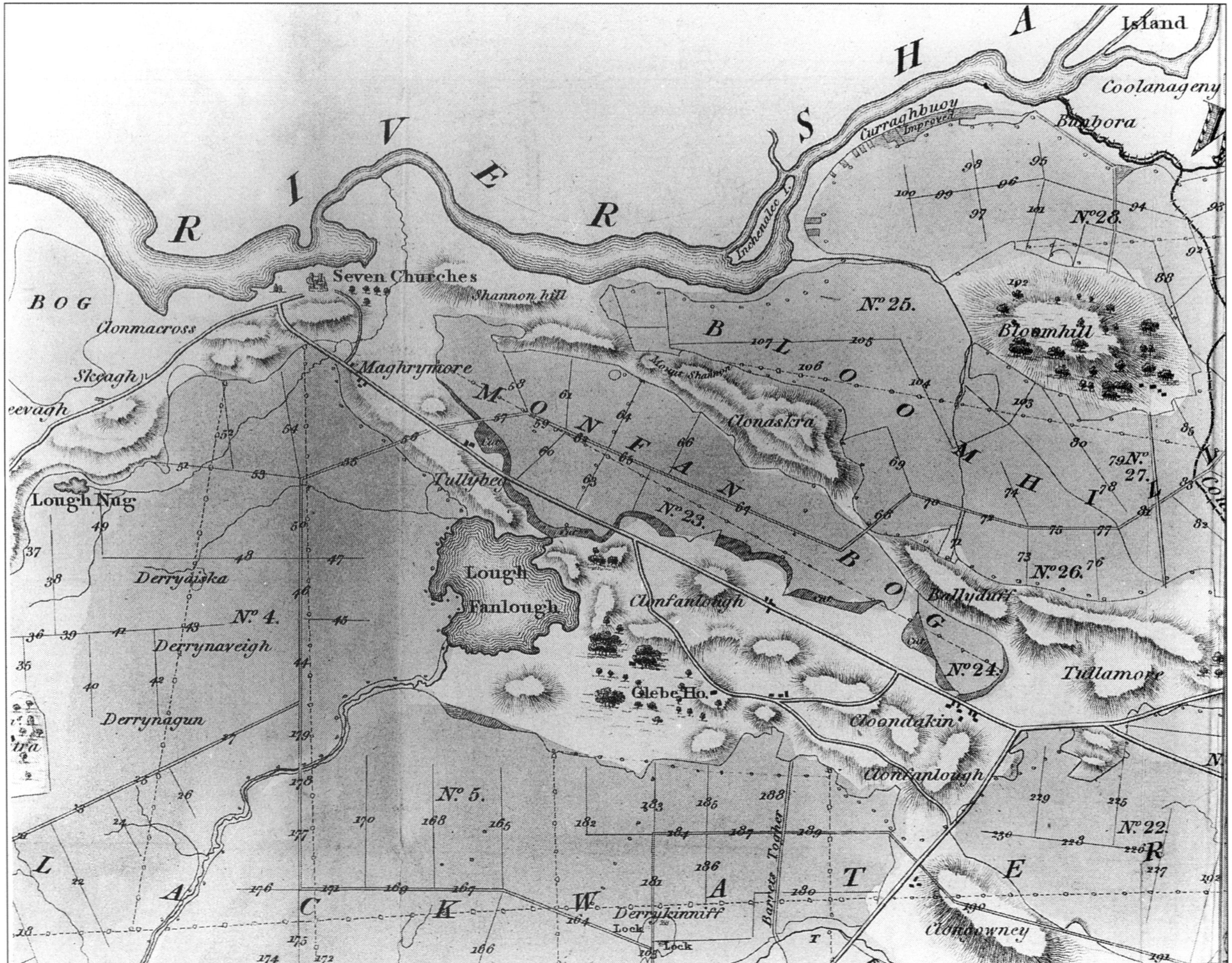


Figure 2.8: Part of Thomas Townshend's map (1811) of bogs in the western side of District No.6 (in Offaly) (Second Report). Clonmacnois (seven Churches) is to the top left of the map. Note the Lake and Bog of Fan (today Finlough and Mongan's bog). Finlough at this time was considerably bigger than today, and there was also a small lakelet (Lough Nug) impounded against the north-western side of the Clonmacnois-Shannonbridge esker. Notice the cut fringe all along the south side of Monfan.

Figure 2.9:
Part of Richard Griffith's beautiful 1810 map of the bogs in the Lullymore area of the Bog of Allen (First Report). This was part of the most extensive raised bog complex in the country, and for this reason was the location for several of the early attempts at large-scale mechanical exploitation.

Reclaimed bog produced marvellous crops of potatoes, cabbage, turnips, carrots and parsnips – 'green crops' as vegetables were then called – but 'white crops' (oats and wheat) required more in the way of fertiliser.

John Longfield advocated main drains 4' deep and 14' wide at the bottom, that could function as canals. These could be used to bring manuring gravel into the bog and take out the 'bog stuff' which was much in demand for upland and sandy soils, and for use as garden compost. In conservation terms, reclamation saw the decline of two great reservoirs of natural diversity – the bogs and the eskers; Townshend calculated that an acre of esker 50' high would cover 600 acres of bog with an inch of gravel, or 360 acres if it was 30' high. A material fact in reclamation was that at least four-fifths of the total bog area was within half an Irish mile of dry land, such was the indented and fragmented nature of the bogs.

The Bogs Commissioners urged that legislation be passed to permit long leases of bog in order to encourage improvement, and to allow free passage through neighbouring estates for those involved in such works, and that measures should be taken to get over the obstacles created by the uncertainty of property boundaries in bogs, and the customary rights of peasants to grazing on the open bog. The problems caused by uncertainty of boundaries was solved in the 1830s and 1840s by an official boundary department set by the Government. The Fourth Report of the Commissioners analysed the difficulties of large-scale development because of ownership problems: but it stopped short of advising the Government to enact legislation to set up a Board to work the bogs even though nine of the engineers strongly recommended that the State itself should carry out the work, and charge the cost to the proprietors. One of the engineers suggested the setting up of a demonstration bog to show by example exactly what could be achieved, and an absent member of the Board wanted a Board appointed to oversee such an experiment and to lend money to enthusiastic and competent improvers.

The level of involvement of the various engineers involved on the survey was very varied, but the most remarkable of them was undoubtedly the young Richard Griffith (1784-1878) [**Figure 2.10**]. Beginning at the age of 25, he surveyed 80,000 hectares of lowland bog and 100,000 hectares of mountain bog in detail during 1,300 days of intensive field work spread over five years (1809-1813). The Reports of the Bogs Commissioners are all the more important for having been written at a time when the bogs were still largely undisturbed, and based on such a vast amount of personal observation. After nearly two centuries, they remain the most valuable single work on Ireland's bogs and they are an essential starting point for local bog studies today. Most of the accompanying maps – 50 in all – were drawn up at a scale of four inches to the mile and were the most accurate maps yet produced for such a large area. They are especially invaluable for the way in which they show the extent of the larger bogs before they were significantly reduced by reclamation and turf-cutting.

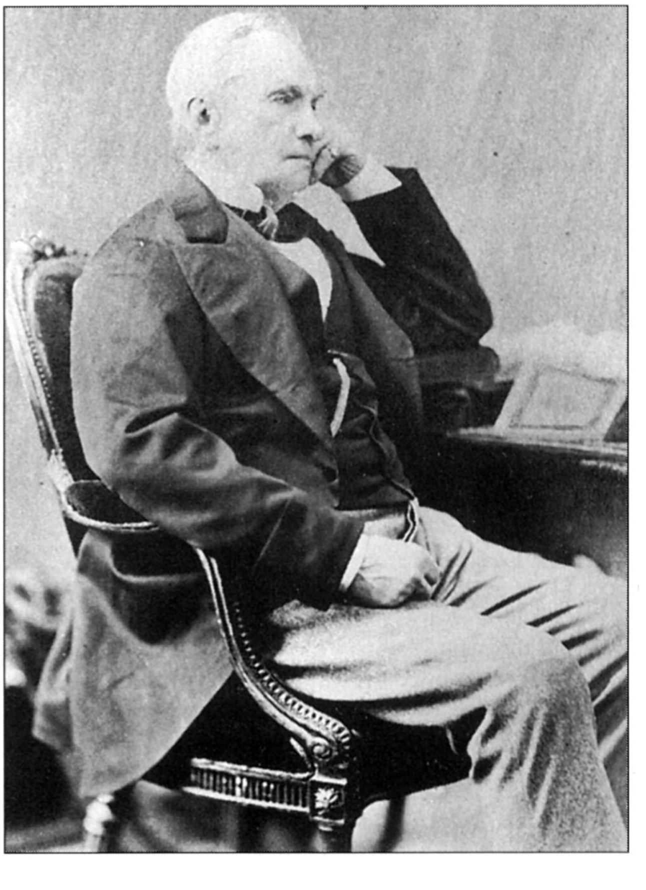


Figure 2.10: Portrait of Richard Griffith.

The RDS set up its own permanent committee of 21 members in 1820, taking evidence from gentlemen 'who have themselves reclaimed bog at a considerable extent and have given most serious consideration to the subject', and this committee reported in 1821 that although experts differed about what the best way to drain the bogs was, 'there exists perfect unanimity as to the important facts, that every description of bog is capable of being reclaimed and converted into profitable land; which would adequately, nay liberally, remunerate the outlay of the capital necessary to accomplish that object; and that the bog thus brought into a state of profit may be preserved in that state by ordinary attention and expense without the danger of its reverting to its original unproductive condition'. This also failed to elicit a response from the Government. Indeed, between 1823 and 1875 no fewer than 18 bills to promote the drainage and reclamation of the bogs of Ireland were introduced before Parliament; one after the other they were debated and rejected [**Table 2.1**]. In the Act of 1847 the Treasury made loans for improvement works available to landowners and certain classes of tenants for the first time; by 1850 some 74,000 acres were said to have been reclaimed, and 20,000 labourers employed on the works – but of course these years were in the dark shadow of the Great Famine.

Progressive agriculturalists were well aware of the difficulties which the subdivision of farmland into tiny holdings posed to efficient farming by 1820. Many felt that the reclamation of the vast expanses of the bogs would provide large, open tracts where the progressive farmer could do things properly:

> In the reclaiming ... of three millions of acres now waste and altogether unoccupied the skilful capitalist will have ample scope for pursuing agriculture upon a large and profitable scale and, so far from being under the necessity of unhousing the humble cottager, will have the opportunity of greatly improving his condition by affording constant employment. *(RDS 1820 Report,* p.5).

TABLE 2.1: The 18 bills presented to Parliament between 1823 and 1875.

6/5/1823	A Bill to encourage the improvement of Barren and waste lands and bogs, and for the employment of the poor in Ireland. (324) 7pp.
15/4/1824	A Bill for improving and draining the bogs in Ireland (243) 29pp.
11/7/1828	A Bill for draining the bogs and marshlands in Ireland (530) 32pp.
16/4/1829	A Bill for encouraging the draining and improving the bogs of Ireland (73) 9pp.
12/5/1829	A Bill (as amended by the Committee) for encouraging the draining and improving the bogs of Ireland (229) 10pp.
4/3/1830	A Bill for the draining and allotting the bogs of Ireland (103) 41pp.
7/4/1830	A Bill (as amended by the Committee) for the draining and allotting the bogs of Ireland (262) 43pp.
21/7/1836	A Bill to promote the reclamation and improvement of uncultivated lands in Ireland (469) 33pp.
24/4/1837	A Bill to promote the reclamation and improvement of uncultivated lands in Ireland (235) 43pp.
2/6/1837	A Bill (as amended by the Committee) to promote the reclamation and improvement of uncultivated lands in Ireland (359) 44pp.
23/6/1837	A Bill (as amended on re-commitment) to promote the reclamation and improvement of uncultivated lands in Ireland (417) 44pp.
18/12/1837	A Bill to promote the reclamation and improvement of uncultivated lands in Ireland, and to render navigable rivers and lakes in Ireland (47) 32pp.
13/6/1838	A Bill (as amended by the Committee) to promote the reclamation and improvement of uncultivated lands, and to render navigable rivers and lakes in Ireland (480) 34pp.
30/6/1840	A Bill to promote the drainage of lands and improvement of navigation in Ireland (432) 64pp.
1/8/1840	A Bill (as amended by the Committee) to promote the drainage of lands and improvement of navigation in Ireland (576) 71 pp.
5/6/1846	A Bill for promoting the reclamation of waste lands in Ireland 0846 Vol. IV, 438-523).
5/6/1848	A Bill to facilitate the reclamation of waste lands in Ireland 0847-8, Vol. VI, 489-508).
1875	A Bill to promote the reclamation of waste lands in Ireland, Vol. VII (41) 5pp.

These conclusions and recommendations seem to have stimulated little in the way of positive action. One of the few experiments that resulted was the enclosure and reclamation of an area of unreclaimed mountain at Kingwilliamstown (Ballydesmond) in County Cork in the 1830s. It included the earliest large scale peat production scheme undertaken in Ireland at that time. The land was divided up into small farms and farmhouses were built, the tenants were given lime, and they brought the land – on which they paid a rent of £6 an acre – into cultivation in the usual way by planting potatoes. Attempts to establish an improved agriculture were made by building up a stock of dairy cattle, the cultivation of fodder crops and proper rotations. But this attempt at state-sponsored reclamation did not meet with universal approval. Caird condemned the Kingwilliamstown experiment as nothing more than a demonstration of how many people could be kept alive on barren land.

Twenty years after the reports of the Bogs Commissioners the Committee on Public Works tried again, complaining sardonically that 'it has not been heretofore considered sound policy to adopt any public measures towards the development of these extraordinary sources of wealth', and recommending that a Board of Works should be established to carry out the necessary drainage and other works on any bog which two-thirds of the proprietors wanted to reclaim.

But the advocates of state intervention in systematic peatland reclamation were voices crying in the wilderness. One of the most convincing and outspoken was G. Poulett Scrope, who in 1835 wrote as follows in an Appendix to the Report of the Select Committee on Public Works:

> I conceive that no state can be justified in conferring upon or continuing to any individuals an exclusive property in extensive tracts of waste lands, which they are neither willing nor able to reclaim or cultivate, whilst there are other individual members of the community in a state of destitution from the want of employment, who might maintain themselves upon such lands, if permitted to reclaim them upon their own account.

Nor was Scrope the first to express sentiments like this. Even in the 17th century there were those who felt that the neglect of such a great resource should not be tolerated by Government, which should confiscate bog from landowners who made no effort at improvement and give them to those who would – but not surprisingly, such sentiments had little influence at the time. Germany under Frederick the Great passed such a law a century in 1765. Napoleon transferred the bogs in several European countries to the nearest municipal authority to be held in trust for the inhabitants of the district.

One of the experiments in the reclamation of bogland which attracted most attention in the 1840s was William Steuart Trench's conversion of blanket bog at Baunreagh in Slieve Bloom (County Laois) to highly productive potato land. He was successful for a number of reasons: he was an experienced land agent (or farm manager as he would be called nowadays); there was no shortage of cheap labour – he had no fewer than 200 full-time labourers at work draining, levelling, applying fertiliser, then sowing and harvesting the enormous quantities of potatoes; and he applied liberal quantities not only of lime, but of that most crucial nutrient lacking in peat: phosphate, in the form of guano, which was just at that time beginning to be imported from Chile.

His method was based on several years of painstaking experimentation, and is worth looking at in a little more detail:

1. Lime was first spread broadcast over the land at a rate of 50 barrels to the statute acre (1 barrel was 32 gallons).
2. Five-foot wide lazy beds were prepared, and the potatoes were planted on the ridges.
3. Guano was scattered on top of the ridges, 6 cwt. to an acre.
4. Finally, clay was dug up from the furrows and spread on top of the guano, and the beds were levelled off.

Excellent crops were produced in this way, and when they were harvested, 'the act of digging mixed the lime, manure, and the several soils together into an even texture, leaving the land which had hitherto been scarcely worth one shilling per acre, in excellent order for sowing corn crops or grass seeds, and permanently worth at least one pound per acre'. Apart from this enormous increase in the value of the land, the costs of reclamation were repaid by the sale of the first year's crop of potatoes, at that time worth about £30 an acre, which was 3d a stone. Steuart Trench was awarded both the silver and gold medals offered by the Royal Agricultural Society of Ireland for the best report on the largest quantity of waste land reclaimed in Ireland. Lord Devon and all the members of his Commission visited Baunreagh, and were greatly impressed.

These remarkable examples all relate to bigger landowners, and no doubt for every improving landowner there were a hundred who took little interest in bogland reclamation. Among tenant farmers and cottiers the situation was equally complex. Many cottiers were assiduous improvers; along the Shannon and its tributaries much bogland was reclaimed by cottiers in the 18th and early 19th centuries; Dutton remarked that there was 'scarcely a tenant near a bog that does not improve a little'. On the other hand he, along with many other observers at the time, believed that short leases discouraged many cottiers from improving bogs on their holdings:

> What can be expected from a cottier that can scarcely exist, or that, if he improves bog without having a lease, furnishes the certain means of dispossessing himself, by creating ground that will be measured on him by a new agent ignorant of country affairs, or of the poor man's exertions?

It is very probable that upland reclamation would have taken a different course but for the intervention of the Famine and the new course into which Irish agrarian history moved as a result. In 1846 Steuart Trench had planted 162 statute acres of potatoes in Baunreagh; his account of the total failure of the crop – which in July was 'for its extent and luxuriance ... the wonder of everyone who saw it' – is one of the most vivid eyewitness accounts we have of the arrival of the potato blight in Ireland. By August 1846 the blight was in the Irish Midlands, and by August 6th it was in Slieve Bloom:

> Each day, from the time I first heard of the disease, I went regularly to visit my splendid mountain crop, and each day saw it apparently further advanced in course of arriving at a healthy and abundant maturity.

Figure 2.11: William Steuart-Trench.

> On August 6, 1846 – I shall not readily forget the day – I rode up as usual to my mountain property, and my feelings may be imagined when before I saw the crop, I smelt the fearful stench, now so well known and recognised as the death-sign of each field of potatoes. I was dismayed indeed, but I rode on; and as I wound down the newly engineered road, running through the heart of the farm, and which forms the regular approach to the steward's house, I could scarcely bear the fearful and strange smell, which came up so rank from the luxuriant crop then growing all round; no perceptible change, except the smell, had as yet come upon the apparent prosperity of the deceitfully luxuriant stalks, but the experience of the past few days taught me that all was gone, and the crop was utterly worthless.

There was disillusionment among investors in the latter part of the 19th century about the prospects for the economic large-scale exploitation of peat. 'Few are now disposed to believe in the practicability of the profitable utilisation of peat' wrote Robert Alloway in 1869, 'but on the contrary are more inclined to consider with the London *Times* that the "one huge succession of bogs" which fill up a large portion of the central parts of Ireland, are useless and unsightly excrescences, growing over and covering up three million acres of good land'. Robert Dennis, writing in 1887, gave an extreme view:

> It is useless, we are convinced, to think of planting or cultivating the bogs. Extensive reafforestation will prevent them from forming or spreading, and the edges of them might be planted with osiers and pines; but the main body of them must be made the best of in the condition in which we find them. Perhaps there is hardly any natural substance the use of which has been made the subject of so much experiment as peat. It has been dried and compressed in order to improve it as fuel; it has been largely used as the latter; oil and gas have been extracted from it; it has been tried in the manufacture of paper; and even table-tops have been made from peat converted into a hard substance by enormous pressure. But the fact remains that the only thing to do with peat is to burn it.
>
> From all this it will be apparent that we do not regard the bogs of Ireland as belonging to those resources which are likely to bring much wealth to the country. The bog-covered surface of Ireland would be far more valuable in almost any other character. We can think of nothing worse save the glaciers of Switzerland or the lava-beds of Sicily. Vegetation of any sort would be better than the stagnant, sodden, rotting substance which constitutes the bog-land of the sister-island. Instead of peat being one of the natural resources of Ireland we regard it as one of her natural calamities – like St George's Channel. If it serve any purpose at all, it will be by providing the Irish peasantry with fuel during the interval which must elapse before the replanting of the country has provided them with wood, or the development of her carboniferous deposits has given them the blessing of cheap home-gotten coal.

Living on the bog

Not only have people been making a living on the bog for centuries, but people have also made the bog their home from time to time. These bog settlements were often the direct or indirect result of eviction. Settlements like those around the bogs at Redwood in County Tipperary, where families evicted from their holdings on the better land were forced to settle on the only ground available to them and make use of the only resources available to them for building and making a living, could be found around bogs all over the country.

These bog houses were usually made with large sods of turf, but occasionally walls of standing, uncut peat were used. Estyn Evans described an extraordinary example of this kind from Leck near Ballymoney, which was still inhabited in 1954. In the north of Ireland, sod houses were especially characteristic of the Lower Bann Valley in the country around Toome. The house at Leck was in an area of reclaimed bogland; it had solid turf walls 3′ thick and stood 5′ high, raised a further 1.5′ by turf sods. Similar houses were common in parts of Scotland, and sod houses of one kind or another have been characteristic of many periods and places. Sod houses were sometimes half underground: houses of this kind were still inhabited in Mayo in the last century.

Sod houses existed in great numbers in 18th and 19th century Ireland, and before the introduction of the mud wall – which may not have been until Anglo-Norman times – they may have been more widespread still. They were often very impermanent, especially when they were abandoned and unroofed, melting back into the bog from which they had been taken. The sod houses round the Westmeath bogs in the 17th century were described as 'standing not much longer than their fences'. They were also probably highly susceptible to fire, as Coote's account of the destruction of a bog settlement near Geashill, quoted earlier, suggests. Scraw sods for roofing – either bog scraws or scraws from heath or grassland – were cut with special tools; in the north this was the flachter, a tool for thrusting and lifting, but in the south the graffan – a kind of mattock – was used.

What is probably the most graphic account of these dwellings is found in Cesar Otway's description of turf houses in Erris just before the Famine:

> Now the road takes the northern side of the ridge, and skirts the extreme shallow end of the Estuary of Broadhaven, where it flows up to Belmullet; like all such shallows, this is ugly, particularly so *here*, where the brown bog comes down and meets the water's edge, and it is hard to say which is the ugliest, the muddy waste of a wide

> estuary, now that the tide is out, the sea gulls screaming, and the curlew piping dolorously, or the dreary bog banks, along which the road passed, at whose sides were here and there constructed some of the most wretched hovels that in all my wanderings in my poor native country it has been my lot to observe.
>
> I have seen and described the oval huts of the natives of Achill, where art had not arrived at the crft of raising a gable-end, but still *these* were over-ground, they were constructed of stones, and their inmates, whether squatting or reclining therein, might be dryas well as warm.
>
> But the dwellers here were bog troglodytes – the foundations of their dwellings are sunk eight feet or more below the surface of the surrounding black bog, the walls are constructed of wet sods, cut off from the surface of that bog; there is no door or door-case, no chimney; the orifices by which the people enter, and through which the smoke should issue, are filled up as suits the wind, with bundles of heath or turf-kreels, filled with potato-stalks; a drain comes out from under the floor of the dwelling, from which the superabundant moisture escapes, or else it would be a common bog hole; but, by its means, the water that springs abundantly from the sides and bottom, flows away, and the people sitting or standing within, are free from actual overflow. Observing, as I did, the prattling, lively urchins playing about these cabins, and the certainly not unhealthy aspect of the adults, I could not but admire that wonderful adaptiveness of the human constitution that could enable people, both young and old, to remain healthy in the midst of superabundant moisture, which, in consequence of the constant and large fire necessarily kept up on their hearths, must be in a state of misty smoky steam, a sort of perpetual vapour bath; and, on inquiry, I do not find that pulmonary complaints, or even rheumatism are especially prevalent in this district; I believe there is not much longevity, which is seldom the case when the diet is low, I also have reason to consider that there is not much premature decay.

After the Famine

Much of the cultural fabric of the countryside today was created in the pre-Famine decades, and could only be maintained by the dense population of that period. The new fields won from the bog, in particular, could only be maintained through constant attention. As population declined steadily after 1845, many of the bogs reclaimed at great and generally unrecorded expense and effort reverted to poor pasture, wet and generally infested with rushes. In most parts of the country, many facets of the infrastructure of the cultural landscape, which was extremely labour-intensive to maintain, stagnated. The network of tracks on the fringes of today's profitable lands, walled on either side, was increasingly neglected and crumbled into decay as the century advanced. But it still survives to haunt us in the landscape of today, this web of fossilised arteries to the abandoned waste. Interest in the large-scale reclamation of bogland waned after the Great Famine. Interest shifted to making the great rivers navigable, deepening the channels and reclaiming the adjacent callows. The reclamation of the bogs for agriculture now became a secondary objective, and it was realised that their main value for a long time to come would be as the country's major native fuel resource.

The Famine defused the enormous pressure on marginal land, and enabled landlords to replace the pattern of expansion and sub-division of cultivated land which had been prevalent during the century before the Famine with one of *consolidation*, and an emphasis on improving the quality of farmland. Lord Longford's estates in Westmeath and Longford afford a good example of this consolidation. The scattered patches of land which constituted the pre-Famine holdings were squared to 6-field compact farms, mostly of 30-50 acres, designed for a 5-course rotation; the sixth lot was for a farmhouse and outbuildings. New roads, hedges, fences, dykes and ditches were put in, and arterial drainage was carried out. A considerable area of raised bog was incorporated in these new farms. The key factor here was the system of massive, wedge-shaped 10'-deep drains which were dug. These drains were not continuous; 3-4' baulks were left at regular intervals to provide support as the bog shrank, and these 'bridges' were tunneled through to allow the water free movement.

The farm of Mr Moore, described by RO. Pringle in 1872, is an excellent example of what could be done on this system. His new farm consisted, to begin with, of nothing more than 50 statute acres of bog eighteen feet deep:

> The first thing done was to put up a house in the centre, for the purpose of serving, in the first instance, as a shelter for the labourers employed, and afterwards as part of a farmstead. Before this could be done a large quantity of brushwood had to be carried to the intended site of the house on men's backs, the ground being too soft to admit of any other mode of transport. The brushwood was intended to serve as a foundation and a floor for the building. All the other materials, wood and clay, were carried to the place in the same manner, no four-footed animal capable of carrying a burden being able to walk safely over the shaking bog. The next step taken was to layoff the land into squares, containing about three acres in each, with an open drain five feet deep between each lot. The covered drains were then cut four feet deep on the wedge-drain system. The first crop taken was potatoes, which were planted with the spade in ridges, or beds, four feet wide, with open spaces two feet wide between each ridge. On part of the land two successive crops of potatoes were grown before sowing a grain crop with grass seeds, whilst another portion of the bog was brought in without breaking the surface. In this case the land was laid out in beds, and the soil from the intervening spaces was spread over the broken surface. Oats and grass seeds were then sown, and covered with a compost made of old earthen fences and stable-dung. The crop of oats was very fair, and the sward of grass was better than that on the land where the surface was broken. The crops of potatoes grown on this bog were most abundant, and being quite untainted with disease, realised very remunerative prices as seed. The entire appearance of the land when reclaimed and laid down in grass presented a remarkable contrast to the expanse of brown heath by which it was surrounded. It now grazes a number of Kerries during summer.

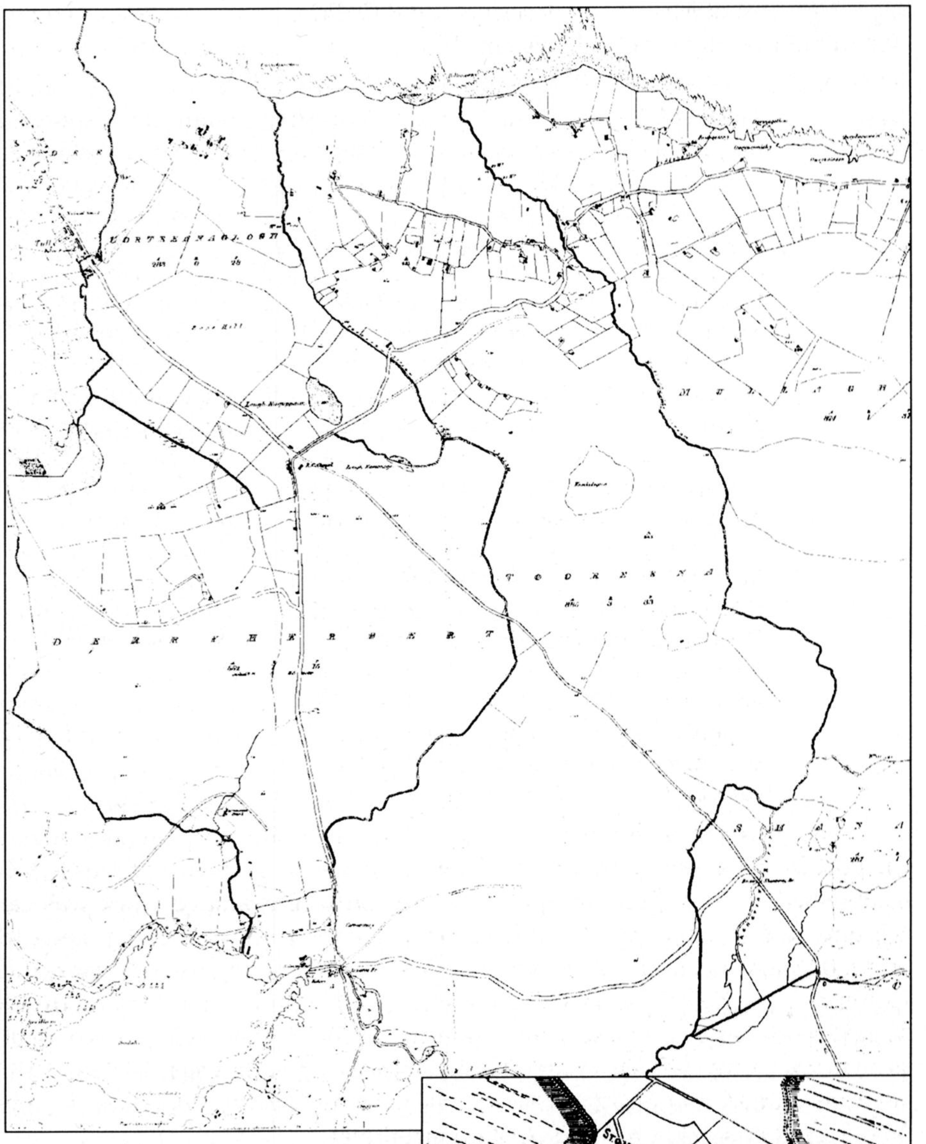
There was considerable reclamation of blanket bog to provide grazing for sheep in the post-Famine period under the various schemes of the Board of Works, which had been established in 1831. For example, extensive surface drainage work was carried out on Kippure and Luggala by David La Touche and W. J. Armstrong between 1850 and 1855, and 4,000 acres were drained by James Foster at Glantreague, Banevagh and Lecarrow in County Galway. The whole of Clough Bog was drained, subsoiled and divided into large, square fields, 'and let to a solvent tenant who expects to have 30 acres of oats growing this year where water lay 4 feet deep twelve months ago'. Between 1845 and 18755,249 acres were reclaimed and 9,877 acres improved in the twelve Poor Law Unions in Galway, Mayo and Donegal as a result of State incentives.

One of the most impressive bogland reclamation projects on blanket bog in the second half of the 19th century was that undertaken on the Kylemore Estate in County Galway. This estate had been purchased by Mitchell Henry M.P. in the early 1860s, and under the direction of his agent, Archibald D. MacAlister, considerable tracts of bogland were reclaimed for agriculture in the townships of Mweelin, Addergoole, Bunnaboghee, Dowrosmore, Currewangaun, Mullaghglass, Tooreena, Lemnaheltia and Pollacappul. The project is of particular interest because the process of reclamation was recorded in detail, field by field for some areas. This consisted of drainage followed by ploughing or ridging, and then the application of lime which often had to be carried for a considerable distance, by women in baskets on their backs, by an ox drawing a small sledge, or by means of a portable tramway. Perhaps the best example is the townland of Tooreena **[Figure 2.12]**.

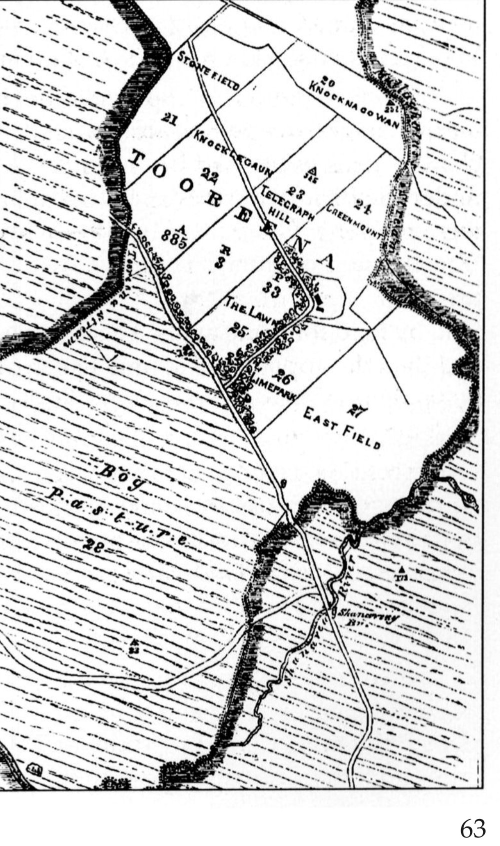
There was little evidence that this project was undertaken for sound economic reasons, but (as Charles Roberts remarked in his account of the project), 'anyone who has been long amongst dark peat-bogs and barren mountains, will understand how great an ornament in such a landscape is a patch of cultivated land'.

Figure 2.12:
The reclamation and improvement of Tooreena (Galway 6" sheet 10). Before the Great Famine Tooreena was an area of peaty pasture on a hilltop overlooking the sea, surrounded on nearly all sides by bog (a). Much of the pasture was reverting to bog, with an average of 20" of peat. It was so rocky and treeless that huge boulders were everywhere used as gateposts. Very little of the land had ever been cultivated. Most settlement was at the edge of the sea, to the north of the coast road, with little encroachment onto the blanket bog on the south of the road. Notice the classic clachan settlement of Gorteennaglogh on the shore.

As a result of the intensive improvements in the years after 1874, 150 of the 260 acres of moorland were bearing crops in 1877, and the rest was being reclaimed (b). A detailed record survives of exactly how each field was improved. For example, Green Mount (consisting of a little over 29 acres) was originally one of the best fields of seminatural grazing in the area. 'Cattle that had been wintered upon the black sedge in the valleys, were driven to such fields as this to feed upon the white sedge in the spring, and by the month of June they would be sufficientlly "warmed", i.e. strong enough to be driven to the fairs, or sold for England or Leinster' (Roberts, 1878). Part of the field was left as it was, 'the herbage consisting chiefly of white and black sedge, with small heath, and a little grass'. Eight acres at the top of the field were drained and ploughed by oxen at the rate of three days per acre; a ploughman and two boys were employed at this work, one boy to lead the oxen while 'the other was employed in clearing the ploughshare of the long fibres of the peat'. A further twelve acres were ploughed by horse, drained, fertilised with lime, superphosphate and guano, and laid down to grass (perennial and Italian ryegrass, cocksfoot, timothy, along with mixed clover and rape). The first hay crop in 1876 produced 30 cwt. a statute acre (after lambs had the run of the field over the winter and down to the middle of March). In the following year, nitrate of soda and superphosphate were applied broadcast, followed by harrowing. The yield this year was considerably poorer (20 cwt.), 'especially so on the levelland at the top, where the peat attains a depth of 3 feet'.



(a)



(b)

The engineering challenge

The extensive bogs of Ireland posed an engineering challenge at several different levels. There was the basic problem of drainage associated with reclamation and peatland development, which has already been discussed. Then there was the multifaceted challenge posed by mechanisation of the many different operations involved in the winning of peat. This is a fascinating and complex story both from the viewpoint of technological evolution and that of the people involved; some key elements of that story are reviewed in the next two chapters although another volume would be needed to tell it properly: and thirdly there was the civil engineering challenge of overcoming the obstruction to good lines of communication posed by the 'intractable bog'.

At an earlier period, when the rural population was smaller and more dispersed, communities were more self-sufficient and modes of transport simpler, and especially at times when they were drier, the bogs were perhaps less of an obstacle, at least to those who lived among them. The eskers, which so conveniently meandered through the Midlands, provided dry ridges which could carry roads high above the bogs for long distances. The complex of esker ridges known as the Esker Riada enabled the traveller to go dryshod virtually all the way from Dublin to Galway. Where bogs had to be crossed, they were bridged by toghers (Chapter 15), adequate for the small volumes of traffic they had to carry.

In the modern period, however, with the growth in population, the extension of the market economy into rural Ireland, and the need for military access to remote areas where the rule of law barely penetrated, the challenge posed to easy communications by the bogs was taken up. In the 18th century, individual landowners and Grand Jurys, and on occasion the Government, constructed bog roads, and in the process a valuable body of experience on the problems of building roads across peatland accumulated. The problem was obviously greatest on the deep raised bogs. Long stretches of new road were constructed across upland blanket bog for military purposes and general access in the 18th century: the military road across the Wicklow Mountains, for example, and the Anglesey Roads in Tipperary. The Military Road over the Wicklow Mountains was constructed after the 1798 Rebellion to enable Crown forces to reach and subdue, whenever occasion demanded, this heartland of chronic rebellion. It ran all the way from Rathfarnham in County Dublin, by Glencree and Sally Gap, through Glenmacnass and Glendalough on to Glanmalure, and thence to Aghavannagh on the other side of the mountains. These mountain roads were generally constructed along the contours to minimise engineering problems, and perhaps even with the feet of the long-distance walker in mind. The 18th century turnpike roads also took eagerly to the bogs: the turnpike road from Mountrath to Kinnitty (constructed around 1755) ran straight over the top of Slieve Bloom; one of the main problems in mountain areas like this was the construction of stone bridges to span the mountain glens, and the laying of floodwater culverts.

A major problem with the construction of roads across deep bog is the way it shrinks, as a result primarily of dewatering, followed by decomposition of the now aerated peat. By the middle of the 19th century, the accumulated experience of the preceding century and a half enabled engineers to construct roads across deep bogs with some confidence once sufficient attention was paid to the preliminary drainage and the shrinkage of the peat which resulted. The problems presented by railways were not greatly different from those in road building, and during the great period of railway construction in the mid 19th century the bogs were tackled with confidence and the engineering difficulties they presented overcome. Bernard Mullins' account (published in 1848) summaries the engineering knowledge and best practice of the time.

Roads were made across many bogs in the 18th and 19th centuries. These were accompanied by drainage, and inevitably followed by shrinkage of the peat. The Irish-Dutch Study of Clara Bog estimated that the road made across that bog 200 or so years ago, and the drainage associated with development of the bog, has caused the peat column to shrink by some 5 m – nearly half of the total of 11 m – for more than 500 m on either side of the road. One engineering result of such shrinkage is that bog roads buckle repeatedly, so that they are very difficult to keep in repair. County Council engineers will derive little consolation from the fact that settlement has a logarithmic relationship to time, so that (in Clara's case), the predicted rate for the next 200 years is only 0.5 m!

The construction of canals through bogland was considerably more of a challenge. Smeaton ('the ablest engineer of his day') when advising the Grand Canal company in 1773 had cautioned engineers to avoid cutting deeply into bogs at all costs. There were expensive consequences when the engineering problems posed by the shrinkage of peat were inadequately understood, as the construction of the Edenderry Canal demonstrated. The bottom of Edenderry bog is many feet below the level of the adjacent river, so the Grand Canal had to be excavated in peat. The engineer was no doubt mindful of Smeaton's caution about not cutting deeply into bog; a shallow cut only 6-9′ deep was made in the bog, in the expectation that this would enable the job to be done cheaply and quickly. At the same time the bog was drained, and as a result it subsided dramatically in the years that followed. Meanwhile, the canal was stubbornly maintained at the level originally planned, and by the time it was finished several years later, at enormous labour and expense, the canal ran for a distance of 80 perches through the bog, perched on the top of an embankment 400′ across at its base and 45′ high. The engineers wanted to give up and start again on several occasions, but local vested interest proved too strong: so that (in Bernard Mullins' account)

> ... through the influence of the proprietor of the town of Edenderry, an example has been furnished, for the benefit of the engineering world at least, of an error of the gravest character having been carried to a successful termination.

Mullins was enthusiastic about making canals through bogs. He thought they were particularly suited to the purpose because

> ... the site of the canal is purchasable at a low rate, it is cheap and facile in execution always presuming that the line is judiciously chosen and skillfully worked; it is perfectly retentive, does not gutter the slopes at the water's edge as in clay and gravel banks; and the elasticity of the towing paths is such, that they continue for years without repair if used exclusively as trackways. Moreover, a line of canal passing through bog furnishes the means of reclamation on an extensive scale, as well in the preliminary process of draining as in the conveyance of manure for its cultivation. The increase of fuel, and the employment which its manufacture would afford to the working classes in its vicinity, are great inducements to give a decided preference to bog lands for the site of a canal, other requirements being suitable.

One of the reasons why the Grand Canal (which reached the Shannon in 1802) was routed through the Bog of Allen was the provision of Dublin with turf, and it was anticipated that its construction would drain 77,000 Irish acres of bog. The Canal also facilitated the exploitation and export of the brick clays under the bog; in the 19th century therefore, there were brickworks dotted along the line of the canal wherever it ran through bog.

Mullins had successfully cut an aggregate 40 miles of the Grand Canal through bogs, and long experience had taught him a different approach to Smeaton and other engineers. This approach is especially well demonstrated in the layout of the Ballinasloe Canal, which ran through 12 miles of deep bog averaging 26-46′ deep in a total length of 15 miles between Ballinasloe and Shannon Harbour **[Figure 2.13]**. His method was to first sink a 'centre drain' along the line of the centre of the proposed canal, 'five feet wide at top, one foot wide at bottom, and three feet deep where practicable' **[Figure 2.14]**, two other 'verge drains' parallel to it along the line of the future embankments, other parallel drains further out, and cross drains at regular intervals at right angles to all of these. These drains were regularly and very gradually deepened as the peat shrank, but they were very seldom allowed to become more than three or four feet deep. After two years of this, the entire surface of the bog – which was originally 26′ above the base of the bog at the verges of the canal – had subsided by an average of 20′, as shown in Figure 14 (bottom). The canal itself

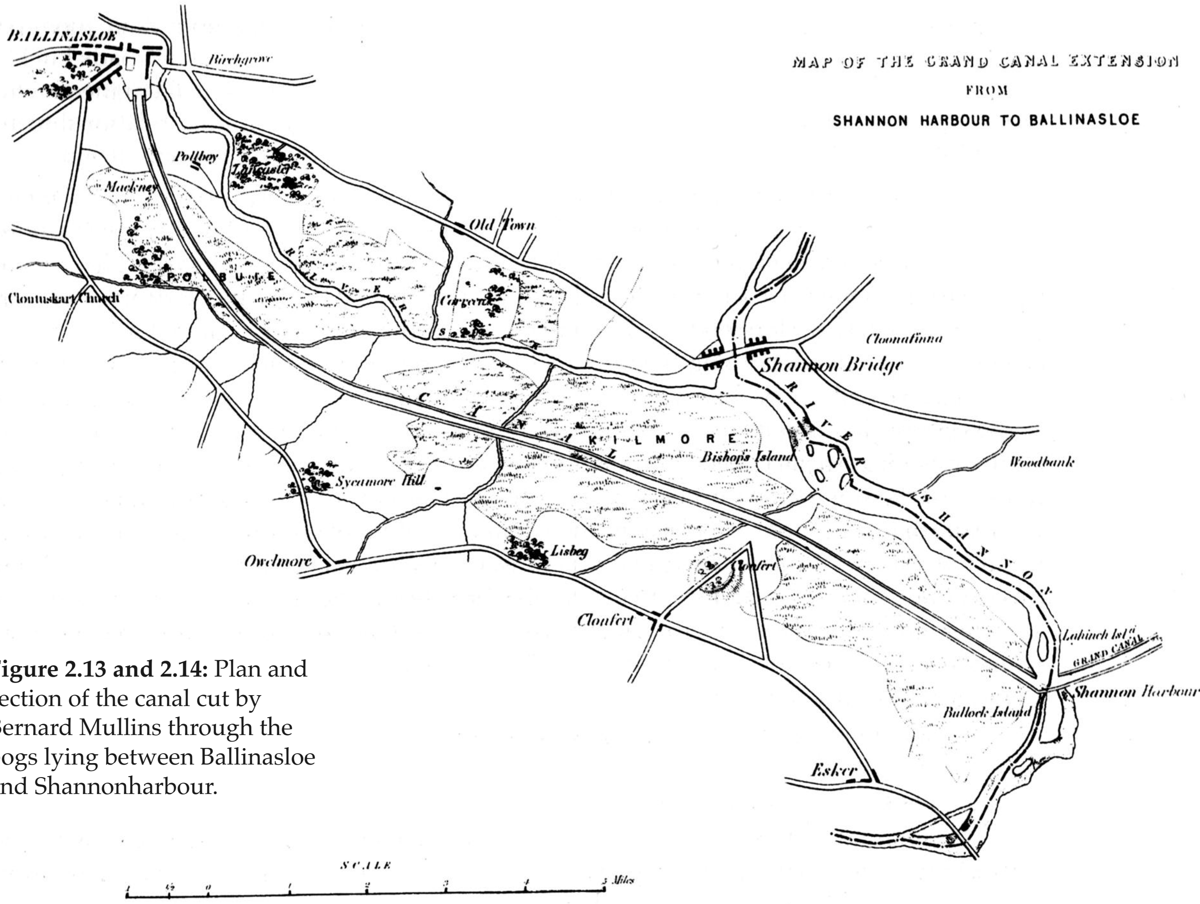
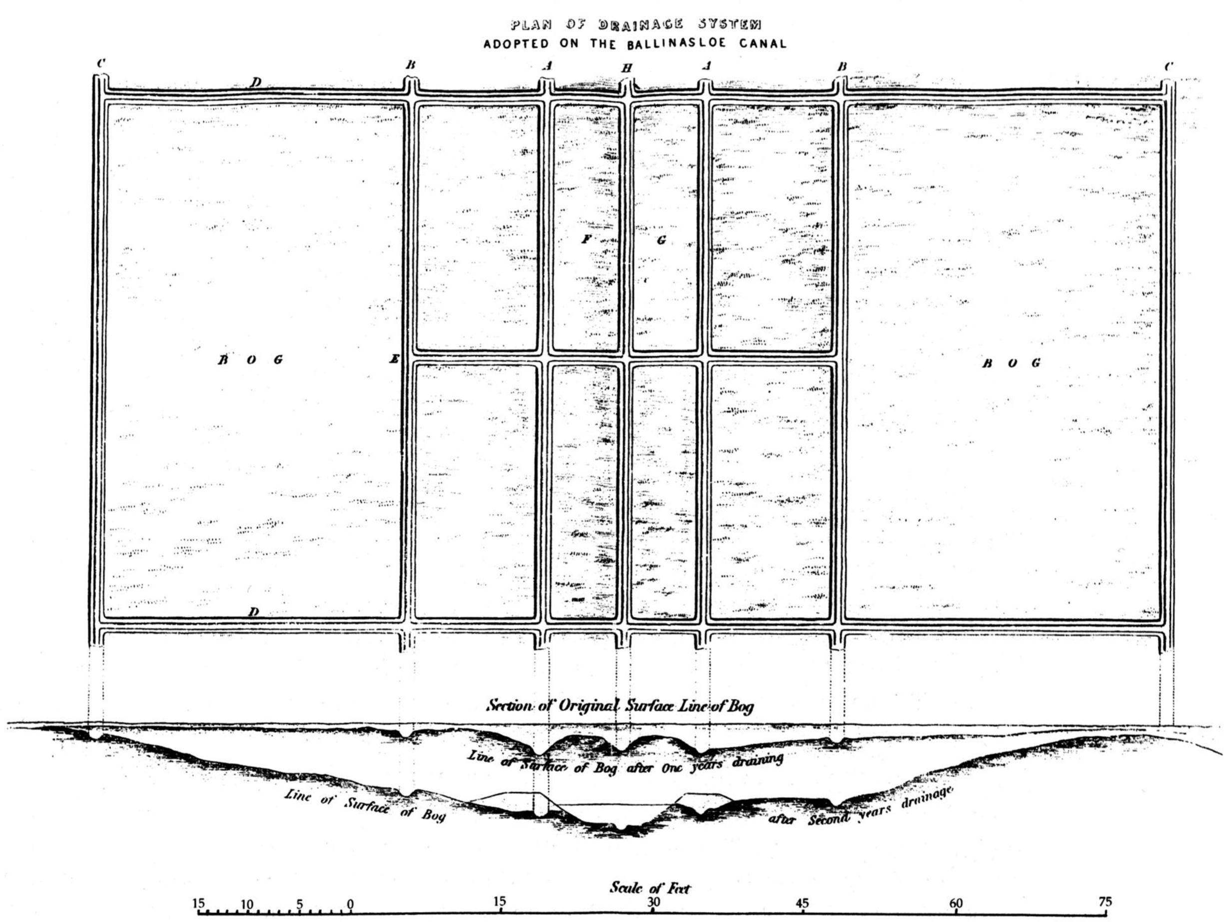


Figure 2.13 and 2.14: Plan and section of the canal cut by Bernard Mullins through the bogs lying between Ballinasloe and Shannonharbour.



was then dug, the sides carefully raised with the lightest and driest of the peat dug out of the drains, and a towing path of clay laid on top.

The role of the Sugar Company

In the years after its foundation, the Irish Sugar Company used turf as fuel in its factories. The company's interest in bogs took a different turn in the early 1950s, under its Managing Director, General M.J. Costello, whose dream of turning the bogs in the west into green fields recalls the great peatland visionaries of the 19th century. General Costello bought 2,367 acres of the great quaking bog at Gowla in County Galway, a morass with a ground bearing pressure of only 1.5 lbs per square inch, with the aim of using it to grow grass for the production of grass meal. The grass was seen more or less as a pioneer crop to be grown in the earlier stages of the reclaimed bog peat 'amelioration'; it was hoped that in the longer term the reclaimed bog might be used for growing sugar beet. The project received substantial grant aid under the Land Rehabilitation Project of the Department of Agriculture. A specially designed plough (known as the Bogmaster) had to be made to drain this exceptionally wet bog. A grass meal factory was built and two German Lilliput turf-cutting machines purchased, the turf being used as fuel to dehydrate the grass. In 1953 five modern Lilliput machines replaced the first two, and in 1956 a larger Bavarian machine was added to the fleet. By 1976 Gowla was processing 4,500 tons of grassmeal from as many as six cuts of grass a year, grown on 900 acres of the former bog, and transported to the factory by narrow gauge railway. 200 acres of the bog were used for turf production.

Gowla Farm ran into difficulties in the late 1970s, as grass meal went out of favour, and was replaced by cheaper sources of protein for animal feed. In 1981 the farm was closed to make way for Derryfadda milled peat and briquetting plant, and the turf-cutting machines were sold off to private developers.

Bogland reclamation today

There are more than a million hectares of rough grazing in the Irish Republic at present: a mixture of low-management grassland, heath and bog, much of it reclaimed from peatland over the last two centuries. Mountain bogs are widely used for grazing, as they have been for centuries, not just in the counties of the western seaboard (West Galway, West Mayo, Kerry, West Cork, Donegal, Clare and Sligo) but also on the Wicklow Mountains, on the Galtees, Knockmealdowns, Comeraghs, and the mountains of the south Midlands; and in Leitrim. One problem with mountain grazing is that it is deficient in several elements that animals need in their diet because of the low nutrient status of the peat – major elements like nitrogen, phosphorus, potassium and calcium, as well as such micronutrients as manganese, cobalt, copper and molybdenum. One sheep needs about two and a half hectares of grazing on deep bog to feed on, and maybe half this on cutover bog. They graze the heather, and where mountain land is overstocked – which tends to happen when there are subsidies and high prices – the heather is often overgrazed and disappears, to be replaced by vegetation with much common cottongrass and purple moor-grass, and in the longer term by very poor mat-grass grassland with heath rush, no lichens, and an increase in the area of bare ground. The quality of the grazing can be greatly improved by adding fertilisers, and reseeding with productive grasses and clovers. The semi-natural vegetation will be replaced within a few years if this is done, but the high input of fertiliser has to be maintained or it will reappear.

One of the main difficulties with the reclamation of mountain blanket bog is that there is often a hard iron pan present, usually less than half a metre below the surface, though it can be as much as a metre down, and occasionally even up to 2.5m in parts of West Mayo and West Kerry. Bogs of this kind can be reclaimed by deep ploughing to break the iron pan, combined with other measures: drainage, and mixing in the excavated subsoil with the surface peat. Deep peat however still presents drainage problems which are just about insuperable; even where it is technically feasible, the economic return would not justify the effort of reclamation.

The main problems associated with the development of peatland for agriculture nutrient deficiency and drainage have of course been appreciated for centuries. Most peats are low in essential plant nutrients, but this is not the case with well-drained fen peat. When work finishes on a bog which has been in production by Bord na Móna for milled peat, an average of about 0.5m of fen peat is left behind, though this varies greatly because of the undulating nature of the mineral surface under the bog. This would be sufficient for arable purposes, but to get the best results for vegetables it would have to be somewhat deeper. Cutover bog with sphagnum peat at the surface is only suited to light grazing, but where fen peat is exposed the land has a much greater range of possibilities, and can give yields which are comparable with the best soils elsewhere.

With the prospect of large areas of cutaway becoming available to farming, three research stations devoted to the problems and possibilities of the agricultural use of bogland were established by An Foras Talúntais (the Agricultural Research Institute) in the 1960s. At Glenamoy in Mayo the focus of interest was on low-level blanket bog, at Lullymore in Kildare on the potential of cutaway raised bog, and at Maam in Galway on hill farming. The research included the mapping of peat and subsoil types, approaches to drainage, the problems associated with development for arable, grassland and livestock and how to solve or ameliorate them. A considerable body of knowledge and expertise in relation to nutritional problems was gained as a result of this research work; particular attention has focused on the mineral status of the new soils for grass and livestock, especially in relation to overcoming molybdenum-conditioned copper deficiency in livestock grazing on shallow peat: the high molybdenum level comes about when the subsoil is mixed with the peat.

The research progamme at Glenamoy was concerned mainly with the reclamation of deep peat soils for agriculture. This was seen as an advance on the 19th century emphasis on the small-scale reclamation of shallow bog to extend the area of the individual farm, which was predominent on the margins of both raised and blanket bog areas. The reclamation of the lagg fens which fringed the raised bogs was of this kind; these fields are still grazed, though very often with ill-considered management. Technically, Glenamoy was a successful demonstration, but it was too expensive – both in financial terms and in terms of what widespread acceptance of the new techniques for the reclamation and management of deep peat might have meant for extensive areas of blanket bog of conservation importance. Moreover, local communities in the west had shown little interest in learning new, ingenious and elaborate techniques that would enable them to drain and reclaim deep bog. Their priority remained what it had always been: the extension of marginal holdings onto adjacent areas of shallow peat in order to achieve viability.

Small reclamation projects of this kind continued until recently in Erris and elsewhere, with the advice of the Farm Development Services. This advance is achieved not at the expense of areas of ecologically important deep bog, but almost invariably in areas of heavily eroded cutover. Professional advice ensured that the areas selected had a suitable gradient and were convenient of access, and made it more likely that the new soils would be properly managed. Internal drainage is seldom necessary; the peat is subsoiled to improve drainage, trafficability and fertility – basic, effective techniques little different from those of the 19th century. Small-scale, piecemeal reclamation projects of this kind can double the productive size of an individual holding, and are often important in achieving viability and sustaining rural communities in the west. They pose no threat to local ecology – an aspect which should always be a factor in the selection of suitable areas – and they add virtually nothing to the EU production overload.

During the First World War some experimental work on the cultivation of cutover bog was carried out in Counties Kildare and Tyrone. Between 1927 and 1942 the Land Commission attempted to put the recommendations of the Peatland Enquiry Committee on peatland reclamation into practice through the establishment of 128 new holdings of about 40 acres each, and the enlargement of 152 existing holdings on bogland, mainly in Connemara, Mayo and Donegal. The Land Commission reclaimed two acres of the forty, leaving the remainder to the occupiers, with very limited success – which can largely be attributed to the rapidity with which degeneration sets in with even the minimum of neglect. Considerable areas of bogland were reclaimed in the years before World War 2 under the Government's Land Reclamation Scheme (1931-40) and the Farm Improvements Scheme (1940-49).

A pilot project set up in 1952 at Dunne's Farm in Rathangan showed considerable promise, and in 1955 the Department of Agriculture initiated experimental work on cutaway bog in the Midlands, and this was continued by an Foras Talúntais at Lullymore. A series of reports and reviews on the use of cutover / cutaway have appeared from the 1960s onwards. One of the first was the report (1973) of a sub-committee set up by the Agricultural Science Association to investigate the issue. This came up with 4 recommendations:

1. The legal position with regard to the purchase and acquisition of the fee-simple of peatland by farmers in general, and also by groups of farmers with grazing and / or turbary rights from the landlord's estate, should be examined with a view towards the establishment of title.
2. Peatland has a variety of potential uses, namely, for peat and peat products, forestry, grassland, horticultural and other crops, and amenity. Better co-ordination of existing peatland users is required to ensure that peatland is used to the best national advantage. A National Co-Ordinating Body should be established for this purpose.
3. A pilot area of peatland of sufficient acreage should be developed to demonstrate the problems and potential of peatland.
4. The conservation of fen peat for horticultural purposes in the light of market opportunities should be ensured.

The ASA report led to the establishment of a Peatland Development Committee which drew up a series of guidelines for peatland development in 1976 (Glenamoy Review Group). A pilot development programme was set up at Clonsast in accordance with these guidelines.

All of this work has shown that carefully selected areas with a good depth of residual woody fen peat, well-drained and with high lime content, are eminently suited to the production of high-value cash crops, if carefully managed. Wild raspberry grows naturally on cutover bog, so it is not surprising that raspberries thrive on reclaimed peat; so too do blueberries, strawberries and currants, and rhubarb can grow to an enormous size – stalks 2 m long and 15 cm thick are not uncommon. Most areas of cutaway however are only suitable for grassland or forestry, but careful management is still necessary to maintain nutrient balance and prevent physical deterioration. Along with the nutritional and physical difficulties, problems of ownership and fragmentation are still a stumbling block to the agricultural development of the considerable areas of 'farmer cutover' which are still in some form of commonage.

With current over-production in the EU there is limited economic justification for an increase in the area of grassland unless this is of the highest quality, or can allow other areas less suited to grazing or silage to be withdrawn and perhaps planted with trees instead. The principal justification for the development of new pasture on cutaway is to further the consolidation of farm holdings at the periphery of the bog, so that as many viable farms as possible can be retained.

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Chapter Three

Mechanical harvesting of peat : the early days

The fact that we are without coal upon a nationally useful scale and that in its place we have such vast supplies of peat in this country should stimulate us to the conviction that, in the allotted order of things, the duty assigned to us is that of turning to account the supplies of native fuel so abundantly provided for our use. If coal is not won from its depths without outlays and labours, gigantic in proportion to other industries, can we expect to win our fuel from the moor and bog without giving to it some industrial efforts and attention?

J. McCarthy Meadows (1873)

Figure 3.1: The title page of Schookius' *Tractatus De Turffis.*

MARTINI SCHOOCKII
TRACTATUS
DE TURFFIS,
CEU
CESPITIBUS
BITUMINOSIS:
Quo
Multa, ab aliis hactenus aut neglecta, aut minus diligenter examinata, accuratius aliquanto excutiuntur.

GRONINGÆ,
Typis JOHANNIS CÖLLENI, Bibliopolæ & Typographi, 1658.

The mechanisation of the peat harvest is not something that suddenly happened with the advent of Bord na Móna. The machines which Bord na Móna and the many private developers use today are the result of a long and fascinating process of engineering evolution which had its origins in the 19th century in the bogs of Northern Europe and Canada. It is important to remember that Ireland is not the only country with extensive peat resources: Germany, Russia, Scandinavia, the Netherlands, Denmark, France, Great Britain, Hungary and Estonia either have or had vast reserves of peat. In many countries these had been harvested for centuries by hand, and by much the same methods as in Ireland, although each region had its own particular modifications of technique to suit local conditions.

For a long time, the peat developer's bible was a book in Latin published in 1658, *De Turfis seu de cespitibus bituminosis,* by Martin Schookius, who was Professor of Philosophy at Groningen [**Figure 3.1**]. What is probably the earliest treatise on the use of peat as a fuel is found in Guicchardin's *History of Holland,* which describes how the inhabitants of the state of Overyssel petitioned Charles V on the occasion of his coronation in 1528 to prohibit the export of peat from their state, so important was it to their economy. After these beginnings, an extensive literature on peat development was produced in the 18th-19th centuries in Germany, France, Holland and Denmark, advising not just on its use as domestic fuel, but for kiln-drying malt, burning lime, firing tiles and roasting gypsum, for distilling brandy, melting glass and the manufacture of salt and soap. Peat was being used for smelting in Saxony as far back as 1560, and was widely used in German iron works and in the French Landes during the first half of the 19th century for re-melting pig iron, and for the puddling and balling processes. It was cut in brick-sized sods, which were first dried for six weeks on the bog and then further dried at 100°C in special kilns that could hold 11,500 sods at a time. This gave very dry, compact sods about half the weight and volume of the freshly-cut sods.

In 1844 Robert Mallet prepared an improved kiln for use in Ireland, but it seems not to have inspired the enthusiasm he himself felt for its potential He envisaged that it would be used on large estates, in distilleries, steam mills and factories, and that it would remove the weather-dependency of peat harvesting:

> At present the making of turf, is the most idle labour in which the Irish peasant engages; one which by its desultory nature, and its entire dependance upon weather for a long continued period, has a strong tendency to induce lazy, half employed habits, but one which nevertheless consumes under the most favourable possible circumstances, about three weeks of the cottier tenant's year, and, during this time, the labour, or at least the time of the able-bodied of his family: while under the disadvantage of broken weather, or a wet season, two or three months are often consumed in unavailingly endeavouring to make up the year's harvest of turf.

Mallet's kiln held 10,000 cubic feet of turf at a time, and it dried the turf in six or seven days, using turf mould and 'clearing' as fuel; he suggested that the ash should be applied as top dressing on grassland. He also designed a small model which could be constructed from turf sods and drystone walling on the bog itself, and which would serve the needs of groups of households. [**Figure 3.2**].

The earliest peat machines essentially mechanised the making of mud turf, which was the type of peat fuel made on many of the wetter continental bogs, especially in Holland, as in some parts of Ireland (See page 22). The method was based on the observation that

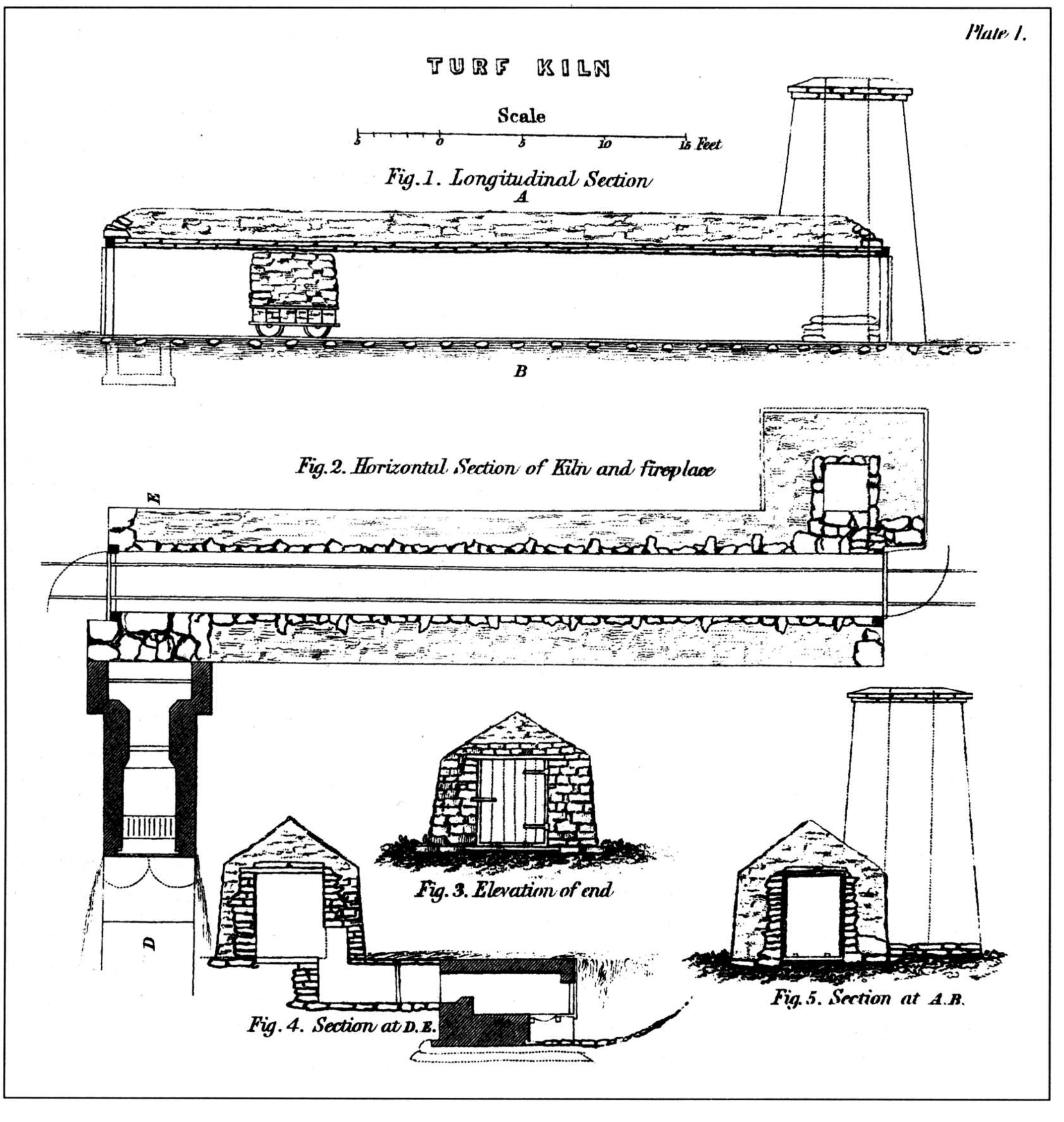


Figure 3.2: Mallet's smaller turf kiln 'for the cottier tenant' which 'might be a joint stock utensil common to four or five homesteads'. The fire place may be made of dry stone at one side, sunk in the bog, and placed at a distance of 12 feet from the wall of the kiln, the communication to be from the fire to the kiln by-a flue or drain of dry stone. The chimney stalk may also be built at the remote end, of sods from the bog, strengthened by a layer of dry stone here and there'. (From Mallet, 1845).

well-mixed raw peat dried into sods of greater density and better quality than sods cut by hand, which are simply intact slices of bog. Macerating machines mix peat from different levels in the profile and then extrude the mixture for spreading.

The first macerating machine was a sort of vertical pug-mill, designed by the Swedish engineer Hasselgren in 1845. This was followed by many variations, some powered by steam and others by horses. The peat was macerated by knives and blades of different kinds, before being extruded through a sausage-forming mouthpiece. Maceration gave a fuel that was denser, firmer, more quick-drying and of more even consistency than hand-won turf. In the beginning, the peat mud was fed into the machine by hand and removed by hand, but these tasks were also soon mechanised. In the decades that followed, an amazing number of machines of increasing complexity and ingenuity were developed. Animal and steam power were replaced by electric power, and sometimes by compression ignition engines. In Europe – and especially in Germany – bogland reclamation was carried out using large steam-powered ploughs from about 1880 on.

Towards the end of the 19th century there was much experimentation into the mechanisation of peat-harvesting throughout Northern Europe. There was also vigorous state participation in many countries: in the German states, Austria, Sweden, Norway, Denmark, Holland, Russia and further afield in Canada. The outbreak of World War I saw a renewal of interest in the development of peat resources in Europe (which had flagged somewhat after 1870), and this was reflected in the growth of Peat Societies and Institutes in many countries. There were bogland experimental stations in many countries to bring the latest developments to farmers; in Ireland there were experimental stations at Inny Junction in Cavan and Castleconnel in Limerick, where the latest continental machinery and processes were tried out and demonstrated.

Peat was widely used in Germany in the manufacture of iron and steel at the end of the 19th century. It was used on the Bavarian railways, and for a time in the manufacture of glass and porcelain. Even in recent times, turf has sometimes been used to run trains and even lorries. Turf-burning locomotives were in use in Clonsast in its early years, and for a time in the 1950s the firm of Curran Ltd. of Clonmel operated a peat-burning steam lorry. This was a converted Sentinel steam truck rescued from a scrap heap in South Wales, which could haul a 16-ton load at around 15 miles an hour. The fuel hopper held half a ton of peat, enough to keep the lorry running for over 100 miles at a cost of 3d a mile. Its biggest disadvantage was the need to refill its 500 gallon water tank every 30 miles!

Peat was used by Lord Rosse at Birr Castle in County Offaly in the late 1850s for melting the materials for casting the six-foot diameter lenses for what was (until 1929) the largest telescope in the world. The hot peat ash may have been particularly well suited for tempering the casting and avoiding cracks. It took 50 tons of the best dry turf to melt the material for each of the three lenses or specula (reflecting mirrors of polished metal), and the casting was allowed to cool for some three days in the pile of hot ash. The turf house at Birr Castle is currently being refurbished by Bord na Móna as part of the telescope restoration, the 'flagship project' of Birr's Historic Science Centre.

The first operation in bog development was the last to be mechanised. It was only in 1936, with the introduction of the disc ditcher, that drainage was mechanised. Before this it was labour intensive and expensive: in those days one man was expected to be able to ditch and cross ditch an acre of bog a week.

In Ireland turf was cut and saved by hand almost exclusively until after the Second World War, and without mechanisation there appeared little prospect of making real progress in peat development. The mechanical harvesting of peat was highly advanced in Germany by the 1930s, and the Turf Development Board studied developments there and in Russia. This was the fourth such study of mechanised peat development abroad since the Purdon Report in 1872! Each of these studies concluded that peat should be produced in Ireland using power-driven macerating machines as in Europe, but the successive committees gave little indication that they were aware of the conclusions of their predecessors. It was difficult to assess the profitability of mechanisation in Russia, because there the State had thrown its full financial support behind it for social reasons, and used compulsory labour. Nor were politicians in the Irish Free State entirely convinced that mechanisation was the solution. Even in 1933 Sean Lemass (then Minister for Industry and Commerce, and of course a politician rather than a peat engineer) saw no great advantage in the use of machines; for him the big problems were the dependence on air-drying, and the need to make peat fuel in a more concentrated form. The Government was also cautious about supporting experimental work of doubtful economic viability.

Machine peat and briquettes

A number of machines were designed in the 19th century for the manufacture of 'cut' or 'dug peat' – i.e. sod peat without macerating. Many were variants of a design introduced by Brosowsky in North Prussia. Within five years of the introduction of small, efficient cutting machines no fewer than 15,000 were in use in the provinces of Mecklenburg-Strelitz and Pomerania alone. The Lepreux machine, which worked on the same principles as Brosowsky's, enabled two men to raise and cut 40,000 sods (5,600 ft^3) a day. A number of machines were also designed by Dolberg. There were several of these in Ireland; in 1903, for example, the Department of Agriculture operated a horse-powered Dolberg machine at its experimental station at Inny Junction.

The black, non-fibrous peat from deep in the bog tends to crack up when exposed to a strong sun. Controlled drying of such peat was therefore essential; sometimes this was done naturally in sheds (as it was at Kilberry), and sometimes the peat was dried artificially. One school of thought believed it was the slimy humic colloids in peat which made it so difficult to dry fully, and various methods were introduced to cause these to precipitate: adding chemicals, heating – or by using an electric current (See below). These colloids actually promote the shrinkage of macerated peat. To facilitate drying, the centre of the sod was occasionally left hollow. The Blunden Process in use at the New Irish Peat Products factory at Coolaney produced macerated 'sausage turf' in continuous hollow tubes that were suspended on wire under cover in open sheds to dry.

From the middle of the 19th century a whole series of different manufactured peat systems appeared. What distinguishes manufactured peat is the important fact that the peat is macerated and mixed before the sods are shaped. When this is done, the peat undergoes a natural contraction, making the application of artificial pressure unnecessary. Machine macerated peat often has a slimy finish which is believed to come from components in fen peat; this dries quickly to a hard varnish, unless it is washed off by rain after the peat is spread. It also seems to playa role in the shrinkage of the peat and in resisting re-wetting by rain. Machine peat needs to be dried to around 30-35% water content, as against 25-30% in ordinary hand-won turf in a dry year.

There were several early attempts to mass produce peat, using machines, in Ireland. The first large-scale attempt to manufacture press-peat commercially was Charles Wye Williams' remarkable enterprise at Cappoge (Cappagh) in the Bog of Allen near Kilcock on the border between Meath and Kildare, which commenced in 1844 [**Figure 3.3**]. The Royal Canal had been cut through Cappagh Bog in 1790. This had been a difficult undertaking, because the rock under the bog had to be excavated, and there were problems because the overlying peat closed in: but when the canal was finally constructed it was a very effective drain, enabling the bog to be reclaimed and excavated, and providing a cheap method of transport for the turf.

Williams had established the first steam packet service between Dublin and Liverpool twenty years before this. He was also a director of the Inland Steam Navigation Company (Ireland), and his business instinct enabled him to see that hand-cut turf might be used as fuel on his Shannon steamers instead of coal. Earlier, in 1838, compressed peat was tried out on the first transatlantic voyage of the Dublin Steam Ship Packet

Figure 3.3: Charles Wye Williams (1779-1866).

Company's steamer, the Royal William; its captain remarked that 'one cwt of this saves three cwt of coal'. Peat was also occasionally used to power steam and condensing engines, and machine peat was even used for heat welding in Scandinavia. The substitution of coal by hand-cut turf on the Shannon steamers gave much employment to turf cutters in the local bogs, and it cut fuel costs by half. In the 1840s, for instance, the cost of turf as fuel for the Lansdowne (one of the Inland Navigation Company's Shannon steamers) was £1,200 per annum, where coal would have cost £1,800. In 1843, 7,000 tons of hand-won turf, bought from the turf cutters at 3/6d per ton, were used as fuel on the steamers. It should be remembered however that this was before coal could be transported across country by rail.

In the 1840s Williams set about the mechanisation of peat fuel production. His aim was to produce a peat coke that could compete with wood charcoal or coal coke for smelting ore, raising steam or even for manufacturing gunpowder. In his patent process, the peat was first cut up to break the fibres, after which the macerated and mixed peat was wrapped in cloths and subjected to hydraulic pressure, which reduced the volume to one third. The peat press-cake – still containing 70-80% water – was then cut into sods, and dried in the air. It was then charred in a retort and the resulting coke compressed into blocks and waterproofed with a coating of resin or pitch; it sold for 5/= a ton. However, the process was too troublesome and expensive to be a commercial success. The product, although superior to hand-won turf, was too dear to compete with it: it cost 5/= a ton as against 3/6 for hand-won turf, and the operation folded after a few years. It did have one longer-term result, because the use of turf as fuel on the Shannon turf boats, which he introduced, continued for long afterwards. Several of his methods were also incorporated into later and more economical processes.

Sir Robert Kane was very enthusiastic about the performance of turf on the Shannon steamers, though Robert Mallet was more sceptical. In his opinion it was not nearly as good as Kane claimed; moreover, it burned so rapidly that it was almost impossible to keep the boiler supplied – besides which, coal had to be mixed with it in wet weather. This, however, was presumably because the grate was designed for coal, which needs many times more air than turf to burn. Mallet's experiments suggested that the claims made by Kane and Williams were a gross exaggeration: according to him it took more than 50 lbs of dry turf to convert 1 ft^3 into steam, which was more than three times the figures they quoted.

In 1846 'The Irish Turf, Peat Coal, and Charcoal Company' was launched:

> for the purpose of producing, by powerful hydraulic pressure, and other suitable mechanical means, coal from peat, possessing the density, durability, brilliancy, and heat of the.best pit coal, and at a very reduced price, thereby effecting an enormous saving in fuel for engine-boilers, distillers, manufacturers, &c. It will be the means of affording to the inland parts of Ireland a plentiful supply of coals at a cheap rate, and will protect the inhabitants of Dublin from the many fluctuations in the price of that necessary article of consumption, which has risen in this city, as compared with the previous 12 months, full 50 per cent.

Little is known of the fortunes of this new company.

Many new machines were introduced during the second half of the 19th century in Germany, Sweden and Russia – by more than a dozen engineering firms – to shape the sods.

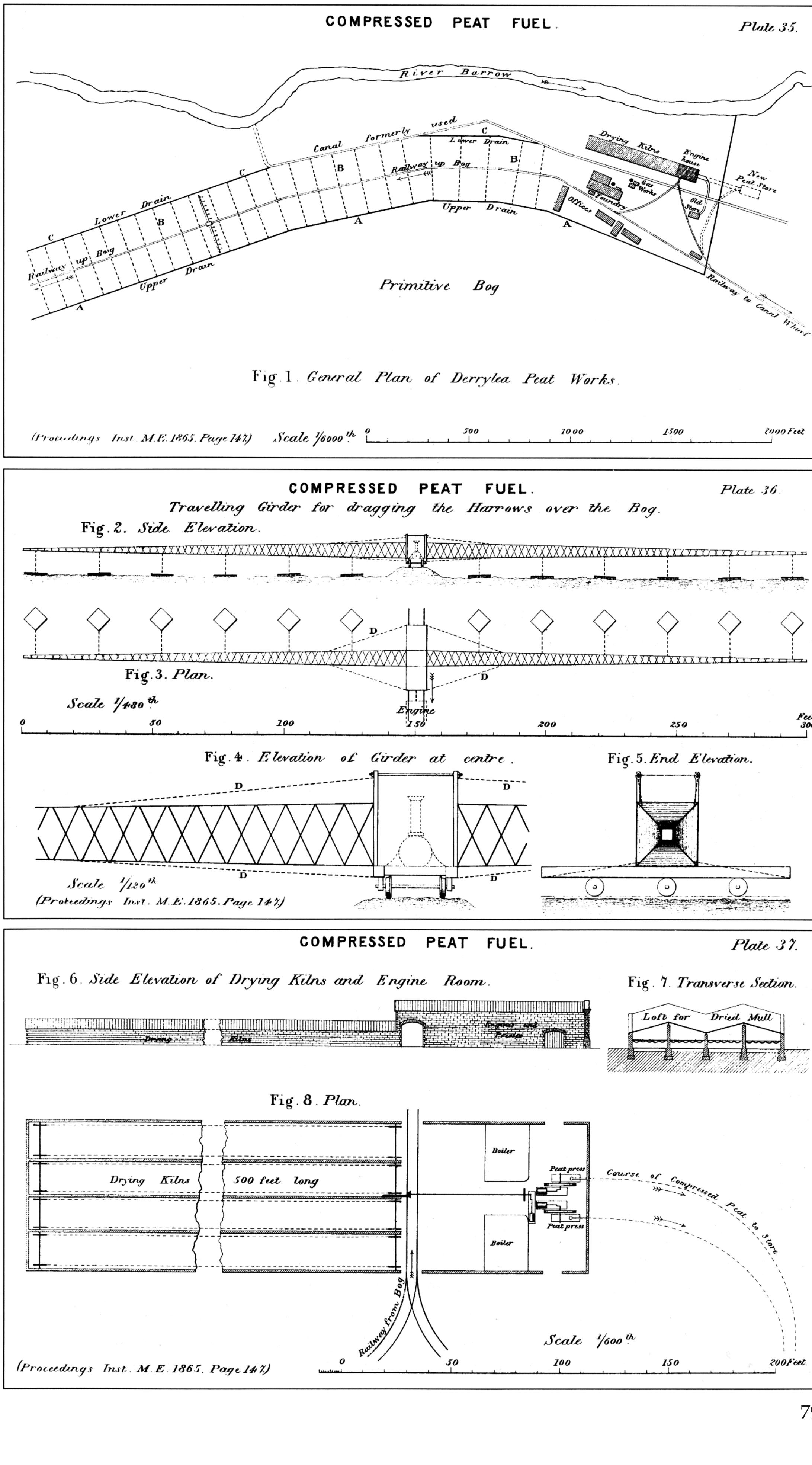
By the turn of the century a whole range of ingenious and compact machines for making macerated peat were being manufactured by several different engineering firms on the European mainland. That made by Heinen of Varel was typical, and one of the most successful, and it is interesting to note how similar it is to some of the machines in use today. It consisted of three cylinders with rapidly rotating screws (spirals) inside; turf was fed into these at one end from a hopper and mixer, and the sausage peat was extruded at the other end either directly onto the spreading ground or onto carts that transported it to the spreading ground. It was driven by a 6hp engine, and could turn out 3,000 sods an hour – 1.5 tons, at a cost of 4/ = a ton, at a time when (early 20th century) hand-won turf sold at up to 10/= a ton. Heinen machines were in use at Kilberry.

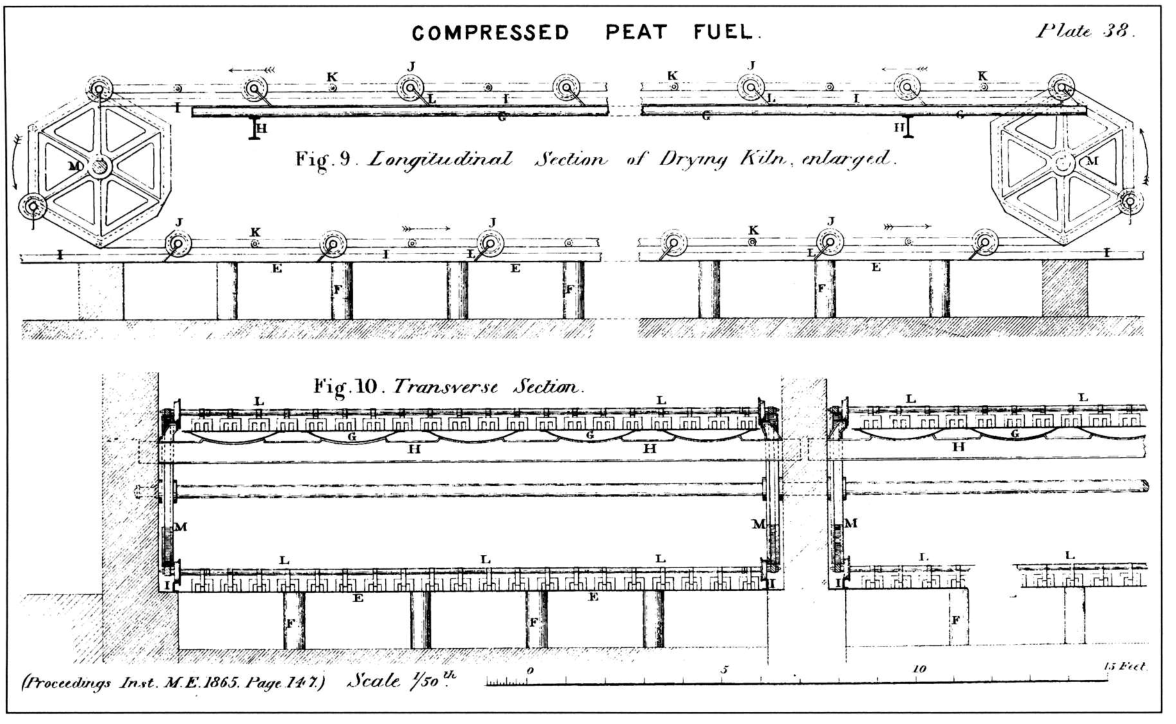
One of the earliest peat briquette-making processes, known as Gwynne's Dry Press Process, was used for a short time in 1855 at Kilberry near Athy, by the Irish Peat Company. In this process the peat was first air-dried, and then dried artificially to 9% moisture. It was then reduced to a powder before being heated to 180°C in steam-heated cylinders and compressed in individual boxes. The shaped briquettes were pushed from the revolving form-table that had twelve shaping boxes, which were compressed one after the other, onto an endless band. The factory produced 240 tons a week, but the process put great strain on the presses, because the *fixed stroke* ram could not cope with an overfull box of peat powder. There were endless problems, so that it finally had to be abandoned. But the product was remarkable: as dense as coal, with only 9% water and a charcoal equivalent of 36%. Charles Hodgson also operated a Gwynne Press in Galway in 1854, but it too failed for the same reason. In its final years, the Irish Peat Company spent several thousand pounds trying to perfect its machinery for the manufacture of compressed peat fuel in Kerry. The company was finally dissolved in 1859 with enormous loss. Of the paid-up capital of £62,000 only £4,000 remained after the company's debts were paid; the sale of the stock and works brought in a further £4,700.

A few years later, in 1860, Hodgson set up a factory at Derrylea, between Monasterevan and Portarlington, to manufacture briquettes using a process he had patented himself in 1858. The machinery was ingenious, the most comprehensive and technically perfect system of peat production in Ireland in the 19th century. The method used for drying the peat was an important innovation, based on the discovery a few years previously – and patented by Hodgson – that if the bog surface was harrowed, powdered peat 4 times as dry as freshly dug peat could be obtained cheaply (at 5d/ton), and in quantity, and (it was supposed) more independently of the weather. The peat was harvested mechanically by 'harrowing', using zig-zag harrows attached to a 300′ girder extending 150′ on either side of a rail-mounted truck propelled across the bog by a 6hp steam engine. Repeated harrowing in dry weather dried the peat to 55-60% of its moisture content, and it could then be collected and transported by rail to the factory. Once inside it was further dried to 10% in elaborate 250′-long drying kilns where it was kept moving, by mechanical rakes, over iron plates heated by waste steam from the compressing engine, and boiler exhaust gases. It took between one and one and a half hours to make the trip **[Figure 3.4]**. In this way, 'peat standing in its primitive bog in the morning is harrowed, scraped, brought in, dried on the steam surface, compressed, and before night falls as a complete and excellent fuel into the canal boat which conveys it to market'. One of the big advantages claimed for this mould peat over sod peat was that it dried so much faster – supposedly as much as 50 times as fast. The dry peat powder then passed to the two presses at 10% moisture content, where it was compressed by a horizontal reciprocating ram working in a cylinder five feet long. As the ram was drawn back after each compression stroke, a new charge of powdered peat filled the cylinder. The briquettes were 4-inch diameter discs, one and one-eight inches thick. The optimal rate of production was 60 briquettes every minute, making in an hour about 15 cwt of compressed peat fuel; in practice the rate was 40 a minute.

Charles Hodgson can be credited as the inventor of the peat briquette press. Herman, in his monograph on brown coal, claims that 'presses for Brown Coal were as for processing peat on lines followed earlier in Ireland, in which country the so-called Exter or Rope-press

Figure 3.4: The layout of Derry lea and its machinery (Hodgson, 1865).





(which is the prototype of all such presses, ancient or modern, really originated'. The big advance in Hodgson's briquette-making process was that he used an open-ended press, from which the compressed peat emerged as a continuous cylindrical bar which broke into briquettes, each formed by a single stroke of the compressing ram. Closed presses were notoriously difficult to regulate: exactly the right amount of peat had to be fed into the mould every time, and the variable nature of the peat made it difficult to get the consistency constant. Carl Exter in Germany had come up with a design very similar to Hodgson. His press patent was ten months earlier in 1858, but Hodgson's was more advanced mechanically, and had long cooling runners attached; these were 90m (about 240') in length. Exter's design would not allow the attachment of cooling runners (Kuhlrinnen) at that time, and runners were essential in making hot briquettes. The English engineer Gwynne seems to have been in constant contact over a number of years with both Exter in Bavaria and Hodgson in Galway and Derrylea. The briquetting presses for peat and brown coal throughout the world are still basically the same; the construction is essentially that of a 'steam engine in reverse' [**Figure 3.5**].

Derrylea was a marvellous example of economy and self-sufficiency. Lighting was provided by gas, which was generated from a mixture of two-thirds peat and one-third coal, and replacement parts were made in workshops on the site where the furnace was fuelled by briquettes. The iron used was smelted from bog iron ore in a furnace fired by charcoal made from peat briquettes. Hodgson built a workers' village at Derrylea, a forerunner of the Bord na Móna villages of a century later, gave plots of land to his workers to grow potatoes and vegetables, and even provided transport by the Company's narrow-gauge railway every Sunday to Mass in Monasterevan.

In 1864 Derrylea had a work-force of 200. Output was about 180 tons a week, and the briquettes sold at the quays in Dublin for 10/= a ton. But this still wasn't cheap enough to enable them to compete with coal, and the factory had to close after four or five years. There were other reasons behind this: the operation was seriously undercapitalised; there was insufficient mull to keep the presses in full work because the time necessary to prepare the bog before it could be harvested (two years) was not appreciated; and because of poor workmanship on the part of some of the contractors. After the failure of Derrylea, experimentation on briquette making continued unabated; by the beginning of the present century some *forty* peat-briquetting processes were registered in Germany.

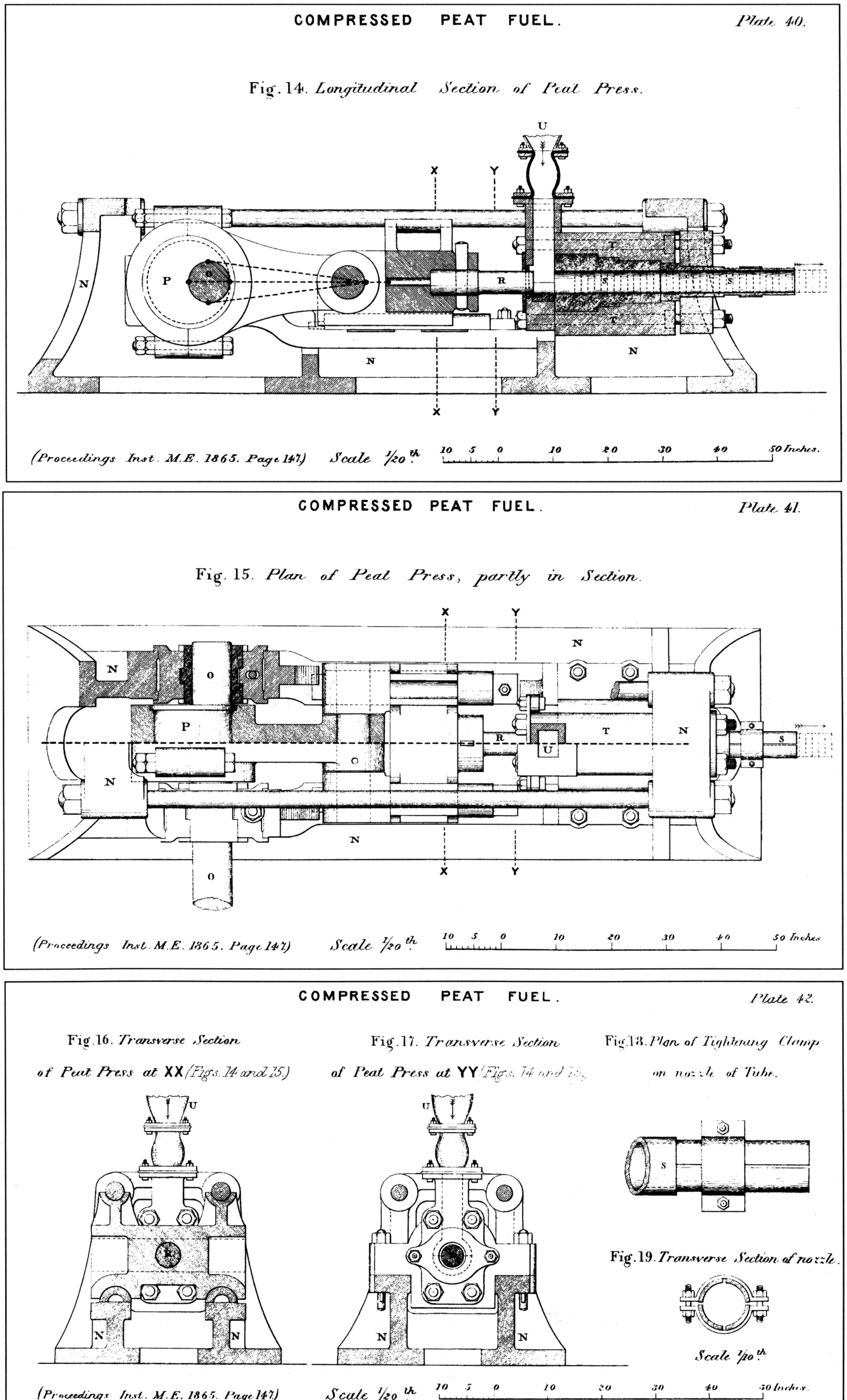
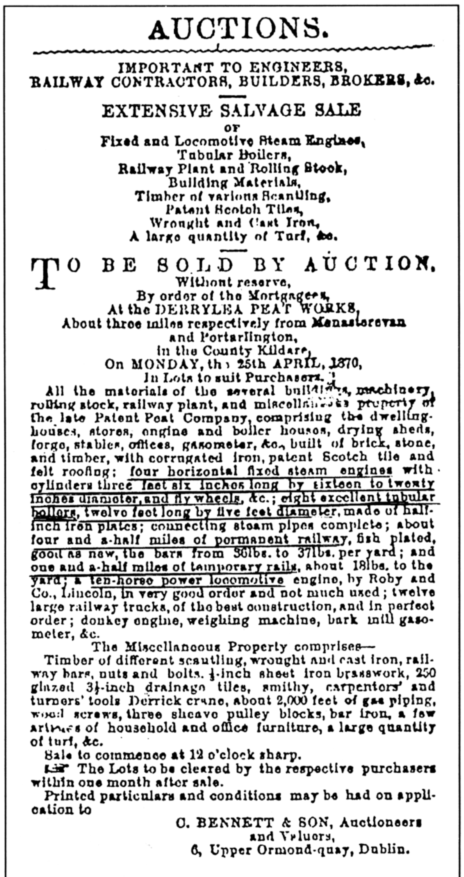


Figure 3.5: Hodgson's peat press (Hodgson, 1865).

One of the important advances at Derrylea was that the peat was harvested by zig-zag harrowing, and air dried to 55% water content on the bog before gathering it into rail piles. By comparison with today's harvesters, Hodgson's apparatus was a veritable bog dinosaur, moving on fixed rails. It was moved slowly along by locomotive at four miles an hour, its huge arms reaching ponderously out over the bog for a distance of 150′ on each side. Ten or twelve massive 6′ square zig-zag harrows scarified the bog surface to a depth of 1″-2″ The dried mould (or 'mull' as it was – and is still – known) was collected by wheelbarrow into rail piles, and here the peat remained until it was needed in the factory. The harvesting field occupied twelve acres or so, and this was expected to have a working life of around five years.

The two presses between them produced about a ton of briquettes every hour, and by 1868 the factory had made 5,000 tons, which sold to houses in Dublin at 11 /6d a ton. But in spite of Hodgson's precautions, and the solution of the earlier technical problems, there were still difficulties. The peat briquettes disintegrated in furnaces designed for burning coal, and were too expensive for domestic use. Another factor in the eventual failure of the enterprise may have been the wear on the machines; corrosion of the iron plates in the kiln dryer would probably have developed after a few years, causing failure or at least introducing a large new cost factor. The process had to be abandoned shortly after 1868. It is unlikely that it could have succeeded without protective legislation and financial assistance from the Government, both of which were in place by the time Lullymore Briquette Factory was set up in 1934.



AUCTIONS.

IMPORTANT TO ENGINEERS,
RAILWAY CONTRACTORS, BUILDERS, BROKERS, &c.

EXTENSIVE SALVAGE SALE
OF
Fixed and Locomotive Steam Engines,
Tubular Boilers,
Railway Plant and Rolling Stock,
Building Materials,
Timber of various Scantling,
Patent Scotch Tiles,
Wrought and Cast Iron,
A large quantity of Turf, &c.

TO BE SOLD BY AUCTION,
Without reserve,
By order of the Mortgagees,
At the DERRYLEA PEAT WORKS,
About three miles respectively from Monasterevan
and Portarlington,
in the County Kildare,
On MONDAY, the 25th APRIL, 1870,
In Lots to suit Purchasers.

All the materials of the several buildings, machinery, rolling stock, railway plant, and miscellaneous property of the late Patent Peat Company, comprising the dwelling-houses, stores, engine and boiler houses, drying sheds, forge, stables, offices, gasometer, &c., built of brick, stone, and timber, with corrugated iron, patent Scotch tile and felt roofing; four horizontal fixed steam engines with cylinders three feet six inches long by sixteen to twenty inches diameter, and fly wheels, &c.; eight excellent tubular boilers, twelve feet long by five feet diameter, made of half-inch iron plates; connecting steam pipes complete; about four and a-half miles of permanent railway, fish plated, good as new, the bars from 36lbs. to 37lbs. per yard; and one and a-half miles of temporary rails, about 18lbs. to the yard; a ten-horse power locomotive engine, by Roby and Co., Lincoln, in very good order and not much used; twelve large railway trucks, of the best construction, and in perfect order; donkey engine, weighing machine, bark mill gasometer, &c.

The Miscellaneous Property comprises—

Timber of different scantling, wrought and cast iron, railway bars, nuts and bolts. ¼-inch sheet iron brasswork, 250 glazed 3½-inch drainage tiles, smithy, carpenters' and turners' tools Derrick crane, about 2,000 feet of gas piping, wood screws, three sheave pulley blocks, bar iron, a few articles of household and office furniture, a large quantity of turf, &c.

Sale to commence at 12 o'clock sharp.

☞ The Lots to be cleared by the respective purchasers within one month after sale.

Printed particulars and conditions may be had on application to

C. BENNETT & SON, Auctioneers
and Valuers,
6, Upper Ormond-quay, Dublin.

Figure 3.6: *Daily Express* advertisement of auction of Derrylea machinery etc..

The collapse of Hodgson's enterprise in the late 1860s, when the price of his briquettes rose slightly above that of coal, had a disastrous impact on the local community and economy. Everything was auctioned off in 1870 [**Figure 3.6**], and today very little remains of this marvellous achievement [**Figure 3.7**]. A partial excavation under Tom Barry's direction in 1975 had all the atmosphere of a journey into prehistory. Many artifacts from the enterprise of a century earlier were uncovered; these are housed in the museum of Peat World at Lullymore.

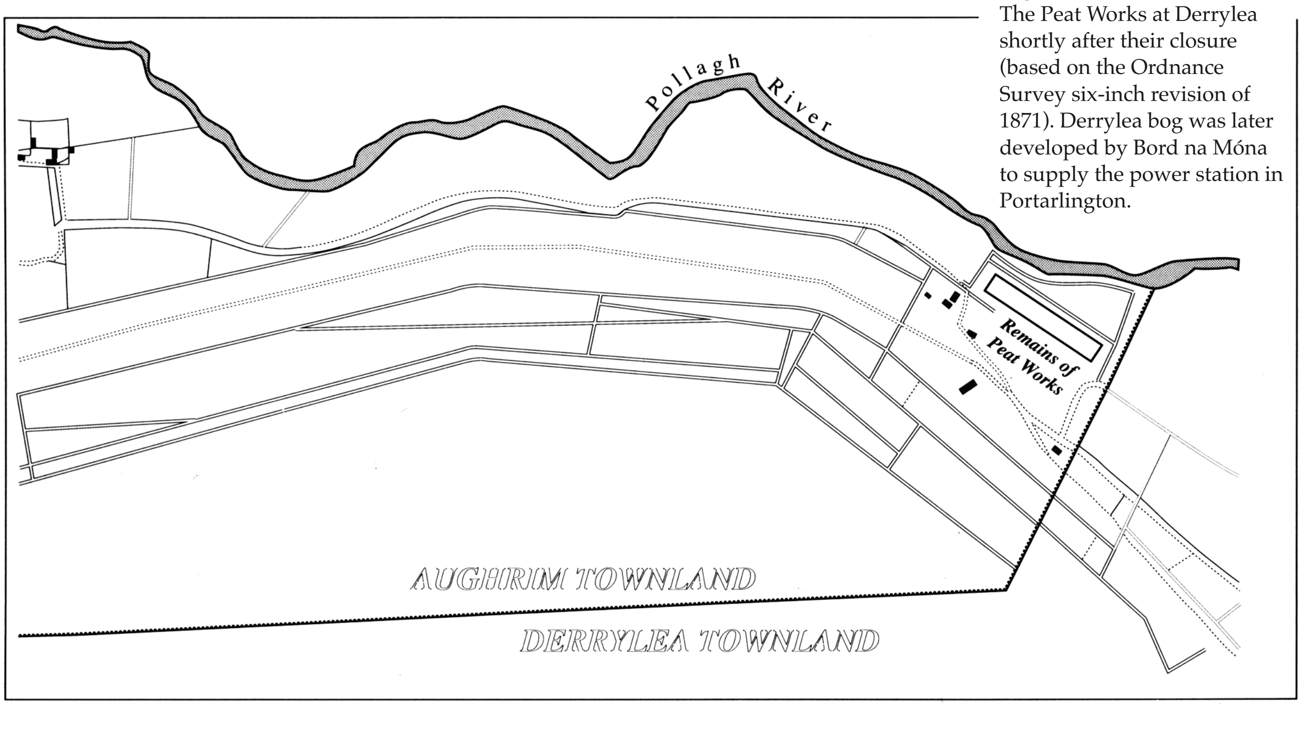


Figure 3.7: The Peat Works at Derrylea shortly after their closure (based on the Ordnance Survey six-inch revision of 1871). Derrylea bog was later developed by Bord na Móna to supply the power station in Portarlington.

The importance of Hodgson's work was well recognised at the time, as were the reasons for the failure of the enterprise. W. Anderson, in his 1867 Presidential Address to the Institution of Civil Engineers of Ireland, referred to Hodgson's 'beautiful and simple process', and went on to pay tribute to

> the ingenuity and perseverance of our Associate, who for more than ten years devoted the best part of his time, his fortune, and his talents, to the question [of the artificial drying and consolidation of peat], and whose name will one day be recorded among the benefactors of his country.

In the early 1870s Charles Hodgson and his brother Henry emigrated with their families to Russia and later to Bilbao in Spain. Charles had earlier taken out a patent for the construction of overhead wire railways for use in mining, and he hoped to exploit this by building demonstration lengths. Both ventures were commercial failures. He then went to Florida, where he tried to support himself and his family by growing oranges.

Figure 3.8:
The last house in Derrylea (John Cooke).

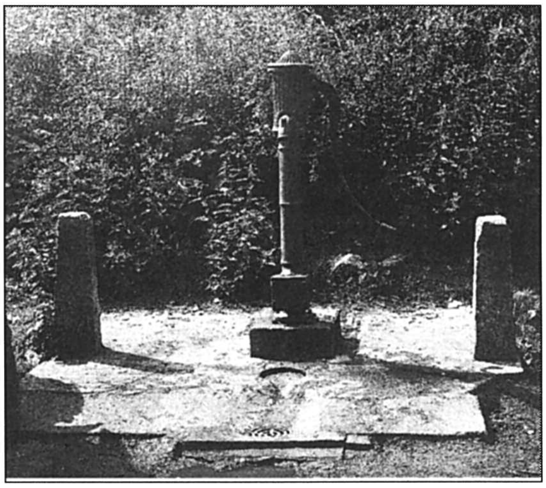
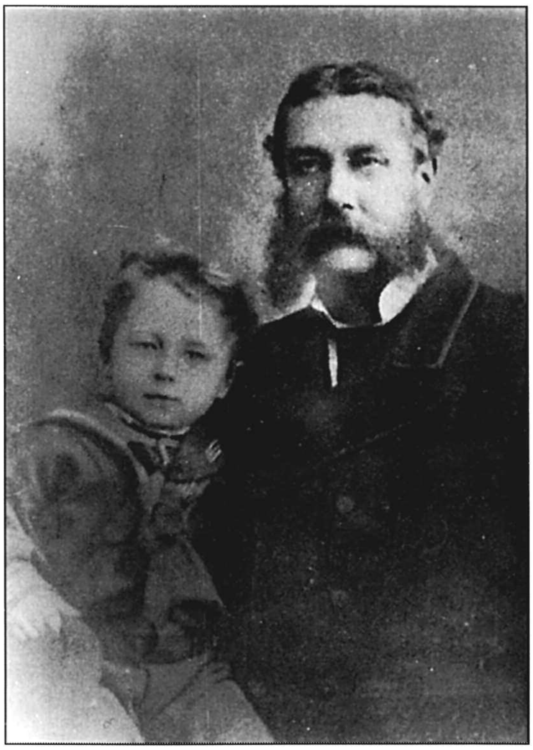


Figure 3.9:
Charles Hodgson and his son.

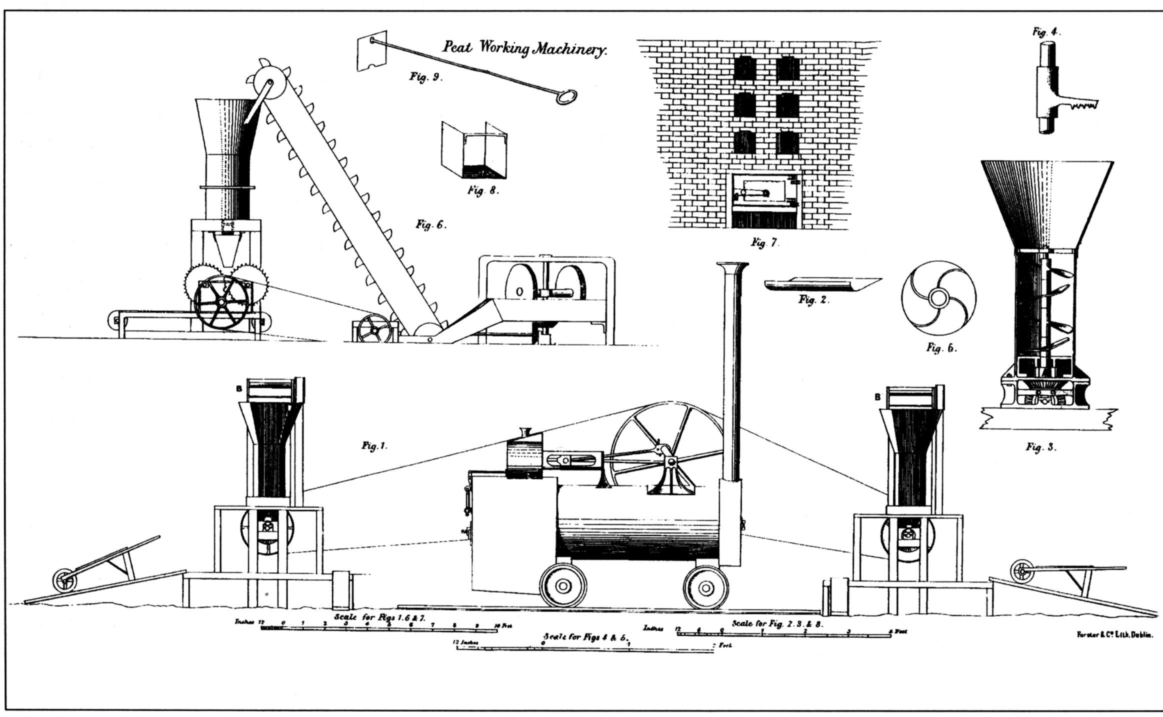


Here again he failed. His marriage broke up and he returned to England, where he died in lodgings in Folkestone in 1901 at the age of 68, his death either caused or accelerated by drink [**Figure 3.9**].

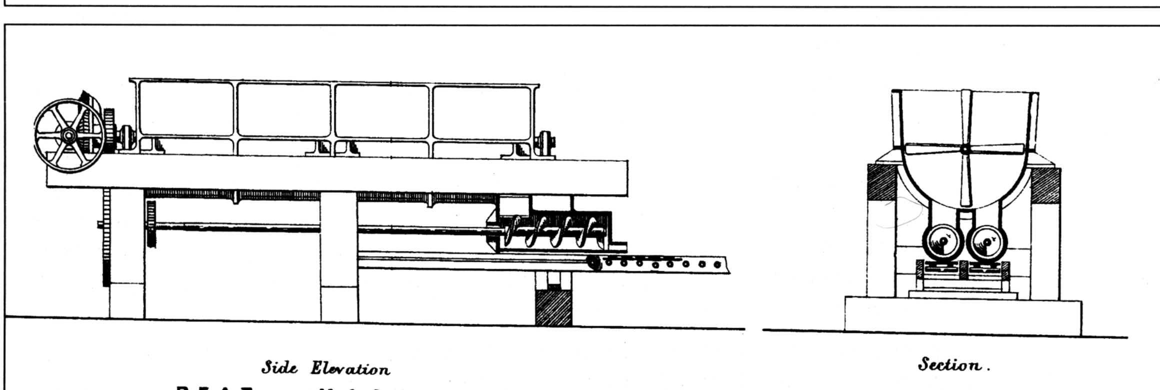
In 1851 Creevelea Iron Works were set up 6.5km north-east of Drumkeerin in County Leitrim by a Scottish company with the aim of smelting ironstone ore from the local coal-bearing Upper Carboniferous rocks, using local coal. There was abundant ore close to hand, but the coal had to be brought from further afield (some 13km), too far for the venture to be profitable. The company commenced work in 1853 and struggled on for a few years before running out of funds. Around 1860 the business was taken over by a new company, the Creevelea Iron Company, which planned to use charcoal made from 'condensed' peat, produced by a new method known as Buckland's 'Sieve Turf Process'. Buckland was a Welsh ironmaster who had recently patented a new machine which ground up raw peat, removing the fibres from it, and dried the paste into blocks of fuel for smelting iron ore. The wet peat was thrown into a hopper, under which there was a strainer enclosed in a heated chamber. This worked like a huge meat mincer, with an Archimedean screw running through it, perforated at the end, and capable of discharging about 8 tons of peat an hour. This mincer had a diameter of 2 feet, with 1/8″ perforations, about 12,000 in all, giving an aggregate aperture of a square foot. The fat cables of peat spaghetti were squeezed out in an endless band that was then fed into a brick machine, where they were shaped into blocks in the shape of 4″ tiles. The peat spaghetti produced by this machine dried very quickly (once the 'worms' were kept separated), because of the high temperature under which the mincer worked. The condensed peat tiles were stored in a drying shed through which a current of hot air passed, where they became 'as hard as oak'. Four or five tons of wet peat would produce one ton of condensed peat, which sold at 3/6d a ton. Left-over peat was used to raise the steam needed for the blast and forge engines for iron working.

The Company took on the very experienced George Murrall, who had spent most of his working life smelting iron in Staffordshire and South Wales, to manage the operation, and work re-commenced in 1862. The raw peat was brought down from the top of a mountain 3km away by means of an endless chain working in grooves, and covered with a web or net on which the peat was carried. This device was invented by Job Hurley, who was apparently also involved in some way in the design of the macerating machine. In Murrall's opinion the iron produced in Creevelea was 'of such a quality as I never made before and equal to any charcoal iron I ever saw ... equal to any Russian or Swedish iron'. However, the new process proved uneconomical for several reasons, including the cost of artificial drying, clogging of the machine and the loss of the coarse fibre, which separated out during mincing. (Normal peat would immediately choke 1/8″ holes with cotton grass fibres. They must have been eliminated by some means, a costly process). Nevertheless, it was an important milestone because it was the first time that maceration, one of the

Figure 3.10: Early macerators: (a) vertical macerator used at Birdhill in the early 1870s; (b) horizontal macerator of a type used by McDonnell around the same time.



(a)



(b)

fundamental processes in mechanised sod peat preparation, was used in a machine in Ireland.

Experimental work on the preparation of 'condensed peat' was also carried out at Ballymena in 1862 under the direction of Ormsby Moore and R. Allison Tennent. The Northern Counties Railway Company took a particular interest in these experiments. The object behind the process of condensation was to break the fibre in the peat so that moisture in the fibre could evaporate and the peat could more readily be 'condensed'. A contemporary account in *Saunders's News-Letter and Daily Advertiser* provides a succinct description of the procedure:

> To break the fibre, which is one of the leading features in the manufacture, the stuff taken from the bog is put into a receiver of a conical shape, perforated like a strainer, or the old household utensil known in Ireland as a 'cullender.' Within this an Archimedean screw turns, and as it moves round in worm-like form it cuts and tears the fibre. The peat so cut up passes through the holes of the strainer, and the refuse portion goes off by a source made to convey such away. The peat so strained is then put through an ordinary tile machine, and is formed into shapes similar to tiles. Being cut in suitable lengths, they are placed in rows on wooden frames, which latter are put standing in a heated apartment, where they are placed to dry. The necessary heat is produced by the waste steam from the engine; and as air is required also in the drying, a fan-like machine is kept at work to produce the necessary current. By this means heat by steam and a heated current of air – the peat is dried in from eighteen to twenty-four hours' time. The farmers, who lose weeks and months of labour in attending to their turf-saving in the open air, will no doubt be surprised to find fuel far superior to anything which they can ever produce, manufactured from the very same material in the course of twenty-four hours.

The strained peat and the charcoal produced from it were of the highest quality. Its ornamental possibilities were even considered, because of the high polish of which it was capable. Turf at this time was selling for 15/= a ton in Dublin. There were hopes that condensed peat could be produced at the bog for not more than 3/6 a ton, but the calculations on which this optimism was founded proved to be wrong.

In 1869 a new method of maceration was employed for a time at Birdhill by Malcolmson, who used a steam-driven pug mill (used for preparing clay in brick making) to make blocks from macerated peat. A pug mill consists of a vertical shaft with spiral blades, which revolves in a cylindrical housing. The raw material (peat or clay) moves down through this, being minced by the revolving blades as it does so. It is cut into lengths as it emerges through the exit hole in the bottom [**Figure 3.10**]. The plant also had facilities for artificial drying of the peat, and for charcoal manufacture. The product was intended for export, but failed with the outbreak of the Franco-Prussian War in 1874.

Another early venture in the production of machine turf was Banagher Peat Works in County Offaly. This was set on foot in 1873 on Clongawny bog, where Hogan and Thorburn – both engineers by profession – began to produce peat, partly for use in the new Banagher Distillery, and partly for sale to the general public. Clongawny bog belonged to Captain Cartaret Armstrong, one of the directors of the new company. *The King's County Chronicle* provided a colourful account of the arrival of the distillery steam engine and the new peat machinery at Birr Railway Station in August 1873, whence they proceeded by road to Banagher and Clongawny.

> It was, therefore, not at all wonderful if Banagher was in high glee on the occasion which suggested a great future for that ancient little town; and no one will say that too much was made of it in sending a deputation escort to the Parsonstown [Birr] railway station where, as soon as the steam was "got up" and the road train put in moving order, Mr Patrick Hynes, one of the principal merchants of the town, with a warm flourish, uncovered a quart bottle and appropriately christened the Banagher Distillery locomotive with a shower of the "Irish mountain dew".

The celebrations continued in Birr town, where Hogan and Thorburn treated their friends to 'some of Dooly's Hotel Champagne', and provided two or three large casks of beer for the crowd, which by this time was several thousand strong, 'the more forward of the crowd soon filling the waggons, and emptying the beer barrels'. Captain Armstrong and his wife met the procession outside Banagher, where the Captain concluded his speech of welcome by inviting the assembly to 'drink the health of the New Banagher Distillery Engine in Mr Williams' public house' whence, after 'full effect was given to the Captain's most generous hospitality' the road train got under way again. To bring the peat engine and other machinery on the final leg of its slow journey to Clongawny bog, the steam engine had to traverse a mile of soft ground 'where a common cart would sink in parts up to the axle':

> Here and there the wide wheels sunk into deep furrows throwing her in the attitude of the rearing horse, which forms what we may call "God Speed Banagher's" Figurehead, but the skill of the driver and the power of the engine eventutally overcame every difficulty, and when the hill was crowned where the peat machinery is to operate the Messrs Hogan and Thorburn gave a sumptuous *dejeuner* in their tent, while in – the open air the hundreds for whom there was no room within sat on the heather and enjoyed as pleasant a repast as was ever laid before man with appetites sharpened by bracing mountain air, At night the engine went into Banagher, and the whole town was out cheering and huzzaing, especially when it was seen how she moved with regular motion as though she were on a railroad.

After this high-profile and well-oiled start, the Banagher Peat Works fades into history.

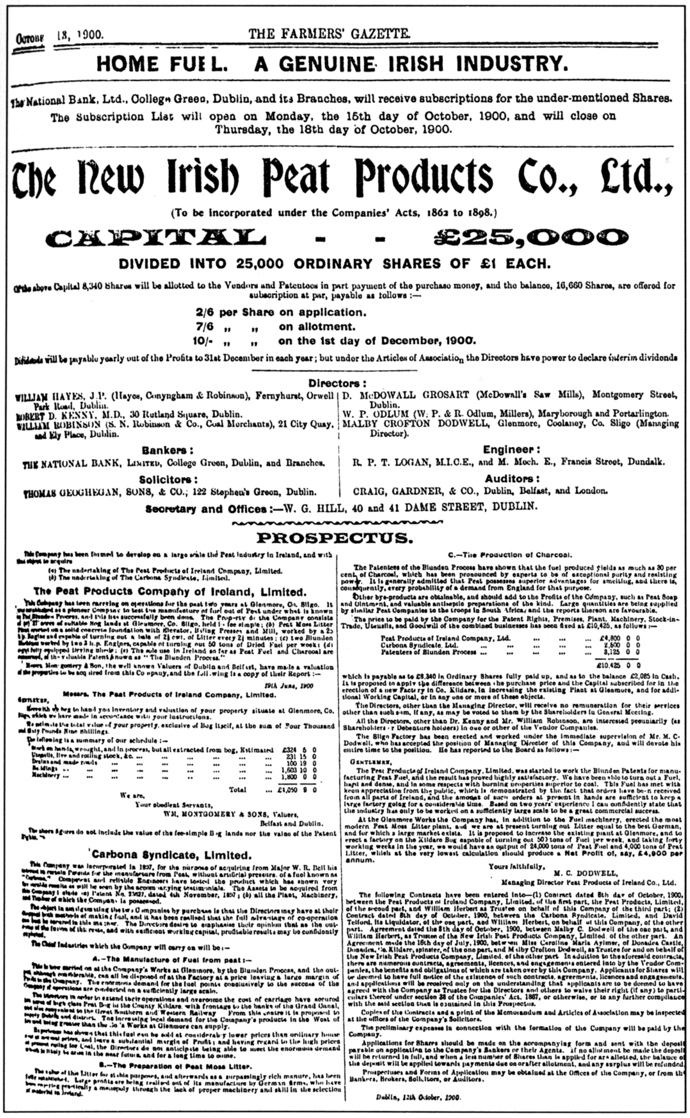
In spite of the failures of the 19th century, attempts to press the water out of peat by pressure continued into the 20th century. By now it was believed that peat was difficult to dry because of the colloidal substances it contained. Ekenberg hypothesised that this 'hydrocellulose' would break down to glucose if the peat was heated to 180º, and the water could then be pressed out. Alexanderson claimed that at low temperatures the colloidal substances would coagulate and the water could be pressed out on thawing. Whatever about the theory behind them, there was considerable reduction in moisture content when these processes were tried, but it was not enough to make either of them commercially useful.

There was much experimentation towards the end of the 19th Century on increasing the value of peat as fuel and for manufacturing purposes. It was realised from the beginning that manufactured peat would need to be dry, compact, of uniform density and have a calorific value that would compare with other fuels on the market. There was considerable interest at one time in the use of peat as a fuel in Siemens' Regenerative Gas Furnace. From about the year 1883 there was extensive experimentation on the mechanisation of the processes of peat harvesting, especially at the Bernau Experimental Bog Station in Germany, as well as in Sweden and elsewhere. But although there were some valiant attempts to introduce these innovations to Ireland, they had little success, partly no doubt because the owners of large bogs at that time were little inclined to expensive improvement of their precarious estates, and the price of the best British coal by railway was rock bottom. Machine-made peat from County Sligo, with a calorific value 2/3 that of coal, as against 1/3 to 1/2 in the case of hand-won turf, was still dearer than Welsh coal in Dublin – largely because of the transport costs involved. The experiments of these early engineers went a long way towards preparing the way for the mechanical harvesters of the twentieth century.

In 1872-3 coal strikes in Great Britain coincided with a complete failure in turf production in Ireland due to two very wet summers; the result was a doubling of the price of coal in Dublin. This led to a new campaign to arouse enthusiasm for bog development, spearheaded by Alderman Purdon, and chiefly promulgated in the pages of the *Irish Farmers Gazette* [**Figure 3.11**], which he owned. It was an important letter to this paper by J. McCarthy Meadows that first drew Irish attention to macerated peat. This letter was the stimulus for the setting up of a new Commission, established and paid for by Purdon. This Commission went on a fact-finding mission to Germany, Austria, France, England and the Netherlands, where they found that macerated peat was in use everywhere. They presented their Report at a public meeting in Dublin in 1873. Meadows also produced a pamphlet summarising his views, and recommending macerated sod peat production or briquetting as the options for Ireland. Another member of the Commission, McDonnell, set up small enterprises in Mountrath and Monasterevan to supply macerated sod peat to the Great Southern and Western Railway's fitting shops at Inchicore. Here he tested it for firing a Siemens regenerative gas furnace, a stationary steam engine and as fuel for passenger trains, but found it clearly uneconomic.

In the 1850s peat had proved to be a very economical fuel on the German (especially Bavarian) railways wherever they traversed areas of extensive bogland. The Great Southern and Western Railway also conducted experiments with the use of turf for trains (1874), and for the smelting of iron. At Coolaney 'condensed turf' was used in a small blast furnace about 23' high; but even though it gave a better, sulphur-free steel, the cheaper price of coal enabled the latter to oust peat as a fuel in steel manufacture.

Some time around 1880 David Sherlock set up Rahan Peat Works, which continued in fuel and moss peat production for some 50 years. Sherlock was the son of the King's County M.P. of the same name who in 1883 – probably inspired by' the Purdon Commission's report – had brought Professor A. Werner Cronquist over from Stockholm; the Swedish peat expert considered Irish bogs 'more suitable for fuel and moss peat production than Swedish bogs and easier to work because of their freedom from buried timber'. Sherlock junior was a barrister, and being of independent means he could afford to experiment to some extent: but being neither a scientist nor an engineer he was easily swayed by the claims of machine manufacturers, and in his time purchased and tested nearly every machine in use on the Continent up to that time [**Figure 3.12**].



October 18, 1900. THE FARMERS' GAZETTE.

HOME FUEL. A GENUINE IRISH INDUSTRY.

The National Bank, Ltd., College Green, Dublin, and its Branches, will receive subscriptions for the under-mentioned Shares.
The Subscription List will open on Monday, the 15th day of October, 1900, and will close on Thursday, the 18th day of October, 1900.

The New Irish Peat Products Co., Ltd.,

(To be incorporated under the Companies' Acts, 1862 to 1898.)

CAPITAL - - £25,000

DIVIDED INTO 25,000 ORDINARY SHARES OF £1 EACH.

Of the above Capital 8,340 Shares will be allotted to the Vendors and Patentees in part payment of the purchase money, and the balance, 16,660 Shares, are offered for subscription at par, payable as follows:—

2/6 per Share on application.
7/6 „ „ on allotment.
10/- „ „ on the 1st day of December, 1900.

Dividends will be payable yearly out of the Profits to 31st December in each year; but under the Articles of Association the Directors have power to declare *interim* dividends

Directors:

WILLIAM HAYES, J.P. (Hayes, Conyngham & Robinson), Fernyhurst, Orwell Park Road, Dublin.
ROBERT D. KENNY, M.D., 30 Rutland Square, Dublin.
WILLIAM ROBINSON (S. N. Robinson & Co., Coal Merchants), 21 City Quay, and Ely Place, Dublin.
D. McDOWALL GROSART (McDowall's Saw Mills), Montgomery Street, Dublin.
W. P. ODLUM (W. P. & R. Odlum, Millers), Maryborough and Portarlington.
MALBY CROFTON DODWELL, Glenmore, Coolaney, Co. Sligo (Managing Director).

Bankers:
THE NATIONAL BANK, LIMITED, College Green, Dublin, and Branches.

Engineer:
R. P. T. LOGAN, M.I.C.E., and M. Mech. E., Francis Street, Dundalk.

Solicitors:
THOMAS GEOGHEGAN, SONS, & CO., 122 Stephen's Green, Dublin.

Auditors:
CRAIG, GARDNER, & CO., Dublin, Belfast, and London.

Secretary and Offices:—W. G. HILL, 40 and 41 DAME STREET, DUBLIN.

PROSPECTUS.

This Company has been formed to develop on a large scale the Peat Industry in Ireland, and with this object to acquire
(a) The undertaking of The Peat Products of Ireland Company, Limited.
(b) The undertaking of The Carbona Syndicate, Limited.

The Peat Products Company of Ireland, Limited.

This Company has been carrying on operations for the past two years at Glenmore, Co. Sligo. It was established as a pioneer Company to test the manufacture of fuel out of Peat under what is known as The Blunden Process, and this has successfully been done. The Property of the Company consists of (a) 27 acres of suitable Bog lands at Glenmore, Co. Sligo, held in fee simple; (b) Peat Moss Litter Plant erected on a solid concrete foundation with Elevator, Baling Presses and Mill, worked by a 25 h.p. Engine and capable of turning out a bale of 2¼ cwt. of Litter every 2¼ minutes; (c) two Blunden Machines worked by two 3 h.p. Engines, capable of turning out 50 tons of Dried Fuel per week; (d) eight fully equipped Drying sheds; (e) The sole use in Ireland so far as Peat Fuel and Charcoal are concerned, of the valuable Patent known as "The Blunden Process."

Messrs. Montgomery & Son, the well known Valuers of Dublin and Belfast, have made a valuation of the properties to be acquired from this Company, and the following is a copy of their Report:—

19th June, 1900

Messrs. The Peat Products of Ireland Company, Limited.

GENTLEMEN,
Herewith we beg to hand you inventory and valuation of your property situate at Glenmore, Co. Sligo, which we have made in accordance with your instructions.
We estimate the total value of your property, exclusive of Bog itself, at the sum of Four Thousand and Sixty Pounds Nine Shillings.
The following is a summary of our schedule:—

Stock on hand, wrought, and in process, but all extracted from bog, Estimated	£324	5	0
Utensils, live and rolling stock, &c. ...	231	15	0
Drains and made roads ...	100	19	0
Buildings ...	1,603	10	0
Machinery ...	1,800	0	0
Total ...	£4,050	9	0

We are,
Your obedient Servants,
WM. MONTGOMERY & SONS, Valuers,
Belfast and Dublin.

The above figures do not include the value of the fee-simple Bog lands nor the value of the Patent Rights.

Carbona Syndicate, Limited.

This Company was incorporated in 1897, for the purpose of acquiring from Major W. R. Bell his interest in certain Patents for the manufacture from Peat, without artificial pressure, of a fuel known as "Carbona." Competent and reliable Engineers have tested the product which has shown very favourable results as will be seen by the accompanying testimonials. The Assets to be acquired from this Company include (a) Patent No. 23627, dated 4th November, 1897; (b) all the Plant, Machinery, and Timber of which the Company is possessed.

The object in amalgamating these two Companies by purchase is that the Directors may have at their disposal both methods of making fuel, and it has been realised that the full advantage of co-operation can best be secured in this manner. The Directors desire to emphasise their opinion that as the outcome of the fusion of these two, and with sufficient working capital, profitable results may be confidently expected.

The Chief Industries which the Company will carry on will be:—

A.—The Manufacture of Fuel from peat:—

This is now carried on at the Company's Works at Glenmore, by the Blunden Process, and the output, although considerable, can all be disposed of at the Factory at a price leaving a large margin of Profit to the Company. The enormous demand for the fuel points conclusively to the success of the Company if operations are conducted on a sufficiently large scale.

The Directors in order to extend their operations and overcome the cost of carriage have secured an area of high class Peat Bog in the County Kildare, with frontage to the banks of the Grand Canal, and also convenient to the Great Southern and Western Railway. From this centre it is proposed to supply Dublin and district. The increasing local demand for the Company's products in the West of Ireland being greater than the Co.'s Works at Glenmore can supply.

Experience has shown that this fuel can be sold at considerably lower prices than ordinary house coal at normal prices, and leave a substantial margin of Profit; and having regard to the high prices at present ruling for Coal, the Directors do not anticipate being able to meet the enormous demand which is likely to arise in the near future, and for a long time to come.

B.—The Preparation of Peat Moss Litter.

The value of this Litter for stable purposes, and afterwards as a surpassingly rich manure, has been fully established. Large profits are being realised out of its manufacture by German firms, who have been enjoying practically a monopoly through the lack of proper machinery and skill in the selection of material in Ireland.

C.—The Production of Charcoal.

The Patentees of the Blunden Process have shown that the fuel produced yields as much as 30 per cent. of Charcoal, which has been pronounced by experts to be of exceptional purity and resisting power. It is generally admitted that Peat possesses superior advantages for smelting, and there is, consequently, every probability of a demand from England for that purpose.

Other bye-products are obtainable, and should add to the Profits of the Company, such as Peat Soap and Ointment, and valuable antiseptic preparations of the kind. Large quantities are being supplied by similar Peat Companies to the troops in South Africa, and the reports thereon are favourable.

The price to be paid by the Company for the Patent Rights, Premises, Plant, Machinery, Stock-in-Trade, Utensils, and Goodwill of the combined businesses has been fixed at £10,425, as follows:—

Peat Products of Ireland Company, Ltd. ...	£4,800	0	0
Carbona Syndicate, Ltd. ...	2,500	0	0
Patentees of Blunden Process ...	3,125	0	0
	£10,425	0	0

which is payable as to £8,340 in Ordinary Shares fully paid up, and as to the balance £2,085 in Cash. It is proposed to apply the difference between the purchase price and the Capital subscribed for in the erection of a new Factory in Co. Kildare, in increasing the existing Plant at Glenmore, and for additional Working Capital, or in any one or more of these objects.

The Directors, other than the Managing Director, will receive no remuneration for their services other than such sum, if any, as may be voted to them by the Shareholders in General Meeting.

All the Directors, other than Dr. Kenny and Mr. William Robinson, are interested pecuniarily (as Shareholders or Debenture holders) in one or other of the Vendor Companies.

The Sligo Factory has been erected and worked under the immediate supervision of Mr. M. C. Dodwell, who has accepted the position of Managing Director of this Company, and will devote his entire time to the position. He has reported to the Board as follows:—

GENTLEMEN,
The Peat Products of Ireland Company, Limited, was started to work the Blunden Patents for manufacturing Peat Fuel, and the result has proved highly satisfactory. We have been able to turn out a Fuel, hard and dense, and in some respects with burning properties superior to coal. This Fuel has met with keen appreciation from the public, which is demonstrated by the fact that orders have been received from all parts of Ireland, and the amount of such orders at present in hands are sufficient to keep a large factory going for a considerable time. Based on two years' experience I can confidently state that the industry has only to be worked on a sufficiently large scale to be a great commercial success.

At the Glenmore Works the Company has, in addition to the Fuel machinery, erected the most modern Peat Moss Litter plant, and we are at present turning out Litter equal to the best German, and for which a large market exists. It is proposed to increase the existing plant at Glenmore, and to erect a factory on the Kildare Bog capable of turning out 500 tons of Fuel per week, and taking forty working weeks in the year, we would have an output of 24,000 tons of Peat Fuel and 4,000 tons of Peat Litter, which at the very lowest calculation should produce a **Net Profit of, say, £4,900 per annum.**

Yours faithfully,
M. C. DODWELL,
Managing Director Peat Products of Ireland Co., Ltd.

The following Contracts have been entered into—(1) Contract dated 8th day of October, 1900, between the Peat Products of Ireland Company, Limited, of the first part, the Peat Products, Limited, of the second part, and William Herbert as Trustee on behalf of this Company of the third part; (2) Contract dated 8th day of October, 1900, between the Carbona Syndicate, Limited, and David Telford, its Liquidator, of the one part, and William Herbert, on behalf of this Company, of the other part. Agreement dated the 8th day of October, 1900, between Malby C. Dodwell of the one part, and William Herbert, as Trustee of the New Irish Peat Products Company, Limited, of the other part. An Agreement made the 16th day of July, 1900, between Miss Caroline Maria Aylmer, of Donadea Castle, Donadea, Co. Kildare, spinster, of the one part, and Malby Crofton Dodwell, as Trustee for and on behalf of the New Irish Peat Products Company, Limited, of the other part. In addition to the aforesaid contracts, there are numerous contracts, agreements, licences, and engagements entered into by the Vendor Companies, the benefits and obligations of which are taken over by this Company. Applicants for Shares will be deemed to have full notice of the existence of such contracts, agreements, licences and engagements, and applications will be received only on the understanding that applicants are to be deemed to have agreed with the Company as Trustee for the Directors and others to waive their right (if any) to particulars thereof under section 38 of the Companies' Act, 1867, or otherwise, or to any further compliance with the said section than is contained in this Prospectus.

Copies of the Contracts and a print of the Memorandum and Articles of Association may be inspected at the offices of the Company's Solicitors.

The preliminary expenses in connection with the formation of the Company will be paid by the Company.

Applications for Shares should be made on the accompanying form and sent with the deposit payable on application to the Company's Bankers or their Agents. If no allotment be made the deposit will be returned in full, and when a less number of Shares than is applied for are allotted, the balance of the deposit will be applied towards payments due on or after allotment, and any surplus will be refunded.

Prospectuses and Forms of Application may be obtained at the Offices of the Company, or from the Bankers, Brokers, Solicitors, or Auditors.

Dublin, 12th October, 1900.

Figure 3.11: Prospectus for the New Irish Peat Products company in the *Irish Farmers Gazette*.

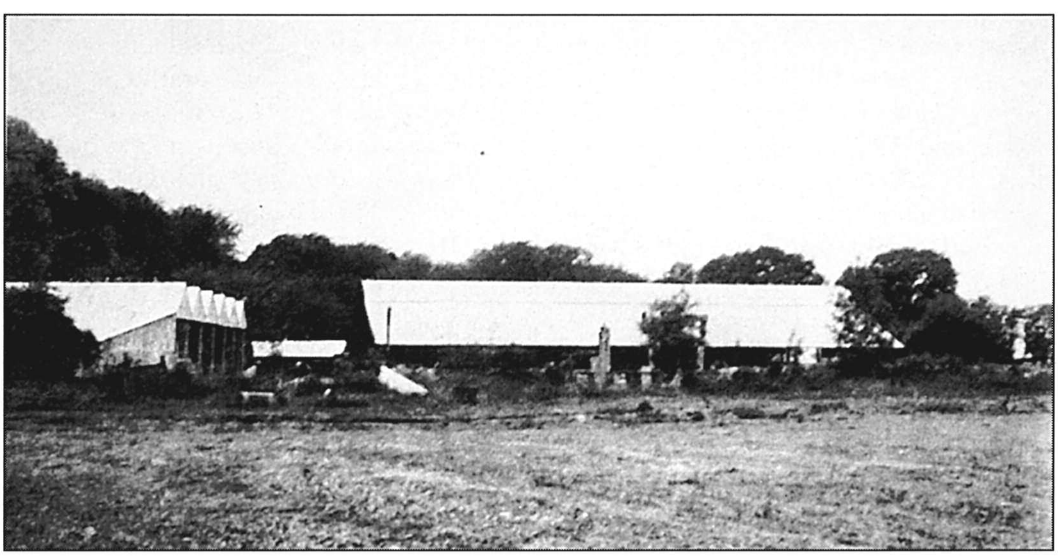


Figure 3.12: David Sherlock's peat works at Rahan.

About 1890 David Sherlock offered the use of his 1,000 acres of Rahan Bog to the Hibernian Utilisation of Peat Syndicate. Sherlock proposed to continue harvesting moss litter from the bog, leaving the underlying brown and black peat for the manufacture of machine turf by means of a Canadian patent the Syndicate proposed to use. Sherlock's bog was only half a mile from the Grand Canal, where he had all the equipment necessary for loading and unloading boats, and he was in the process of laying a narrow-gauge portable tramway between the bog and the canal. A horse would be able to haul ten wagons each holding a ton of turf on this tramway. When the Peat Enquiry Committee visited Sherlock's works in 1917 they found the discarded remains of 'almost every peat machine used to date'; at that time he was using Dolberg and Schlickeysen machines without sod spreaders; the sods were taken by hand from the machines and spread to dry either in the air or in open sheds.

About 1885 Blunden mechanised Alloway's process in his experimental works at Ballywaughter in County Antrim, and the method in use today is basically little different from this. In 1898 the Blunden process, which used a horizontal peat macerator, was introduced at Glenmore in County Sligo by the New Irish Peat Products Co. Ltd. However, the price of this peat in Dublin was twice that of Welsh coal at the time, and the enterprise soon faded.

Briquettes of a different sort were made for a time by the Electro-Peat Syndicate at Kilberry in County Kildare, after the failure of the earlier briquetting and carbonising ventures there in the 1850s. In 1906 the new factory went into production to manufacture 'electro-peat coal' on the site of the earlier peat endeavours. The basic principle was that electric current could be used to dehydrate the peat. The new Bessey Process, which was originally devised in Germany by Count von Schwerin, was based on the idea that the colloidal substances in peat had an electrical charge opposite to that of water. So, if an electric current is passed through the wet peat, the solid matter should move to one pole and the water to the opposite pole. Experiments showed that 13-15 KWH of electricity would expel a metric ton of water from raw peat; 1.5m^3 of peat @ 87% moisture would produce 1m^3 @ 70% moisture after a quarter hour of electro-osmosis; this could then be air-dried to give 169kg of peat at 15% moisture.

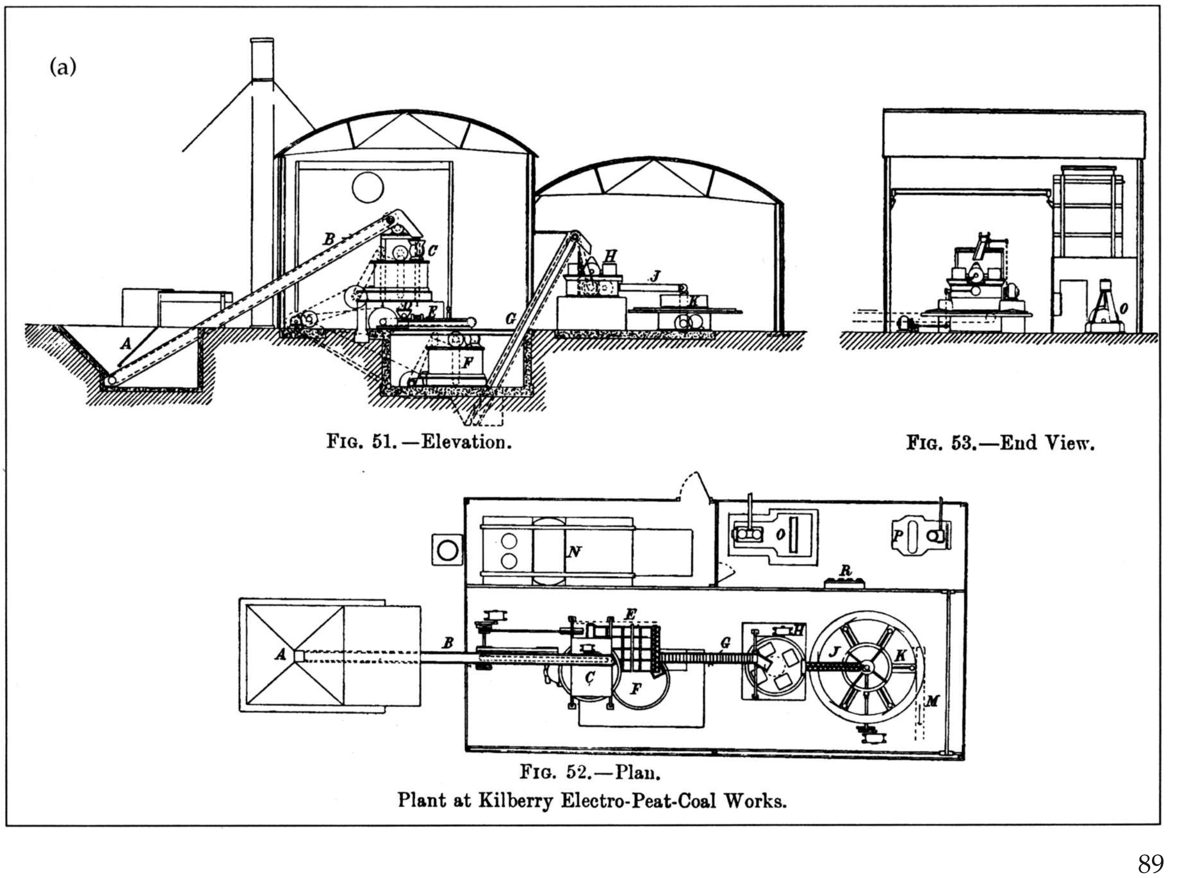
Peat was collected on the bog by a steam-powered excavator and carried on a wire-rope haulage railway to the factory, where it was first of all partially dehydrated in a 'hydro-eliminator'. It was then squeezed between two metal plates across which a strong alternating current was passed, the idea being that the electricity would get rid of 'latent water' in the peat by 'electro-osmosis': the electricity would liberate this 'latent water' by breaking up the cells in the fibres, and this liberated water could then be extracted easily. After passing through the 'electrifying machine' the peat went into another hydro--eliminator, after which it was crushed by heavy rollers and shaped into briquettes in a moulding machine. The output was 50 tons a day from some 300 tons of raw peat. The fuel produced was hard, dense, heavy and comparatively smokeless. It was claimed to have a density of 30 ft^3/ton as against 45ft^3/ton for ordinary coal – which is unlikely at 10% moisture. The steam for the machine was produced by burning waste peat from the bog surface. However, capital and running costs were too high and the process was abandoned. And whatever was responsible for the drying, it is unlikely to have been the electricity, since alternating rather than direct current was used. At a later date a Heinen form machine replaced the moulding machine, and by 1908 the operation had switched to manufacturing macerated machine peat by the Heinen process, which carried on until 1914 [**Figure 3.13**].

Even as late as 1944 some engineers were arguing that turf was simply not suitable for use as fuel because of its high moisture content – although just prior to the War the Russians were using 24 million tons of sod and milled peat per year with moisture contents of 30% and 40% in 3,000 MW of power stations, and Germany was using up to 200 million tons per year of 62% moisture content brown coal in 10,000 MW of power stations, and many combined/separate briquette factories. It was also argued that when peat was used in coal-burning ranges and boiler grates it lost much of its capacity in unburned gases: though this could be easily rectified. Some engineers felt that the only economical way to burn peat was to make charcoal and gas at the bog, recovering the valuable by-products, and using the gas to generate a supply of rural electricity or to fuel gas engines, to work briquette and charcoal machines and turf-tar distillation plants.

The peat moss industries

A range of small industries centred on the manufacture of products from peat moss or moss litter (which is largely made up of the moss *Sphagnum cuspidatum).* This was usually a concomitant of machine peat manufacture; the litter was made from the upper layers of the bog, while fuel was made from the more humified lower layers. The white moss peat had traditionally been used by farmers as winter bedding for horses and cattle. The best moss peat bogs were in Laois and Offaly, and round the southern shore of Lough Neagh. The moss peat was excavated in very large sods which were air dried on the bog for up to a year (until their moisture content was down to about 50%) then torn up into pieces by machines appropriately called 'wolves', of which various models were available, and which could produce up to 40 tons a day. The peat moss was then screened in mechanical sieves, and the divided and screened peat moss was made into bales. A hundred tons of air-dried moss would give an average of 63 tons of peat moss and 25 tons of peat mould. This mould had its uses as a packing material for fruit, and turf mills were available to make more of it if required. In some countries farmers made their own peat moss litter by ploughing and harrowing the bog. It was used for stalling animals, for which purpose it had several advantages over straw: it was three to four times more absorptive of both liquid and gas excreta for instance, which not only kept the stable drier and the air in it fresher, but resulted in manure of higher nitrogen content because the peat absorbed ammonia, it was far less bulky to store than straw manure, and there was virtually no smell.

Figure 3.13 (a): Electropeat: plan, elevation and end view of the machinery.



The peat moss industry as such expanded rapidly in Europe during the last quarter of the 19th century. In Ireland the production of moss peat for horse stable litter began around 1850, the main customer being the cavalry of the British Army. It was another century before the market for horticultural moss peat was exploited. There were peat moss litter factories, producing a range of products, at Umeras near Monasterevan (employing 70 people around the turn of the century), at Coolaney in Sligo, at Maghery in Tyrone and part of Armagh, at Inchicore and Ringsend in Dublin, at Portglenone in Derry, Edenderry, Turraun, Ferbane and Rahan in Offaly. The Umeras factory started around 1890, at first making bales of peat litter. Moss peat was cut by hand, then shredded by machine and baled in steam-powered presses. The factory at Umeras operated for around 50 years, changing hands several times and producing a variety of products, before it was accidentally destroyed by fire around 1940. Total production in 1921 was around 50,000 tons a year.

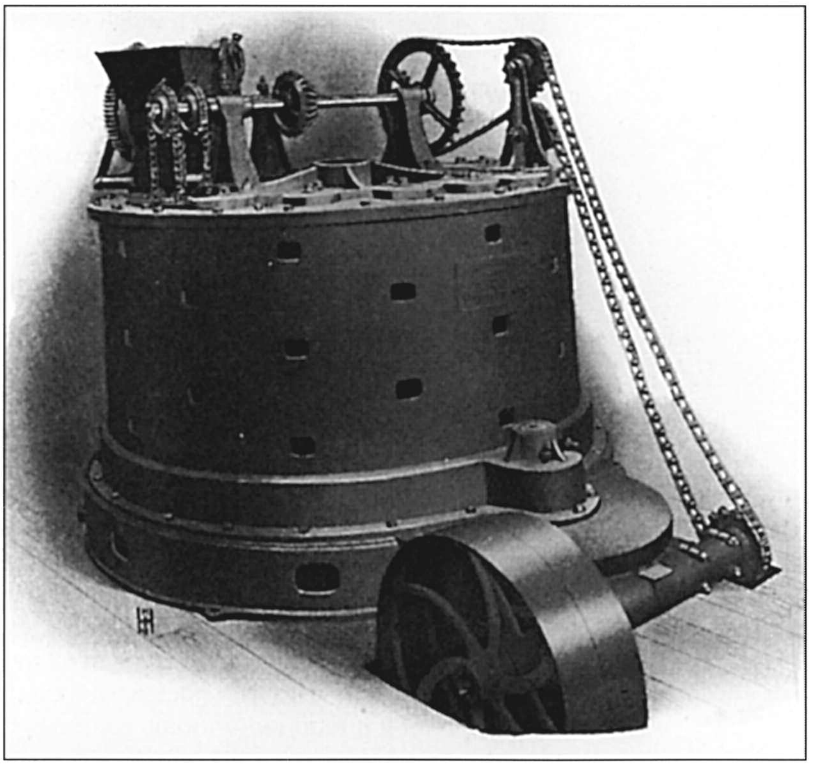
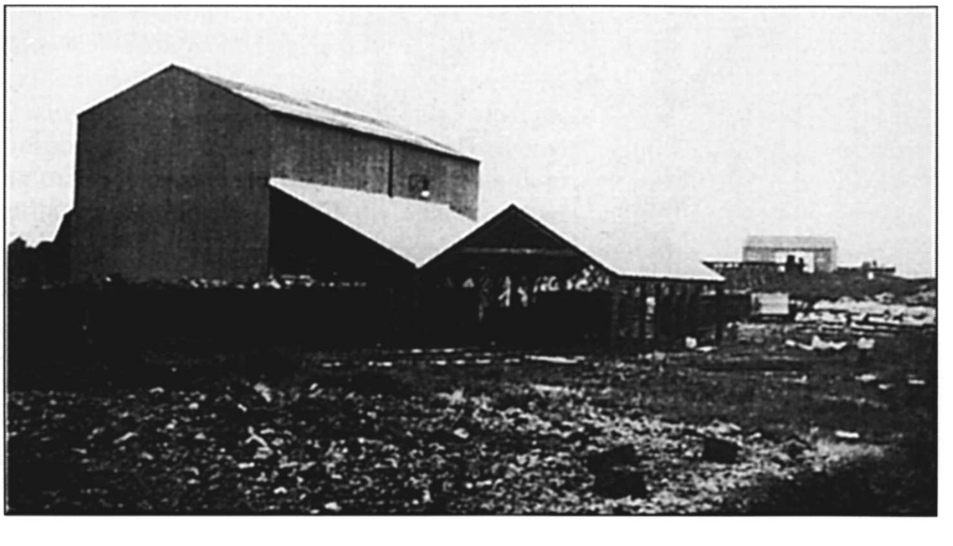


Figure 3.13 (b): Photograph of the rotary hydro eliminator.

The factory at Turraun bog near Rahan was built around 1890 by Kieran Farrelly, a local man who took advantage of the transport opportunity presented by the Grand Canal, which ran through the bog [Figure 3.15]. Farrelly began to develop Turraun for the production of moss peat and fuel peat in the 1850s; he also sold the brick clay below the bog, as well as 'mather' (yellow ochre) to the Dublin Gas Company (See page 100). He reclaimed the cutaway and sowed it with oilseed rape. As business grew, Farrelly built his peat moss factory for producing and baling the peat moss. The prospect of greatly increased sales during the expected war with the Boers in South Africa encouraged him to expand and develop further, and this was to prove his undoing. A flash flood following a breach of the canal after a torrential rainstorm in the winter of 1903 ruined his stocks and damaged his machinery. Farrelly failed in his claim for compensation against the Grand Canal Company on a technicality; he lost all he owned to his creditors, and emigrated to the United States after being evicted from his home at Turraun in 1905.

Figure 3.14: The Irish Peat Industry Ltd. peat works at Edenderry.



One of those who had advanced capital to update the operation at Turraun was Colonel Dopping, a retired army officer. On the failure of Farrelly's claim, he foreclosed and tried to run Turraun himself. He installed an 8hp oil engine and extensive shedding, and later a 40hp suction gas engine that he set up in the bog mounted on 28-foot long concrete reinforced piles. In 1908 he bought from the Agricultural Board

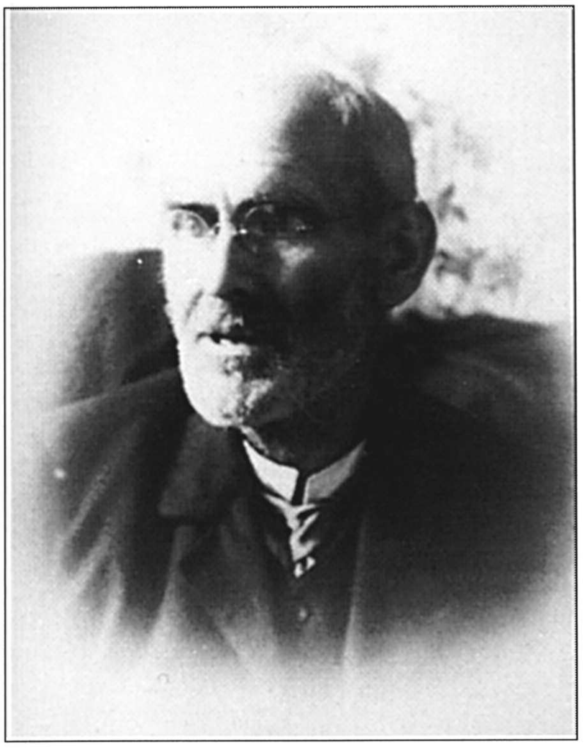


Figure 3.15:
Kieran Farrelly.

'a vast quantity' of German machinery which had been in use at Castleconnel. This he found to be 'a scandalous waste of public money', and he eventually replaced them with home-made machines for making 'good, ordinary black turf for fuel'. He induced the Canal Company to transport this to market by motor boat, finding the canal's horse traffic too slow.

Dopping seems to have served in India. He lived in a houseboat on the River Brosna and had an Indian servant, a source of great astonishment to all who lived in the vicinity. The statistics in **Table 3.1** show very clearly the growing importance of peat litter manufacture in Ireland in the early part of the century, much of it for use as stable litter in cavalry and artillery barracks. Dopping was not the only retired officer who tried to corner the market by investing in it.

Peat litter was also being made by a small company called The Irish Peat Industry at Golden Bridge in Inchicore in Dublin the early years of the century, using peat moss brought by barge from County Kildare. The Inchicore factory was destroyed by fire in 1905, and Norman Palmer, the enterprising Limerick man who owned it, then set up another peat litter factory at the Downshire Bridge beside Drumcooley Bog near Edenderry on the Grand Canal in County Kildare. This was taken over by the Umeras Company in 1920, and after that most of the moss peat used by the company was harvested at Drumcooley rather than Umeras. The factory continued in

Table 3.1
Peat litter exports and imports.

	IMPORTS (direct from Holland)			EXPORTS		
	Tons	Value £	3/Ton	Tons	Value £	£/Ton
1904	3,965	5,948	1.50	243	365	1.50
5	3,395	4,245	1.25	541	677	1.25
6	2,356	3,534	1.50	2,763	4,145	1.50
7	2,348	3,017	1.29	6,256	9,384	1.50
8	3,339	4,257	1.28	7,124	10,686	1.50
9	2,560	3,285	1.28	5,079	7,619	1.50
1910	2,829	3,631	1.28	2,698	4,047	1.50
11	2,712	3,480	1.28	2,547	3,272	1.28
12	2,438	3,129	1.28	3,680	4,723	1.28
13	2,562	3,288	1.28	2,117	2,717	1.25
14	1,590	2,147	1.35	4,721	6,373	1.35
15	39	54	1.38	3,758	5,167	1.36
16	29	40	1.38	6,101	8,389	1.38
17	3	6	2.00	5,040	10,080	2.00
18	16	40	2.50	4,160	10,400	2.50
1919	6	14	2.33	4,284	9,639	2.25

From Reports on the Trade and Imports at Irish Ports - published by the Department of Agriculture and Technical Instruction for Ireland (HMSO). (Compiled by John Cooke).

production until 1945, making peat litter for poultry and livestock, fine peat dust which was used as an adulterant to mix with molasses for livestock feed, and a small amount of horticultural moss peat for export.

Another noteworthy early venture was the Munster Peat Works at Clooncommons bog near Castleconnel in County Limerick, where Anthony Mackey set up a peat moss factory in the early part of the century, employing 50 people. Among the main customers for the moss litter were the British Army Cavalry Stables at Cork, Newbridge and the Curragh. The factory used German machinery and expertise; when the Germans returned to their homeland as war approached, local expertise proved insufficient to keep the works in operation. Another company, the United Kingdom Moss Litter Works, worked bogs at Maghery in County Armagh and Portglenone in County Derry around the same time.

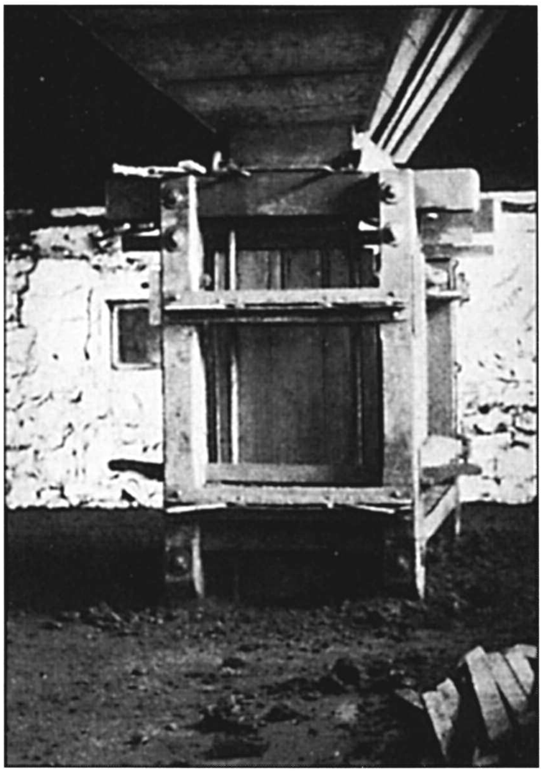


Figure 3.16: Moss peat baling press at Umeras.

Paper was made from peat in Ireland as far back as 1835. A factory for making brown wrapping paper and card from moss peat fibre mixed with waste paper pulp was opened by the Callendar Paper Company at Celbridge in County Kildare in 1903 [**Figure 3.17**]. By 1905 it was producing ten tons a week which, it was claimed, was more than all the other Irish paper mills of the time were producing between them, but it was in debt and its output still uneconomical: it could not compete with wood and straw based papers. (Other peat paper mills on the continent suffered the same fate at around the same time). In the early years of this century Hamilton Robb set up the Irish Peat Development Co. Ltd to produce moss peat litter, peat fuel and peat dust from bogs in Armagh and Tyrone. Much of the peat dust was exported to the Canary Islands, where it was used to pack early potatoes and tomatoes; more was used for mixing with molasses to make cattle feed. Some years later he started using peat as fuel in gas producing engines to power a linen weaving factory which operated profitably for many years. Peat was also used as steam boiler fuel for finishing yarn and for general heating purposes. Robb told the 1921 Commission of Inquiry that in his opinion 'all power required in Ireland could be better supplied from peat than from coal. The only thing wanted is sufficient enterprise to get it done'.

The peat dust or peat mull left over after the manufacture of peat fibre was mixed with coal dust or sawdust and used to make briquettes and firelighters, and was also used as a packing material, and for spreading on the floors of dry closets etc. The possibility of using turf mull as a germicide was even investigated. In Germany it was also mixed with the molasses produced during beet sugar manufacture, and used to make a cattle food called peat molasses powder. The peat was believed to act as a constipating agent, and ensured that the animal's stomach would have time to extract the maximum nutrient value from the molasses. In the 1880s considerable attention was paid in Germany to the possibility of using peat mull as an alternative to water in 'peat closets' for the hygienic disposal of human faeces. It was supposed that the composted mixture could be used as an organic fertiliser; the idea never caught on.

A pliable material which found all sorts of practical applications was made by mixing mechanically-prepared turf litter with other materials such as tar, wood refuse, heather etc. Mixed with plaster of Paris it was used in the preparation of a wood substitute, and for making insulating material, pasteboard, felt and wadding. An English entrepreneur, James Russell, was apparently making drainage tiles from peat at Dunlewy in Donegal in the 1840s, at a cost of 4/ = per 1,000. But at this very time petroleum was also being intensively investigated. Had petroleum not become so cheaply and readily available, the use of materials derived from peat might have become much more widespread.

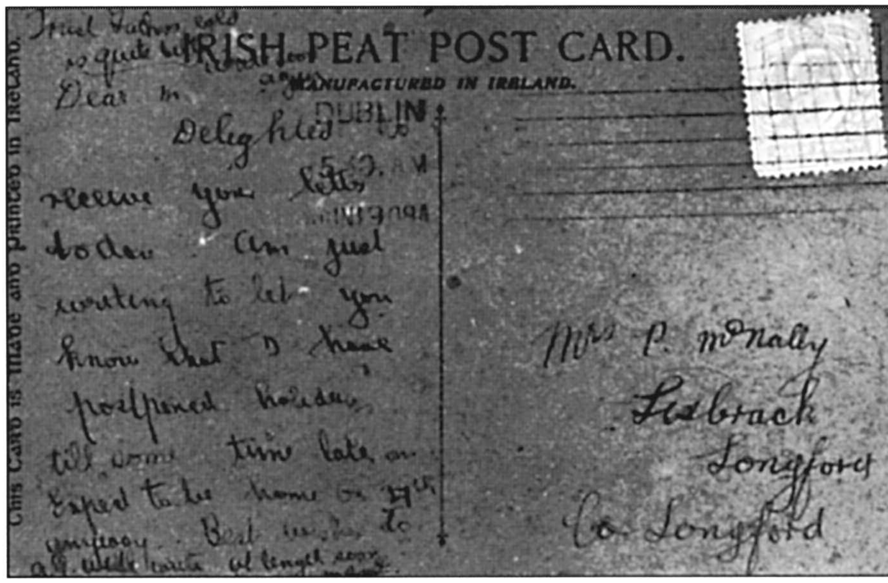


Figure 3.17: Postcards printed on Irish peat card enjoyed a brief vogue at the beginning of the century. As this example shows, they were particularly aimed at emigrants, and were especially popular at Christmas.

Firelighters were made at Umeras from hand-harvested turf from Ticknevin between around 1920 and 1940. The peat was cut into 2″ cubes by steam-powered saws, and then steeped in an inflammable liquid. When they were sufficiently dry, they were packed in greaseproof paper and sold as Dillon's Patent Firelighters. Much earlier, in 1905, peat firelighters were being made at the Irish Peat Industry's factory in Inchicore. A type of hardboard was made at Umeras from the fibrous matter in moss peat, beginning in 1930, but production ceased after about two years. The peat fibre was mixed with waste paper pulp, and the board was used as half-inch thick insulation for railway carriages. Among other ill-starred adventures in the uses of peat were Major Bell's brief attempt at the beginning of the century to manufacture a macerated and air-dried black turf which he called 'Carbona' at Monasterevan.

Peat moss had several other commercial applications that never took root in Ireland; these included the manufacture of wool from moss peat and bog cotton peat. Other early experiments included the manufacture of textiles, pavements and building blocks from compressed turf and slaked lime, peat-and-tar roofing materials, the making of dyes and tannins; and the making of alcohol, ammonia, fertiliser and candles. In 19th century Germany the best candles used in Catholic churches were made from peat paraffin. Brazil had a factory that made peat candles at the beginning of the century; with an output of twenty tons of peat paraffin a week.

Charcoal from peat

Because of its high reaction potential (due to a very great pore surface area), very low ash content and the virtual absence of sulphur, peat charcoal is especially suited for metallurgical purposes, in the production of carbon disulphide and activated carbon, in the making of lighter flints and in the livestock feed industry. Unfortunately, the higher the reaction potential the less its structural strength. Activated carbon produced from peat has an even more exceptional porosity – its surface area is over 1,000 m^2/g, and it is very light: a volume of 250-4001 only has a mass of 100 kg. It is used in the chemical, pharmaceutical and food processing industries, and for clarifying water.

Engineers and scientists have been investigating methods for the preparation of peat charcoal for several centuries, among them Charles de Lamberville in France in the early part of the 17th century, and Charles Patin, whose *Treatise on Turf* appeared in 1663. Several 18th century German, Dutch and French writers describe kilns used for charring turf. A variety of methods for the preparation of peat charcoal were developed and patented abroad, especially in the Vosges region of France, and in the German states of Bavaria, Bohemia and Saxony. The charcoal produced had an excellent reputation, and was much used in the metallurgical industry in these areas. The kilns perfected by C.W. Williams in the 19th century (Chapter 1) were almost identical to those which Dietrich described at work in the Hartz in 1781. The process of carbonisation in closed vessels was introduced by Thorin in France at the end of the 18th century, and further perfected by Platel shortly after that date; Platel used the inflammable gases given off in the process to heat the carbonising retort.

Turf charcoal enjoyed a brief vogue in Revolutionary France, largely because of the belief of Le Sage that it was superior to wood charcoal. However, experimental work in other countries during the 18th and 19th centuries suggested that it was inferior (probably because of its relatively high ash content), although its performance improved when mixed with wood or wood charcoal. Platel recommended a mixture of 3 parts of char-turf to 1 part of briskly burning wood for firing bricks or pottery. Among the disadvantages of turf charcoal were its great friability, the difficulty of getting it to burn evenly through the entire mass, and the ease with which it blew away when a blast was used. These difficulties were overcome by using briquettes, the charcoal from which is much superior to wood charcoal. In the manufacture of activated carbon today, sod peat and moss peat are used.

In the 1750s Robert Rainey claimed to have discovered a method of making completely malleable iron from pig iron using only 'peat coal' (charcoal). Rainey had erected large ironworks near Lough Neagh in 1746, comprising 'not only a Forge for the making of Bar Iron, but also a Foundery for the casting of Pots, Pumps for Collieries, and Furnaces for Soap-boilers and Bleachers, with other Ware usually made at Founderies, which he casts directly from the Ore'. In 1751 he petitioned the House of Commons for support, and was awarded a grant of £300 to further his project:

> Wherefore, as this Manner of making Iron is peculiarly suited to this Country on Account of the great Quantities of Turf Bog with which we abound; as it will, by the Increase of our Iron Works, soon render us independent on the Uncertainty of foreign Markets for that necessary Commodity; and, by reducing the Price of Iron, have a sensible Effect upon Agriculture and all Arts and Manufactures, wherein Iron Utensils are considerable; as it must, by so great a Consumption of Turf, in Process of Time reclaim great Tracts of our richest Land, now useless both to the Proprieters and the Public; and as it cannot fail to produce so large a Saving to the nation as the yearly sum of £66,460 in the single Article of unmanufactured Iron, besides the Saving which in Time may reasonably be expected in the Article of Iron Utensils, with other great national Benefits, in the Employment of a Multitude of Hands and consequently a large Increase of People.

In 1838, C. W. Williams patented a process for making peat charcoal, and started to manufacture it on a commercial scale at Cappagh, near Kilcock. The peat was compressed in a perforated cone before being transferred for charring to a cylindrical stove. Once the peat was alight the fires were extinguished and the stoves closed except for small air holes which allowed slow combustion until carbonisation was completed. Williams claimed that his charcoal was superior to wood charcoal for the manufacture of gunpowder and the smelting of iron ore.

Turf charcoal was used in the smelting of iron for a short time at Creevelea in Leitrim's coal-mining district; this has been described in some detail earlier [See page 83]. It took 2.5 to 3 tons of 'condensed' peat to produce one ton of charcoal at Creevelea. The charcoal sold at 12/ = a ton, but the cost of producing it was nearly covered by the one cwt of peat petroleum and tar produced as a by-product of the manufacturing process (See below).

One of the earliest experiments on the manufacture of charcoal from peat on a large scale was by Col. Kitchener (the father of the famous general), who arrived with others in County Kerry around 1850 and started a charcoal manufactory at Ballycarbery, influenced perhaps by Williams' claims for the superiority of peat charcoal in the manufacture of gunpowder. They had hardly started before their engineer made a discovery that persuaded them to change course: he found a way to compress peat into briquettes as hard as coal. The important observation he made was that it wasn't enough just to compress heated turf mould: when the pressure was taken off, the briquette just broke up. But if at a critical temperature the block was subjected to a sudden concussion blow, the briquette developed a texture more compact and just as hard as coal. The blow probably doubled the compression pressure to give a density of 1.2 gm/ cc or more; retention of the pressure for at least a minute in the press is also essential (except where very fine, very black peat is used). Perhaps Kitchener was seeking a source of harder charcoal for use at the Ballincollig Gunpowder Mills near Cork: charcoal from peat briquettes is heavier and denser than wood charcoal. These mills had an output of nearly 100 barrels of gunpowder per day at this time (30,000 barrels/year), 35% of the total European demand.

The experiment failed, apparently because the money that should have been spent on developing the necessary machinery was spent instead on expensive offices and officials in London – on top of which there was a disastrous fire at the works. A somewhat similar venture was started up about 20 years later at Lacavrea in County Galway; the main difference this time was that the bog surface was first harrowed and the peat mull air-dried before being put into the kiln. What put an end to this venture was a series of very wet summers during the 1870s, when there was mud on the bog instead of harrowed peat mull – the summers of 1872 and 1873 were the worst in 150 years:

1871 Average dry summer

1872 Disastrous wet summer: no peat harvest

1873 Disastrous wet summer: no peat harvest

1874 Average dry summer

1875 Average dry summer

1876 Better than average summer

1877 Very poor summer

1878 Poor summer

1879 Very poor summer

1880 Poor summer

We have already seen that iron made with turf charcoal had a great reputation, and not only in Ireland. One reason is that it is almost completely free from iron and phosphorus; this makes it comparable to the best wood charcoal. In earlier times iron had been manufactured extensively in countless forges all over the country, but by the late sixteenth century the native Irish tradition in iron manufacture was smothered, together with the entire rural economy in which it functioned. A new industrial tradition took its place, differing in its being commercial rather than community-based, and also because it exploited the remaining forests as a source of wood charcoal. The decline of the forests, and the development of cheap coal for smelting in England brought an end to the Irish industry – although even Gerald Boate had advised the new iron masters to think of adopting turf charcoal since the woods would not last forever.

Until 1850, by which time the newly-constructed railways could deliver coal cheaply to almost any part of Ireland, the charcoal used by blacksmiths in rural areas was usually made from turf, especially in the north of the country. Particular bogs were favoured for this purpose, and forges for the making of spades, scythes, billhooks and other tools grew up near these bogs; the only trace now remaining of these centres of industry is their memory in place names like Ballygowan (*gabha* = blacksmith); more than 30 townland names mean 'the town of the blacksmiths', and *gabha* features in numerous other placenames as well. Spade-makers have left their mark in names such as Ilaun-na-rawan in Kilcrohan Parish in County Kerry, and Inishloy south-west of Castlebar in County Mayo.

Carriage axles made from iron produced with turf charcoal had the reputation of great durability, and farm tools made with it were much harder and longer lasting than the cheap imports that replaced them. In the days when boats went out from the Claddagh in search of the great ground shark, which was hunted for its oil, the only harpoons which never broke when the harpooned shark ran to ground, rolling on the bottom in its attempts to break the spears, were made by a man who had a small forge in which he used only peat for smelting the iron. When peat charcoal went out of use, the whetstone industry followed it; the stones used to sharpen Irish tools came from special quarries in several parts of the country, but these Irish whetstones would 'rub the life' out of the softer imported tools, so softer whetstones also had to be imported. Why turf charcoal should be superior in this way is not clear; perhaps it had to do with the absence of sulphur, and tempering with slow cooling in the ash to produce the ideal temperature? The charcoal was produced in an apparently rather makeshift way, though no doubt experience had everything to do with success. A trench was dug at the edge of the bog and filled with white or brown turf; when this had got really hot and the turf was glowing, a load of black stone turf was heaped on top and quickly covered up with wet scraws and peat mud taken from the trench.

Jasper Rogers and the Irish Amelioration Society

In 1850 the manufacture of charcoal on a much larger scale commenced at Derrymullen, between Robertstown and Lullymore, north of the Grand Canal. This was undertaken by the Irish Amelioration Society, which had been founded to provide employment to 'the miserable and half-starved spectres who inhabited this dreary waste', while at the same time reclaiming that waste for agriculture. It should be remembered that the effects of the Great Famine were still being felt in this area at the time. The initiative and driving force for this extraordinary venture came from the no less extraordinary Jasper W. Rogers, who threw himself heart and soul into it; he even named his home at Robertstown 'Peat House'. The area of Rogers' 'dreary waste' had already been greatly reduced by turf cutting in previous decades to supply the Dublin market by barge and by horse and cart. This trade continued right down to the 1950s, when quarter-ton loads of beautifully shaped turf were still going by horse and cart each day to Smithfield market. At 5 a.m. in the morning the drivers breakfasted at Manzors' Pub in Clane on bread, raw onions, cheese and Guinness. On the return journey the driver would go to sleep in the cart at Lucan, and the horse would travel the well-remembered road without guidance.

Rogers had a clear, enthusiastic vision of transforming Ireland by systematic exploitation of the country's three million acres of bog. He saw that one of the main reasons why bog exploitation was economically unprofitable was because of the unsystematic and inefficient way in which it was saved. He planned to set up 200 'Receiving Stations' in different parts of the country, to which the peasants could bring turf, for which they would be paid. The turf would be converted to charcoal on the spot. Rogers had a passionate enthusiasm for turf charcoal based on his eight years as an engineer making locomotive carriages for road transport. The iron in these had to be strong and light, and Rogers found that iron produced using turf charcoal in the smelting had greater strength and malleability. Boilers fired by peat lasted twice as long as coal fired boilers because of the absence of sulphur in the peat. The problem with charcoal made from hand-won turf however is that it is very light and friable.

One of Rogers' contributions to posterity was his demonstration of the importance of combining organised hand-winning with systematic drainage. The turf was cut and dried on the bog – when weather permitted – before being taken into the factory, which consisted of three wooden sheds. The centre shed housed the furnace, which consisted of an ash pit running all the way down the middle, bounded by railway tracks. The carbonising kilns were pyramidal sheet iron structures, with hood-like chimneys, and there were 36 of them. The turf received its final drying on a framework above the furnaces. At the start of the process, the conical kilns were inverted and filled with turf; each could hold around 600 lbs, which gave 23-25% charcoal after five hours – three hours carbonisation, two hours cooling. The kilns were then wheeled along the railway tracks into position over the ash pit. The movable hoods over the kilns could be raised or lowered at will, and the draught was regulated by means of a damper. However, at £1/5/- to £1/10/- a ton it was too expensive to be economical. Three hundred people were employed at Derrymullen, which was intended as the first of 200 similar stations the Irish Amelioration Society planned to build. The charcoal was used for medicinal purposes, Rogers claiming enthusiastically that it was a remedy for cholera, 'an anti-putrescent and a tonic, combined with an absorbent power, which has no equal'. In the 1840s peat charcoal was making a reputation for itself as a 'disinfector, absorber and deodoriser'.

It was anticipated that the charcoal would be largely exported, and Rogers painted a glowing picture of the effects charcoal export would have on the economy:

> And here would commence the first flow of prosperity to our country, after so long and sad an ebb; a flood, too, which would be genial and beneficent, for its influence would commence among the poor. English capital would legitimately reach us, in return for honest labour, and the unhappy peasant, who now lives from year to year on the barter of labour for potatoes, and scarcely knows the value or use of money, would become comparatively rich, by money payment for his time, and happy in the possession of even lowly competence, earned by free will.

He saw the development of the bogs in a two-fold light: as a sound economic proposition and as a unique way of bringing about social change. He felt certain that the setting up of his Stations would stimulate turf cutting on a large scale by providing an easily accessible and secure market for hand-won turf, and put an end to the laziness which he saw as the root of the Irish problem:

> Privations and poverty have changed the very nature of the lower class from an honourable feeling to a 'low cunning', and if it become public, that eleemosynary aid will be granted by government, many an acre of potatoes will lie undug, which might otherwise be saved; that exertion, which all God's creatures have the power of putting forth on emergency, will be allowed to lie dormant; – and the sin of the Irish peasantry, indolence, become even deeper than it is at present.

The Famine gave an impetus to combine these two objectives. Rogers' Report to the Relief Commissioners was the basis and inspiration for the setting up of the Irish Amelioration Society, which in Rogers' eyes would supply the 'stimulus to body exertion' and the 'means for Moral and Social improvement', the lack of which he saw as 'the two great evils under which the Irish poor are now sinking'.

The capital to be raised in shares of £10 each was £500,000, and subscribers were asked to make a preliminary payment of 1/= to enable the Society to set up a first demonstration Station at Derrymullen. The superior Patent Fuel would cost only a quarter the cost of wood charcoal, and would, Rogers imagined; replace imported wood charcoal and coal coke in iron and other manufacturing, and in grain kilns.

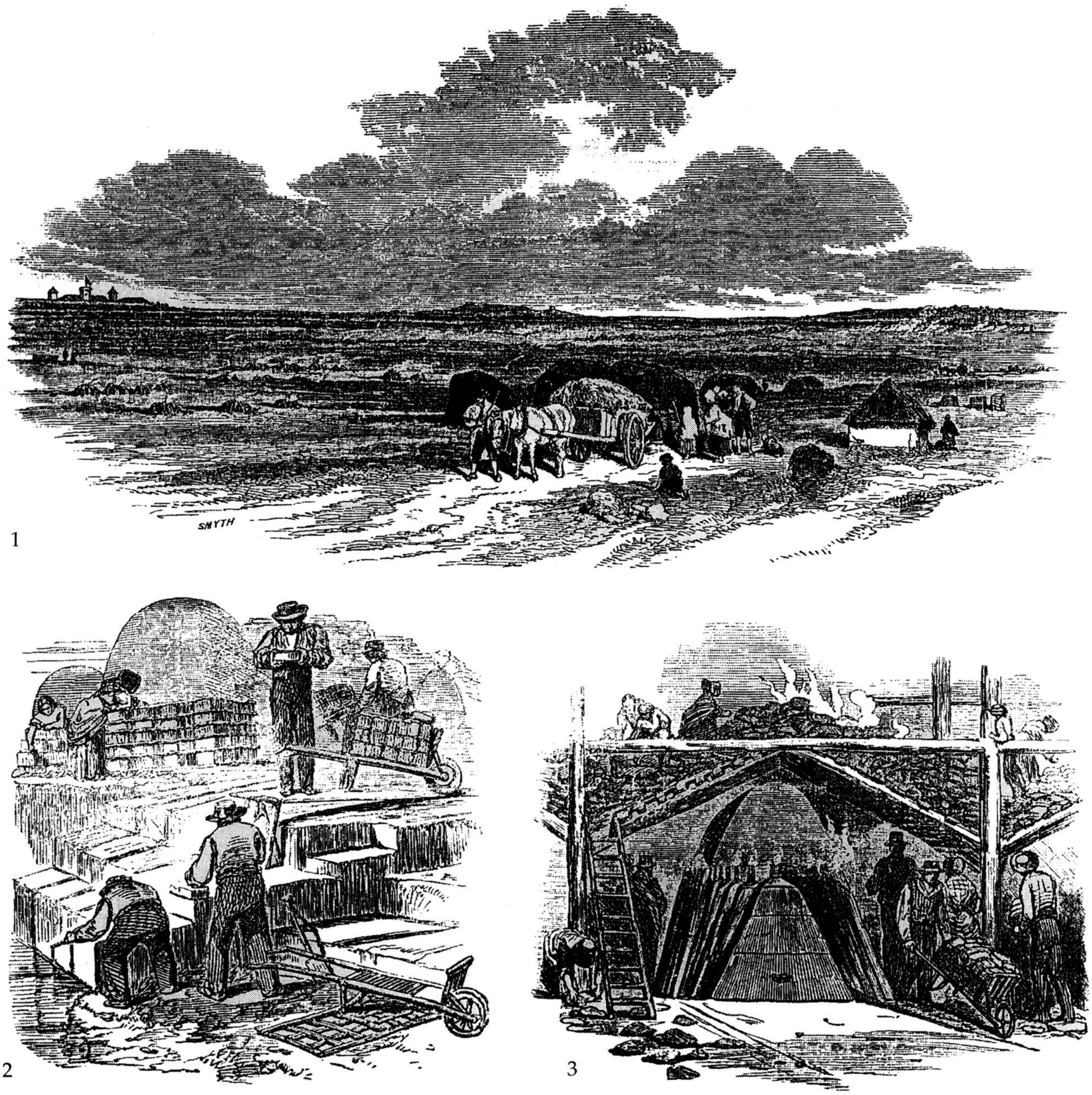


Figure 3.16:
Sketches from the Illustrated London News report on the grand opening of the Irish Amelioration Society's works at Derrymullen on 19th September, 1850. (1) is a general view, from the bank of the canal. (2) shows the cutting of the turf: 'two skenes are used to chop or make a long incision in the bank or bench from which the turf is taken with one forward thrust or cut; and the other having the side of it so turned up as to enable the man cutting with it to take out a perfectly square turf measuring six by four inches; he then throws it to another man, who stands, on a platform raised over the bank; and he flings it to a third, who places it on a barrow and takes it away to a distant spot, where he again passes it to women and girls, who pile the pieces up, and place them in what are technically called "short clamps"'.

This process of, short clamping, was of particular interest. The clamps consisted of 'hurdles at equal distances from each other, so as to admit of the air passing through them, and thus causing the turf to dry in a much less time than if placed, as heretofore, on the ground. From this layer of hurdle upon hurdle the turf is next removed to the rick, where it remains until conveyed into the furnace-house'. (3) is the artist's impression of one of the retorts used for burning the turf into charcoal.

Extensive and enthusiastic publicity accompanied the opening of the first station at Derrymullen in 1848 [**Figure 3.18**], and even at that early stage the Society was looking to the future, actively setting about acquiring large tracts of bogland in other parts of the country. The company hoped to achieve an output of six million tons of peat annually, generating a wage bill of between £500,000 and £lM for turf cutting alone. The expected annual profit was in the region of £200,000. The reclaimed land, which they expected would be 2-3,000 acres a year, would be set out in farms and let 'to those whose industry had been most conspicuous'. Rogers reserved 'a small Royalty' on each ton of peat – but even if this was 3d, that was £50,000 on the anticipated annual output of 4,000,000 tons of peat fuel, not to mention the 500,000 tons of charcoal. On these figures, the Society might well have hoped to be able to set money aside for its Amelioration Fund to pursue its social objectives, which included

> a building sufficiently large at each peat station, where the peasantry may assemble every evening, except Sunday:- that useful and entertaining publications be read for their gratification and instruction, and lectures given on the culture and preparation of Flax, with the object of introducing it into general use throughout Ireland; – thus affording constant employment to almost every member of each labourer's family: that Lectures be also given on agricultural and other subjects suited to their sphere in life, and tending to their general benefit. In short, that every possible effort be made to improve their social position, by giving them permanent and comfortable maintenance, to be earned by steady labour:- providing dwellings deserving the name of homes:- opening to them and their children means for moral and mental improvement, adapted to their habits and desires – thus advancing their happiness, and, it is hoped, securing their contentment.

Work continued at Derrymullen for about 7 years, but demand for the product, in spite of the remarkable properties claimed for it, declined steadily, and in the final years it was being sold as fertiliser to local farmers – one of Rogers' patents was for a method of mixing peat charcoal with farmyard manure.

In more recent years, there was a proposal by the consulting engineer Desmond McAteer (who had surveyed a 600 acre bog for the. purpose in 1941) to produce turf charcoal for household use during the War, and particularly to provide gas for use in motor vehicles as a substitute for petrol. Activated charcoal for use in the making of glucose was manufactured in the 1950s by the French firm Irish Ceca Ltd at Allenwood, from sod peat supplied by Bord na Móna. The output of the industry was 10,000 tons a year, which was exported for use as a purifying and decolorising agent in the food and chemical industries. The process required the use of hard, good quality sod peat from Ballydermot bog, but often they were supplied with poorer quality peat, which made the economics difficult. Peat is still an important raw material in the manufacture of activated charcoal in Germany and the Netherlands, but the market is presently 'sewn up' and difficult to break into.

Bog iron ore

Total length 50"

Deposits of iron ore frequently occur in bogs. They are usually about a metre deep, although there have been occurrences where the thickness was twice or three times this. When it is dug out of the bog the ore is light grey or brownish in colour, but it oxidises to deep red or brown once exposed to the air, and dries to a fine powder. Bog iron ore was widely used for extracting sulphur and other impurities from the coal gas that was used in urban lighting and domestic purposes into the early years of this century. The spent oxide was then a valuable source of a whole range of chemicals: sulphur, salts of ammonia, prussian blue and carbon bisulphide. A company was set up in London in 1874 by a group of enterprising Irishmen to deal in bog ore, and this company (the Gas Purification and Chemical Company Ltd.) supplied the leading gas companies in the United Kingdom, France and the Netherlands very successfully until the use of coal gas was supplanted by electricity and natural gas.

The iron in bog ore comes ultimately from the rocks and sub-soils beneath the bog. It is supposed that iron silicates in the rocks are dissolved out by the acids in the peat; ferrous sulphides are oxidised to ferrous sulphates, and substances in solution are converted to carbonates. Carbon dioxide later escapes, and the resulting oxide, in hydrous form, is deposited from springs welling up through the bog. Under the reducing conditions present in bogs, both iron and manganese are more mobile than in ordinary soils.

However, deposits of ore buried in peat could also originate in another way. Superficial ochre deposits are produced in stagnant bog pools by the action of filamentous iron bacteria, which oxidise the ferrous salts in the water, and precipitate the iron as ferric hydroxide in a sheath around the bacterial filament. In time these limonite sheaths can build up thick deposits on the bottom of the pool. The brown, fluffy masses of ochre often seen on the bottom of boggy pools today are a product of these *Leptothrix* ochre bacteria. It is possible that some at least of the bog ore deposits were earlier ochre deposits of bacterial origin, which accumulated in long-lived shallow bog pools, and that they were later buried by peat, or that these bacterial deposits may have subsequently migrated to suitable reservoir areas. Indeed, the organic nature of bog iron is often apparent under the microscope.

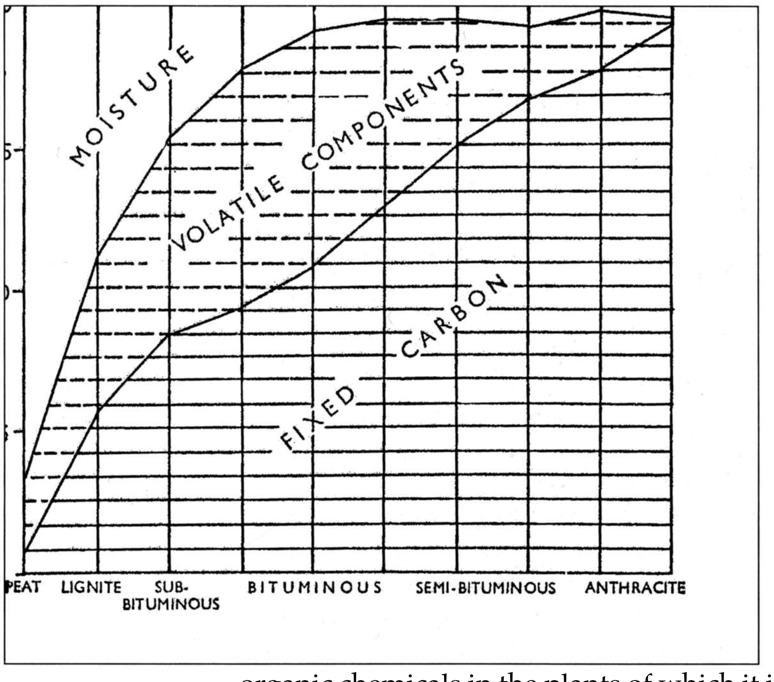
Most of the known major deposits of bog ore are now exhausted. They were particularly extensive in Donegal. Between 1864 and 1882,80,000 tons of ore were shipped from the little port of Ballyness, near Falcarragh. In the 30 years prior to 1907, 100,000 tons were exported from Buncrana, Moville, Culdaff and Dunaff, and a further 50,000 tons from the districts of Mountcharles, Donegal town, Teelin and Inver. Large deposits were also mined elsewhere in Donegal, at Letterkenny, Rathmullen, Rathmelton and Killygordon, and elsewhere in the country around Tullamore, Daingean, Mountrath, Cush, Athboy and Ballina.

But iron bog ores had probably been exploited in Ireland at a much earlier period. They were easy to smelt, and were particularly suitable for the making of cast iron objects. Some time around 1854, at a period when bog ochre (or 'red mine' as it was called locally) was being raised in County Laois, around 50 wooden implements with handles up to 6m long were found in a deposit near Clonaslee. These had presumably been used to reach in from the bank to scoop ochre from the bottom of the shallow, boggy lakes which had existed in this area several centuries earlier. It is not possible to say with any confidence how old these shovels were, but it is probable that the ochre deposits in which they occurred were being exploited as an ore of iron centuries before. Bog ores supplied the majority of the numerous small iron furnaces scattered throughout the country in early modern times, and recent excavation suggests that there was widespread regional and even local self-sufficiency in iron in Celtic Iron Age Ireland. Bog ochre is likely to have been a major resource underpinning this self-sufficiency. Bog iron was mixed with iron ore mined from other sources for smelting in Coote's iron furnaces at Mountrath in the eighteenth century, and this may represent the end of a more ancient Irish tradition in the use of ochre. Iron ore was exported from Derrygreenagh to England in the early 1850s, using the extensive stone quays along the Grand Canal at Daingean that (it is said) were erected for this purpose by the Canal Company.

Chemicals from peat

Peat formation has been taking place wherever conditions were suitable for as long as there has been abundant plant life on land. Great accumulations of undecayed plant material cover enormous expanses of today's cold northern tundras, and in more temperate areas they accumulate wherever conditions of high precipitation and low evaporation, or poor drainage prevail. Under tropical conditions peat can only develop where drainage is impeded. If peat is buried for a sufficient time by sediments deposited later in geological time, it undergoes physical and chemical modification under the influence of prolonged pressure and heat. As a result, there is a progressive decrease in the proportion of volatile material and water, and an increase in the proportion of carbon present. At the same time the texture changes, and it becomes harder and more compact. The oldest, deepest and most compacted peat, which shrinks and cracks much more than brown or white turf, and which is found maybe 6m below the surface, is nearly as good a fuel as coal. If the peat is compressed further, it will become brown coal and eventually lignite. (Brown coal is like black, earthy compost and can easily be dug with a shovel, whereas lignite is like very hard and compact turf, black or brown in colour, but with its plant constituents still partly recognisable). If the changes are continued for a sufficient length of time the lignite is further compressed to coal. In other words, peat is the first stage in a genetic *coal series* that goes from peat through brown coal, lignite, bituminous coal and finally anthracite. The average chemical composition of peat is about 56% carbon, 37% oxygen, 5.5% hydrogen and 1.5% nitrogen, which gives it a carbon: hydrogen ratio of ten on the coal classification scale as against 25-30 for anthracite, with the various kinds of bituminous coals somewhere in the middle [**Table 3.2**].

Table 3.2: The coal series.



Organic debris may also accumulate in the sea, in this case principally the remains of the single-celled plants and animals that live in such enormous numbers in the oceans. This too may be buried by later sediments, and in time alters to petroleum. These ancient organic sediments are not only the main source of the energy without which our modern world could not survive, but the complex chemistry of these organic rocks constitutes the base of the modern petrochemical industry which underpins the whole of our civilisation. Because of its organic origin, peat has an equally complex chemistry. And just as with coal and oil, the burning of peat for fuel is only one of many possible uses – and in many ways the simplest and most wasteful use of a versatile and finite resource that can be used for many other purposes.

The organic part of peat results from the partial decomposition of the complex organic chemicals in the plants of which it is made; much of this consists of a complex of substances which cannot easily be given chemical labels, and which are conveniently known as 'humic substances'. The inorganic part of the peat consists of calcium, iron, magnesium, sulphur, phosphorus, a high proportion of nitrogen compounds both of organic and inorganic origin, and traces of many other chemical elements.

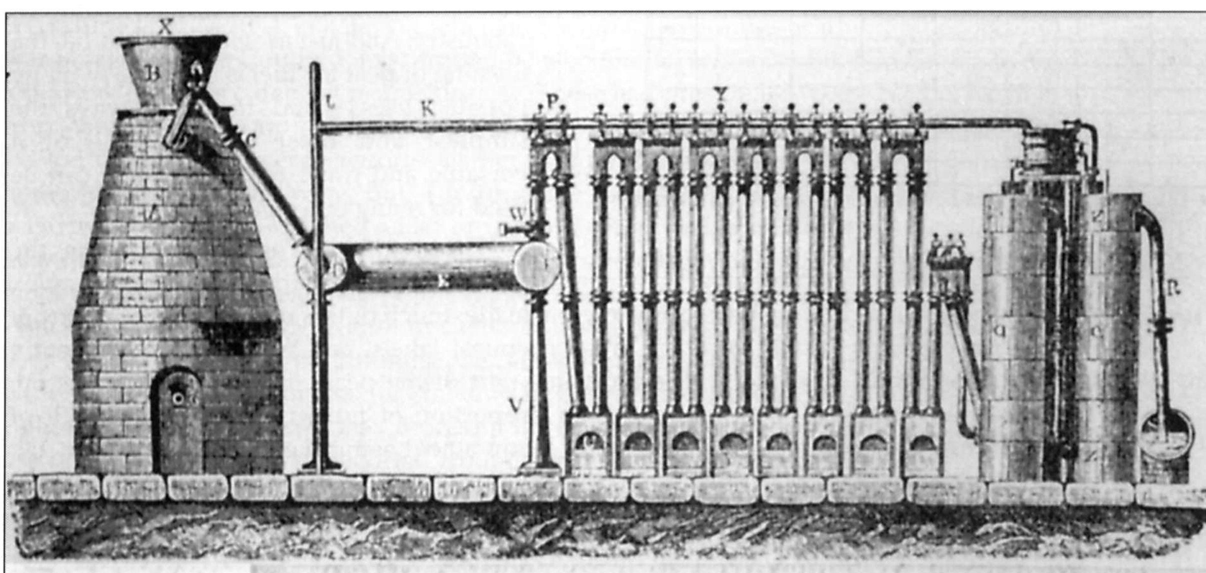
Nitrogen is usually higher in the top few cm of bogs, and in blanket bogs there are generally higher concentrations in the peat of shallower bogs. Phosphorus (both readily soluble and total) is also most concentrated here, generally with a very pronounced fall-off lower down. The degree of solubility correlates with humification. In raised bogs there is a sharp rise in the fen peats at the bottom. Magnesium decreases with increase in depth. In raised bogs the rise is especially steep across the main humification change, in parallel with a fall in calcium. In raised bogs sodium and potassium are distinctly higher in the upper zone, whereas they are relatively uniform in the profiles of blanket bog. The variations in potassium, magnesium and sodium relative to calcium in raised bogs are attributed to cation balance factors. The level of potassium in particular is very low compared to that in the plants growing on the bog, suggesting loss of potassium. Levels of sodium are influenced by distance from the sea (in other words, by the level of sea-salt in the precipitation). In blanket bogs there are higher levels of readily-soluble phosphorus, calcium and potassium near the top of the profile than lower down, a change attributable to change in the degree of humification. Although there are often higher amounts of trace elements (lead, tin, vanadium copper, nickel, cobalt and iron) in the upper part of the profile, the pattern differs considerably from bog to bog, but there are often notable changes in concentration across horizons of humification change. The elemental composition relates not only to the chemical legacy of plants which once grew on the bog, but is considerably influenced by elements in sea-derived salts and dust.

Prom the very earliest days of the industrial exploitation of bogland, scientists realised that peat had a comparable potential to coal or oil, though it was later lost sight of for a long time as the furnaces and grates began to eat away at this irreplaceable asset. Today, as the end of the great bogs comes in sight, there is a new revival of interest in the alternative uses to which peat can be put. In ways peat is more versatile than coal or oil. It is not simply a vast hydrocarbon reservoir; it also has physical and biological properties that it has inherited from its more recent plant ancestry. Coal and petroleum, because they have been so much more altered during the long time of their metamorphosis, have lost these properties. In the later part of the last and the early years of this century there were several carbonising processes for the extraction of the chemicals in peat. One of the most successful as Wieland's carbonising process in Oldenburg, whose three ovens had an output of ten tons of charcoal every 24 hours. Here the turf was broken down to the following constituents:

Turf charcoal	30%
Tar	2.5%
Tar water	32.5%
Gas and loss	35%

The tar was then broken down to produce illuminating oil, creosote, paraffin wax and pitch, methyl alcohol and calcium acetate. Other valuable by-products were ammonia and acetic acid.

Figure 3.19: Retort for peat distillation at Kilberry.



Turf Distillation Plant, Kilberry, near Athy, Co. Kildare.

Prior to the unlocking of the chemical reservoir stored in coal tar, there were some tentative efforts to exploit the chemical potential of turf. One of the pioneers in the field was a Welsh chemist named Rees Reece who patented a process for distilling peat in an air blast in 1849. Reece had spent some time in France before setting up at Newtown--Crommelin in Antrim, whence he moved to Kilberry. Reece's method differed from the distillation of coal in that the heat generated by its own combustion was used to distil the peat. In Reece's patent, a blast of air was introduced at the bottom of a furnace filled with peat. The heat developed in the lower part of the furnace passed up through the peat mass along with the gases, bringing about the destructive distillation of the peat further up, and resulting in the 'expulsion of the empyreumatic products'. The desired end products were condensed and removed. The 'waste' gas produced was used to fuel the process, and the charcoal left over was used as fuel for the distillation.

Table 3.3: Distillation products of peat, starting with 1,000 lbs air-dry turf.

1,000 lbs.

Turf charcoal	Tar	Tar Water	Gas
350 lbs.	40 lbs.	400 lbs.	210 lbs.

Illuminating Oil	Creosote Oil	Wax	Pitch and loss	Calcium Acetate	Methyl Alcohol	Ammonia Sulphate
23.2 lbs.	4.8 lbs.	4 lbs.	8 lbs.	6 lbs.	6 lbs.	6 lbs.

In the same year (1849) a large plant using this process was set up by Reece and his Irish Peat Company at Kilberry near Athy, the first of its kind in the world. The aim was to produce peat gas and tar; along with a range of by-products including calcium acetate, ammonium sulphate, methyl alcohol, paraffin wax, petroleum and lubricating oil. The Company anticipated that it could extract the following amounts of the various products annually from 100 tons of peat a day:

EXPENDITURE	
36,500 tons of peat, at 2s per ton	£3,650
455 tons of sulphuric acid, at £7 per ton	£3,185
Wear and tear of apparatus, *et cetera*	£700
Wages, labour, *et cetera*	£2,000
Freight and incidental charges	£2,182
	£11,717
PRODUCE	
365 tons of sulphate of ammonia, at £12 per ton	£4,380
255 tons of acetate of lime, at £14 per ton	£3,570
19,000 gallons of naptha, at 5s	£4,750
109,500 pounds of paraffin, at 1s	£5,475
73,000 gallons of volatile oil (petrol) at 1s	£3,650
36,000 gallons of fixed oil, at 1s	£1,800
	£23,625
Net profit:	£11,908
Cost of manufactory for above quantity	£10,000

These claims were in general substantiated by experimental work at the Museum of Irish Industry of Professor Sullivan and Sir Robert Kane – who became an enthusiastic supporter of Reece's enterprise. However it failed after a decade or so, possibly because coal gas became a cheaper raw material for the manufacture of these products. Much later (in 1907), a plant for the specific manufacture of ammonium sulphate for fertilisers from turf (turf contains between 0.5 and 3% nitrogen) by the Woltereck process was set up in Carnlough, County Antrim.

The different hydrocarbon fractions distilled from the peat tar were petroleum, lubricating oil, paraffin wax, creosote and asphalt. The light petroleum fraction was used in paraffin lamps and as a stain remover. The heavy petroleum fraction was used mainly as a lubricant; the wax was used for making candles. Lampblack was made from the distillation residues, and this was used in making boot polish and printers' ink. The O'Gorman Mahon once caused something of a sensation in the House of Commons when he exhibited paraffin candles made from peat, though the effect was somewhat dampened by the revelation that they cost a guinea each to manufacture. When the expenditure on raw materials, the cost of labour, transport and so on were reasonable, and high prices could be obtained for these products – as they could during the heyday of the Irish Peat Company at Kilberry – turf tar distillation was profitable: but this quickly changed as the century advanced.

Gas for lighting and heating was also manufactured from turf. Lighting gas was made from turf on a large scale in several European centres, but it did not prove commercially viable. Too many retorts were needed for its manufacture and it produced too much carbon dioxide. On a much smaller scale, lighting gas was made in counties Laois and Westmeath in the last century – Mullingar was lit by peat gas in the 1850s – and during the Second World War turf was used to generate gas in several towns in Ireland. Several different gas mixtures were prepared for heating purposes, and these were burnt in specially-designed furnaces such as the Siemens Regenerating Gas Furnace. It was used in other countries for specific industrial applications: it was ideal in glass manufacture, and was also used in the porcelain, brick, tile and lime-making industries, but not, apparently, in Ireland. Around 1875 it was used in the iron and steel industries for a time at a number of locations.

Gas water was a solution containing a considerable variety of valuable chemicals, the proportions depending on the nature of the turf used: mainly methanol, ammonium salts and various allied substances such as aniline, pyridine and toluidine. The methanol was used as a fuel, and in dye and varnish making. Ammonium sulphate (made from other ammonium compounds present in the gas water) was used as a fertiliser or for making ammonia or its valuable salts. Calcium acetate was used to make acetic acid and acetone, which had many uses. Ammonia is still produced from peat in Finland.

Peat has almost all the nutrients needed for the growth of decomposer organisms, and once the physical and chemical constraints that prevail in the bog are removed, it would be very quickly broken down by natural decomposers, especially fungi. An extract prepared from peat chemically, and then concentrated, contains a good supply of nitrogen and carbohydrate, though it is deficient in phosphorus, and could be used as a fermentable extract. With phosphorus added it is capable of supporting biomass yields comparable to standard microbiological media.

In 1891 Kapesser in Germany patented a method for extracting sugar and alcohol from peat. Peat charcoal was found to be a valuable product, very friable and porous, easily kindled and of high calorific value. An aromatic mixture of creosote and other products (called sphagnol) was used in the manufacture of a soap which was said to have valuable curative properties for skin conditions.

The health-giving properties of peat are not just a detail of outmoded 19th century medical science. Trace element-rich minerals extracted from Irish peat by the German company Antake GMBH are available in Germany and America at $55 for a month's supply in liquid form under the name 'Mineral Life'. Peat baths are still in vogue in Germany and elsewhere, where they enjoy a very high reputation in cases of chronic rheumatism, muscular pain and stiffness of the joints, gout and sciatica and other such ailments. The 'mud' is generally peat mull from which all the fibre has been removed, before it is mixed with mineral water and charged with carbonic acid. Irish peat is exported for this purpose.

Into the 20th Century

In 1898 Dr T. Johnson inspected various peat producing enterprises in Germany, and reported to the RDS on his return. In Germany at this time crude hand-operated cutting machines were still in use and horse-powered vertical cutting machines were still being used, but the latest technology was transportable horizontal macerators carried on rails and fed with hand-dug turf. The new automatic 'great-industry' machines developed rapidly in the early decades of the present century, those of Wielandt, Strenge, Dolberg and Baumann being among the best known. These were designed to reduce the dependence on human labour, and were characterised by the combination of a ladder of bucket-dredgers, a macerating machine with a sod cutter, and an endless belt or plate conveyor. These machines worked on the 'bagger' principle, excavating the peat from a vertical or inclined cutting face by means of a ladder of bucket-dredgers [**Figure 3.20**], which emptied their contents into a macerating machine. They could excavate to a depth of sixteen feet or so; the dredging width varied in the different machines from 3.5 to 13 feet. As the macerated peat emerged in a continuous band it was cut into sods automatically. The sods were then carried on a belt or plate conveyor that extended out over the surface of the bog as much as 100 yards from the cutting trench, where they were tipped to dry. The commercial advantage of fully automatic machines like these was enormous compared with machines such as the hand-fed Dolberg, which had an output of only one ton per man per ten-hour day, and the peat was of more uniform and reliable quality than slane-cut turf. With the fully automatic machines a team of four men could do the work of 40 to 60, dredging, macerating, shaping and spreading 5-7 tons of air-dry sods every hour.

In these early years field presses were widely used in Sweden, Norway and Canada. In Norway and Sweden an Anrep-Svedala machine was used for dredging and macerating the peat pulp, which was then transported to the drying ground, where a Jakobbson field press was used to extrude and then cut the peat lengths into sods.

In the early part of the century, the government department, which had responsibility for the winning of turf – considered to be a farming operation – was the Department of Agriculture and Technical Instruction for Ireland (DATI). The Government showed little interest in the *industrial* development of peat in Ireland. The MP Laurence Ginnell argued that there were two reasons for this:

1. It was English State policy that agriculture should be Ireland's only industry; and
2. England was afraid of the potential competition Irish peat might offer to British coal.

Figure 3.20: Loading an Akermann peat macerating machine. Eleven of these machines were bought by Bord na Móna in the late 1940s under Todd Andrews, but only a few were used.

At the Cork Exhibition held in 1902 the Department convened an industrial conference, and invited the German peat expert J.T. Tatlow to lecture on continental peat production methods. The following summer Tatlow was employed to demonstrate the horse-powered Dolberg machine in County Cavan, with a view to its adoption by farmers and labourers. That same year Tatlow went with two officials from the Department to see what was being done along these lines in Holland and Sweden. The Dolberg demonstration was repeated the following year at Inny Junction, but the Department ran into legal difficulties because it had no authority to purchase bogland. Also in 1904, Mackey installed a steam-powered Dolberg at Castleconnel in County Limerick for sod-peat production (with technical assistance from Tatlow) (See Chapter 1). A similar machine was used between 1905 and 1910 by the Standard Peat Fuel Company at Umeras near Monasterevan. After the failure of their Bessey process experiment, the Electro-Peat Coal Syndicate at Kilberry changed over to a large stationary Heinen macerator in the years up to its closure in 1914.

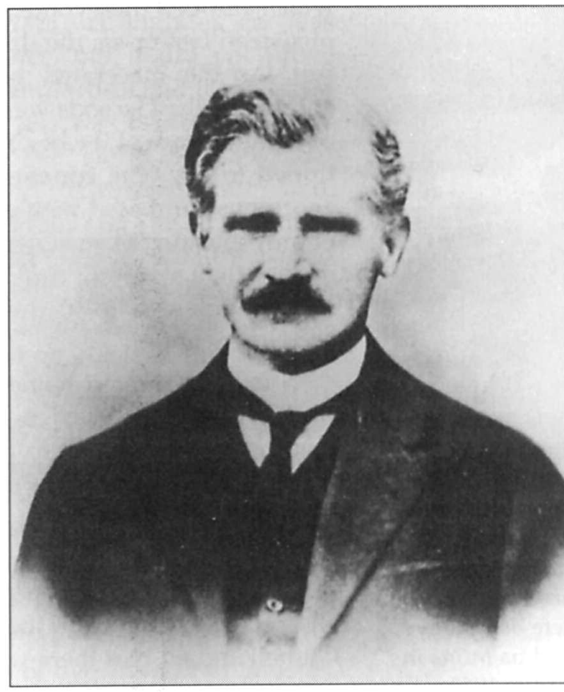


Figure 3.21: Hugh Ryan (Professor of Chemistry at UCD, 1899-1931).

Professor Hugh Ryan [**Figure 3.21**] produced his two important RDS papers in 1907-8. These summarised earlier attempts to harvest and process peat in Ireland, and reviewed the existing state of peat technology. In 1921 he produced his translation of Hausding's *Handbuch der Torfgewinnung und Torfuerwertung,* the bible of the German peat producers, first published in 1876 (with later editions in 1904 and 1917: Ryan translated the most up-to-date third edition). This in its turn became the bible of Irish peat development until after the Second World War.

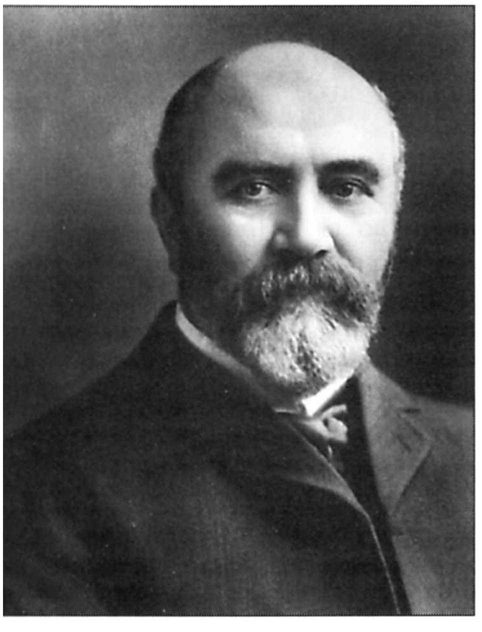
One of the most intriguing of all the early bog developments was the Hamon Coal factory set up at Bellair between 1917 and 1922 by a man who, on the face of it, might appear a most unlikely peat entrepreneur. This was Count Louis leWarner Hamon who was born in Bray in 1866 [Figure 3.22]. Count Louis was probably more widely known than any other bog developer of his time, though not on account of his achievement in this area. He was a skilled linguist and an experienced traveller, and in an earlier stage in his career had been a war correspondent in the Far East. He owned and edited a London newspaper called *The Anglo-Colonial American Register* from 1900 to 1914, and founded *Entente Cordiale* in Paris in 1901. But his reputation at the time of his arrival in Bellair rested less on these achievements than on the fame of his extraordinary psychic powers, and his reputed ability to tell the future by palmistry and astrology. He had consulting rooms in Bond Street in London for his many well-to-do clients, and published several books on palmistry, astrology and the occult under the pen-name of Cheiro – some of which are still available today in paperback.

Figure 3.22: Count Louis leWarner Hamon.

In 1917 Hamon settled at Prospect House near Ballycumber. With the assistance of a French chemist called Daubier, he set up a chemical laboratory in one of the outbuildings, and here they experimented with the extraction of gas, dyes and waxes from local peat. Hamon's aim was to extract chemicals from peat and to "briquette" the residues as an 'artificial coal'. He leased part of Bellair bog and hired men to harvest moss peat which was brought on hand-operated railway wagons acquired from Major Sherlock's moss peat works at Rahan. In 1919 he patented his idea and set to work on his factory; his machinery consisted of a breaker and screens for the peat, a pitch breaker, a rotary retort for coking and a briquetting press adapted from a machine for making artillery shells; power was provided by a steam engine. The ingredients for his fuel were moss peat, sand and pitch in proportions of 50:30:20. These were mixed by hand and loaded into the rotary retort, where they were heated over a strong fire. This procedure coked the mixture, driving off the smoke-producing volatiles from peat and pitch, and leaving a dry, charcoal-like powder. From this powder briquettes were made in the 20′ high press, the ram in which exerted a pressure of 130 tons, moulding the powder into hard black blocks which measured 8″ x 6″ x 1.5″ with polished edges and bearing the imprint 'HAMON COAL'.

About 30 people were employed, 20 of whom were provided with accommodation on site. Trial briquettes were successfully produced in 1921, but in the following year the factory, with all the machinery and stocks, was destroyed by fire. Hamon obtained substantial compensation on foot of a malicious damages claim, and then disappeared to Hollywood, where he exploited his other talents in the screen portrayal of the occult. The possibility that the fire was an accident due to spontaneous combustion seems not to have been considered.

Figure 3.23: Sir John Purser-Griffith



Turraun and Sir John Purser Griffith

The development of the bogs owes a great deal to the inspiration of Sir John Purser Griffith [**Figure 3.23**], who spent £70,000 of his private fortune to show, by example, what could be done. Sir John had been chairman of the Irish Peat Committee appointed by the Fuel Research Board to investigate the peat resources of Ireland. The failure of the British Government to act upon the recommendations of this Committee, and the subsequent failure of the Free State Government to act on the recommendations of the 1921-2 Committee, spurred him to show, by his own example, what could be done. He purchased bogs at Ticknevin near Edenderry and at Turraun near Ballycumber, where he set up the Leinster Carbonising Company Limited in 1924. Here he established one of the earliest machine peat operations in Ireland, using German machinery adapted to suit local conditions. Sir John's objective in setting up at Turraun was to show on a small scale what he knew could be done on a much larger scale. His approach can be summed up in a quotation from James Fintan Lalor which he was fond of using: 'Somewhere, and somehow, and by somebody, a beginning must be made'.

Figure 3.24: Advertisment for machine peat from Turraun.

Turraun was selected because it was a very deep and extensive bog, and – very importantly – it was located right on the Grand Canal, enabling the fuel to be transported cheaply to Dublin. The company carried out systematic drainage on some 4,000 acres, and manufactured machine peat, peat moss litter, poultry peat and garden moss peat. There were 16 permanent and 50 seasonal workers. The plan was to use electric power plant on the site to run the machines in summer, and to generate electricity for distribution to the adjacent towns of Athlone, Birr and Tullamore in winter. The arrival of rural electrification using hydroelectric power from the Shannon after 1927 made this plan obsolete.

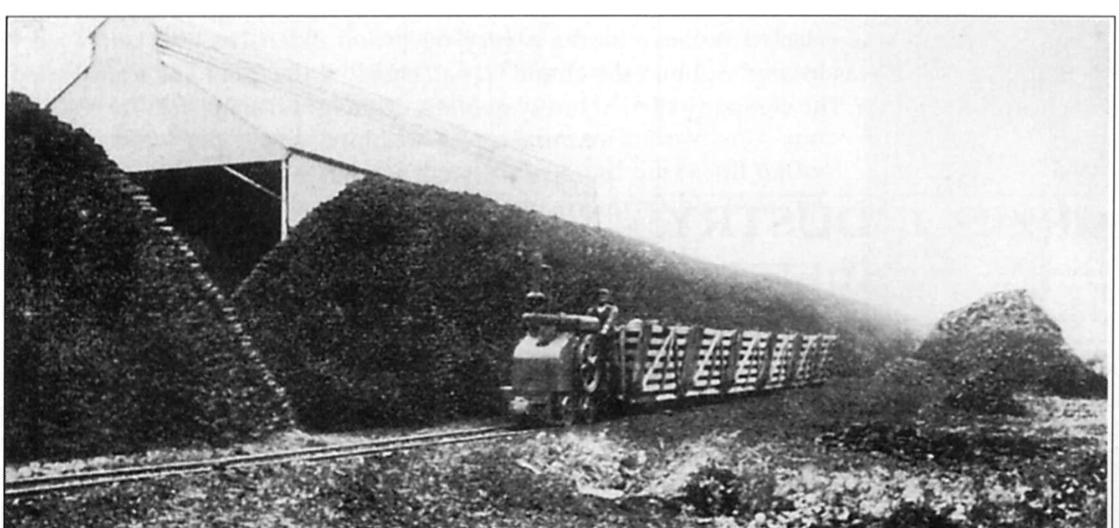
The peat was dug, macerated and distributed over the drying surfaces by automatic machines. These two 'travelling' Wielandt sod-peat machines were operated electrically by a small peat-powered 2,500-volt steam generator driven by a 110 horse-power locomotive-type Garrett stationary engine; the current was distributed over five miles of overhead wires to the machines. The machines cut trenches that were between a mile and a mile and a half in length, three feet wide and twelve feet deep, excavating about ten miles of trench sides each season; they were also used to dig drains. Around 8,000 tons of fuel were harvested from these trench sides each year. The extruded peat was spread in rows, and when sufficiently dry the sods were stacked in large clamps. There was also an engine-driven Dolberg machine that was fed by hand, and this was employed for the production of special peat blocks of uniform size and shape.

The air-dried peat was carried in rail wagons by Lanz and Austro-Daimler locomotives on a narrow gauge railway. The manufactured fuel was transported to Dublin and elsewhere by barge on the canal, and by road using a fleet of lorries. The cost of transport was one of the things that made it difficult to sell the fuel in Dublin at a competitive price; Sir John estimated that they needed a market for 12,000 tons of turf to break even. The peat moss factory was fuelled by a National Gas Engine powered by a Peat Gas Producer in a smaller peat-fired power station.

Turraun was managed by Frederick Purser Griffith, Sir John's son, who died in 1940. Sir John himself died in 1938, at the age of 90. The Turf Development Board, which had also been studying developments in Germany and Russia, bought Purser-Griffith's plant for £4,500 in 1935; the Government also gave the Board a grant of £3,000 as working capital to continue development. During World War 2, the generator was also used to provide power for an experimental charcoal plant for two years or so; during this period Turraun was operated with the primary aim of producing turf charcoal to be used as a fuel in wartime vehicle gas producers. Two full-sized retorts were installed in 1941. The weekly output of charcoal was 20 tons; between February 1943 and the end of 1944 9,235 tons of turf were burned with a yield of 1,218 tons of charcoal. Upwards of 3,500 tons of turf were used in the production of producer gas.

Because of its early start as the first bog to be mechanically developed in a systematic way, Purser-Griffith's Turraun bog was the first to be 'bottomed' or finish excavated by Bord na Móna. The natural recolonisation of the cutaway during the 25 years or so since the first section of the cutaway bog was left to Nature has provided much insight into the potential for the ecological regeneration of cutover peatland.

Figure 3.25: Purser-Griffith's works at Turraun.



One of the Company's locomotives which haul raw material and finished fuel over five miles of track to the factory, and to points of despatch by canal or road.

Pierce Purcell and the Irish Peat Fuel Company

Figure 3.26: Professor Pierce Purcell.

Professor Pierce Purcell, Professor of Civil Engineering at UCD, served as secretary to the 1917-19 Peat Enquiry Committee, and in 1918 he was appointed Peat Investigation Officer to the British Fuel Research Board, with E.J. Duffy as his research assistant [**Figure 3.26**]. Between 1919 and 1920 Duffy carried out experiments with the Dolberg macerator on Purser-Griffith's bogs at Ticknevin and Turraun, where he demonstrated conclusively that mechanical sod peat production was economical under Irish conditions. Purcell collaborated with Purser-Griffith in the setting-up of Turraun; however, the focus of his interest at this time lay in Scotland, where the Peco Company was experimenting with peat drying. In 1924 this company developed the Peco Method of harvesting peat under the direction of the Norwegian engineer Thomas Gram. In 1933 Purcell acquired and drained Lullymore Bog. In the following year he set up the Irish Peat Fuel Company Ltd, and started to harvest milled peat for the manufacture of briquettes using the Peco method. The briquette factory, which was to have a capacity for 50,000 tons of briquettes a year, was completed by the British engineering company Babcock and Wilcox in 1936. However, it experienced financial difficulties from the start. It needed a Government subsidy in order to survive: it received grants of £175,000 during its three years of operation. When this subvention was withdrawn in 1939, production ceased and the Company went into liquidation. A budding state company, the Turf Development Board, then acquired the assets of the Irish Peat Fuel Company and – with little acknowledgement – adopted Purcell's system and methods. The TDB recommenced full-scale work at Lullymore in 1941 with a Government grant.

The Peat Fuel Company's problems arose from having to develop bog and factory processes at the same time, and the difficulty of briquetting large amounts of unsuitable peat from the upper layers of the bog. (Well-humified peat is best for briquettes, but blending of well-humified and sphagnum peat is also beneficial in briquetting). But in spite of its difficulties, during its few operating years the Peat Fuel Company carried out much pioneering work on machine, bog and briquette process development at Lullymore – work which many felt the Government should be doing. With the failure of the Peat Fuel Company an excellent group of experienced engineering and managerial personnel was lost. However, the Government, while sympathetic, was reluctant to invest money in experimental work of (what it considered to be) doubtful outcome. An additional factor may have been the personal and political closeness between the Government and TDB personnel.

Table 3.4: MILESTONES: EARLY DEVELOPMENTS IN MECHANISATION etc.

1751	Richard Rainey using peat charcoal in Derry to make malleable iron.
1839-48	Wye Williams (City of Dublin Steam Packet Company) at Kilcock: attempted dewatering of pulped peat by hydraulic presses, followed by artifical drying and coating of peat bricks with pitch or tar (wet press). Also produced coke from peat, but at prohibitive cost.
1844	Mallet's Kiln.
1846	The Irish Peat, Peat Coal and Charcoal Company founded.
1849-59	Rees Reece's Irish Peat Company at Kilberry near Athy. Chemicals and candle wax ('parofina') from distillation of peat. Kane played an active role in setting this up. Abandoned after 10 years because of failure to find a market.
1850-57	Irish Amelioration Society and Jasper Rodgers: elaborate peat sod drying plant for charcoal manufacture near Robertstown County Kildare. Large quantities of peat charcoal produced.
1850	Kieran Farrelly commences harvesting of moss peat at Turraun.
1852	English company manufacturing peat charcoal at Cahirciveen, County Kerry; factory accidentally burned down 1853.
1854	Hodgson builds Gwynnc Dry Press in Galway: briquetting of artificially dried peat powder. Constant press breakdown forces abandonment.
1855-58	Irish Peat Company milling peat for briquette manufacture at Kilberry: Gwynne Dry Press fails.
1857	Exter patents extrusion press without cooling runners.
1858	Hodgson patents extrusion press with cooling runners.
1860	Peat Gas used in Mullingar.
1861	Hodgson patents his 'milled' peat method.
1860-67	Hodgson and the Patent Peat Company Ltd. at Derrylea (Clonsast): artificial drying and successful briquetting of peat mould by extrusion press.
1862	Moore and Tennent condensed hand-won peat in a steam-powered vertical macerator at Ballymena, County Antrim.
1863	Buckland's Sieve Turf Process for peat maceration and briquetting (patented 1859) tried in manufacture of condensed sod peat at Creevelea, County Sligo.
1865-70	Robert Alloway produced 'peat coal' from raw peat moulded by hand at Ballybrittas, County Laois.
1870-74	W. Malcolmson attempts to condense hand-won turf in a pug mill and dry it artificially at Birdhill, County Limerick; attempts also to distil oil and produce charcoal from peat.
1872	Purdon Commission visited European machine turf producers - fact finding.
1873	Banagher Peat Works on Clongawny bog.
1874	Alexander McDonnell produces machine turf for use in railway locomotives at Mountrath (Laois) and Monasterevan (Kildare), introducing continental horizontal maceration methods to Ireland.
1885-1925	David Sherlock successfully produces machine sod peat and peat moss at Rahan.
1883	Prof. A. W. Cronquist in Ireland advising on suitability of Irish bogs for peat fuel and moss peat.
1890-1940	Umeras, County Kildare. Established by retired army general McQuaid to supply stable litter to cavalry barracks. Various peat enterprises at different times.
1898	Blunden horizontal macerator process at Glenmore, Sligo by the New Irish Peat Products Company. Abandoned because of competition from cheap coal.
1899	Professor Johnson's reports on the Irish Peat Question after German tour.
1903-05	Callender Paper Company produced brown wrapping paper from a mixture of peat fibre and paper pulp at Celbridge, County Kildare: financial failure.
1903	Malby Crofton Dodwell established The Peat Products of Ireland Co. Ltd. at Coolaney. Ceased operations within a year.
1904-08	Anthony Mackay and J.T. Tatlow produce sod machine turf with steam-powered Dolberg at Castleconnell, County Limerick.
c.1904	Experiments with Dolberg machines at Inny Junction, Co Westmeath and Co Cavan; abandoned for legal reasons.
1905	Midland moss peat baled for sale in Dublin by Connell & Co. at Ringsend.
1906	Norman Palmer sets up peat moss factory at Drumcooley (Edenderry), County Offaly; this later joined with Umeras under Hamilton Robb, and continued production until 1945.
1907	Bessey electro-osmosis of peat tried at Kilberry by the Electro-Peat Syndicate; process soon abandoned and replaced by machine sod peat production (until 1914).
1907	Midland moss peat baled for sale in Dublin by The Irish Peat Industry Ltd. at Inchicore.
1907	The London-based Sulphate of Ammonia Corporation Ltd. builds its factory at Carnlough, County Antrim.
1907-08	Hugh Ryan reports to the RDS.
1907-20	Hamilton Robb producing peat litter at Mahery, County Tyrone.
1911-20	Hamilton Robb using producer gas from hand-won turf to power his linen factory at Portadown.
1917	Department of Scientific and Industrial Research Committee.
1918	Purcell's superb lecture to the RDS: *The Peat Resources of Ire/and.*
1918-20	F.A. Evans producing peat moss at Mulgeeth, County Kildare.
1918-22	Count Louis Hamon's attempt to produce smokeless fuel for trench warfare from peat.
1920	Dáil Commission on Ireland's peat resources.
1920-35	Sir John Purser-Griffith at Turraun: successful production of sod peat with German machines.
1921	Hugh Ryan's translation of Hausding's *Handbuch*
1933	Milled peat technique for briquetting introduced by The Irish Peat Fuel Company (Purcell's company) at Lullymore.
1934	Turf Development Board formed.
1935	TDB mission to Germany and Russia; TOB acquires Turraun.
1936	TDB purchases Clonsast and Lyrecrumpane.
1940	TDB purchases Lullymore and continues milling and briquetting operation there.
1946	Bord na Móna established.
1954	First International Peat Symposium organised by Bord na Mona in Dublin.
1968	International Peat Society founded.

Table 3.5: EARLY PEAT PATENTS EXPLOITED IN IRELAND.
(Compiled by John Cooke)

1837:	Charles Wye Williams. 'Certain Improvements in the Means of Preparing the Vegetable Material of Peat-Moss or Bog, so as to render it Applicable to several Useful Purposes, and particularly for Fuel'. British Patent No.7468; 1837.
1838:	Charles Wye Williams. 'Certain Improvements in the Means of Preparing the Vegetable Material of Peat-Moss or Bog, so as to render it Applicable to several Useful Purposes, and particularly for Fuel'. British Patent No.7744; 1838.
1842:	Charles Wye Williams. 'Moulding Bricks, Artificial Fuel and other Substance'. British Patent No.9244;
1848:	Jasper W. Rogers (of Nottingham Street, in the City of Dublin, Civil Engineer). 'Preparing Peat for Fuel, and Using the same in Combination with other Substances as Manure'. British Patent No.12, 169; 1848.
1849:	Rees Reece. 'Improvements in Treating Peat and Obtaining Products therefrom'. British Patent No. 12,436;
1850:	Jasper W. Rogers. 'Certain Improvements in the Preparation of Peat, and in the Manufacture of the same into Fuel and Charcoal'. British Patent No.13,258; 1850.
1858:	Charles Hodgson (of Ballard, Rathdrum, Co. Wicklow). 'Improvements in the Manufacture of Fuel from Peat, and in Apparatus employed therein, Parts of which are also applicable to the Moulding of Bricks, Tiles and other Plastic Materials'. British Patent No.2837; 12.58: Briquette Press Patent.
1860:	William Buckland. 'An Improved Preparation of Peat'. British Patent No. 1734; 20.1.1860.
1860:	Charles Hodgson (of Ballyreine, Co. Wicklow and Merlin Park, Co. Galway) and Patrick Moir Crane (of the Irish Peat Works, Athy). 'Improvements in Manufactures from Peat'. British Patent No.233; 30.1.1860.
1860:	William Buckland. 'Improvements in the Preparation of Peat'. British Patent No.2218; 20.3.1860.
1860:	Jasper W. Rogers. 'Improvements in the Mode of and Apparatus for Preparing Peat for Fuel'. British Patent No.2487, 12.10.1860.
1861:	Charles Hodgson. 'Improvements in the Manufacture of Fuel from Peat, and in Apparatus employed therein, Parts of which are applicable to the Moulding of Bricks, Tiles and other like Materials. British Patent No.1592; 20.6.1861. This patent covered the design of a clamp to restrict the outlet of briquettes from the press.
1861:	Charles Hodgson. 'An Improved Method of partially Drying Peat before removing the same from the Bog'. British Patent No.1593; 20.6.1861. This patent covered the production of dry peat mull ('milled peat') from a drained bog surface.
1873:	Robert Alloway. 'An Improved Process for Dessicating Oak Bark, Flax, Hemp, Tobacco, Peat, Mustard and other Substances by Atmospheric Evaporation, and in Apparatus therefor'. British Patent No.2138; 14.1.1873.
1905:	George MacGinty (of 184 Clonliffe Road, Drumcondra) and Anthony Mackey (of 54 Russell Avenue, Drumcondra, Post-card Manufacturer). 'Improvements relating to the Printing of Post-cards, Letter-cards and Envelopes constructed from Turf, Peat or Brown-Paper'. British Patent No.21 ,339; 28.6.1905.
1918:	Comte Louis Ie Warner Hamon (of 30 Elgin Road, Dublin). 'An Improved Fuel'. British Patent No. 121,102; 5.12.1918.

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Chapter Four

The Turf Development Board and Bord na Móna

In a matter of national interest such as this, no private corporation can be expected to bear the brunt of the initial experimental work on mechanical peat-winning, the results of which may be of much wider interest. Many and good reasons can be given in support of the view that this work is a responsibility for the State.

Within the past two years we have had two important reports on peat. Any person reading these reports will agree that a good case has been made for the initiation by the State of an experimental scheme of peat-winning on a comprehensive scale, which will, let us hope, lay the foundations of a prosperous peat industry.

Pierce Purcell: *Presidential Address* (1922), *Institution of Civil Engineers of Ireland.*

Different Bord logos 1946-95

Introduction

The investigations of the Bogs Commissioners in the early 19th century had shown that it would be possible to drain nearly all the large bogs in the country naturally, and that such systematic drainage would open the way to proper development of the bogland resource. Nine of the ten engineers employed on the survey recommended strongly that the State should reclaim the bogs, and charge the cost to the proprietors. For a variety of reasons, nothing was done to follow the recommendations of the Commissioners. In the first place there was the problem posed by the indeterminate nature of property boundaries on bogs, and by the complexity of turbary and grazing rights. Nor was it an auspicious time to be asking the British Government to dip into its coffers on behalf of Ireland, because the long Napoleonic War had almost emptied them, and Irish influence at Westminster was neither strong enough nor interested enough to attempt to force the recommendations on the Government. And finally, even if the Government had bestirred itself, the Corn Laws and their associated 'free-trade' ethos discouraged home agriculture, and any inclination on the part of landowners to significantly extend the area under tillage. Consequently, nothing much happened at government level for over a century. Numerous bills concerned with the reclamation of bogland for agricultural use were presented to parliament in the 19th century (See page 57), but it seems to have been the policy of the Irish Department of Agriculture and the Board of Trade to make agriculture Ireland's only industry, and to discourage the development of peat fuel because of possible competition with British coal.

The Irish Peat Enquiry Sub-Committee and the Turf Committee

In 1917, during the First World War, an Irish Peat Enquiry Sub-Committee was established by the Department of Agriculture and Technical Instruction at the request of the British Government's Fuel Research Board 'to inquire into and consider the experience already gained in Ireland in respect to the winning, preparation and use of peat fuel and for other purposes, and to suggest what means should be taken to ascertain the conditions under which in the most favourably situated localities it can be profitably won, prepared and used, having regard to the economic conditions of Ireland'. It consisted of five members:

Sir John Purser-Griffith as chairman, Professor Pierce Purcell as secretary, Professor Hugh Ryan and Sydney Young, and George Fletcher [Figure 4.1]. Its two reports were published in 1918, but they were rejected by an unenthusiastic Government in much the same way as the recommendations of the Bogs Commissioners almost exactly a century before. Nevertheless, they established the framework for the systematic exploitation of Ireland's peat resources.

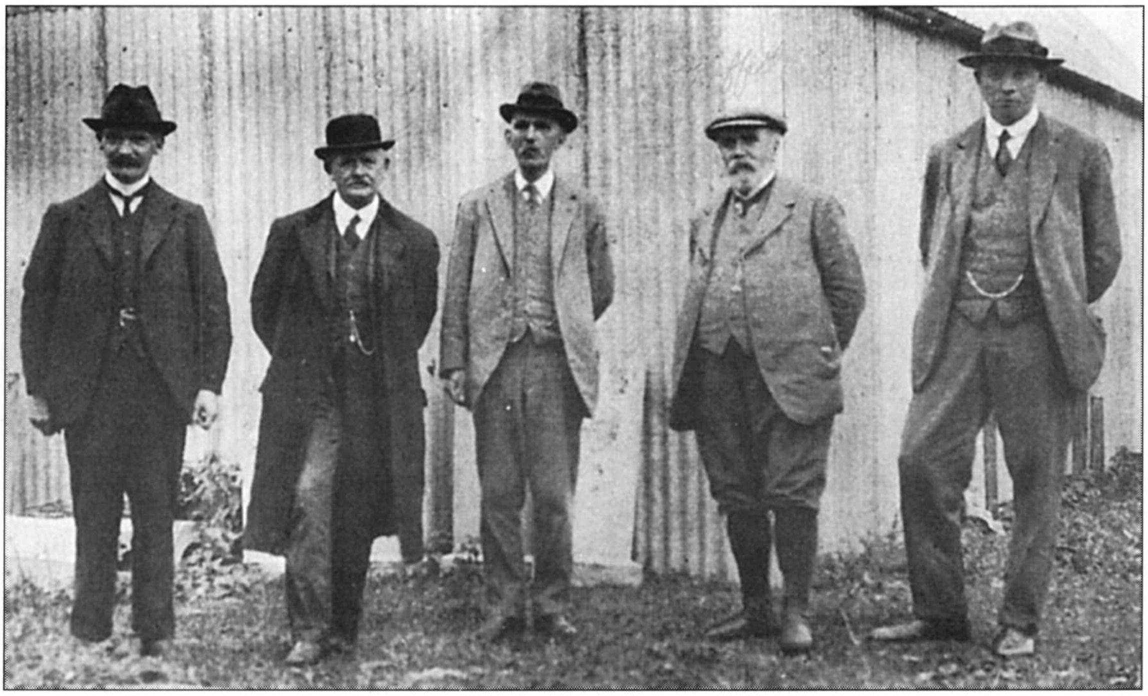


Figure 4.1: The Irish Peat Enquiry Committee, on a visit to Turraun c. 1920.
From left: Hugh Ryan (Professor of Chemistry at UCD), George Fletcher (Secretary to the Department of Technical Instruction for Ireland), Sydney Young (Professor of Chemistry at TCD), Sir John Purser-Griffith (Chairman of the Committee), Pierce Purcell (Secretary to the Committee).

The key recommendations of the Committee were as follows:

1. Purchase of a bog of at least 10,000 acres on which to carry out experimental work with several different types of electrically-operated automatic peat machines; it should be able to produce 100,000 tons of air-dried peat yearly. If necessary, compulsory bog purchase should be used.
2. (a) Provision of four electrically operated peat-winning machines of the automatic dredger, macerator and transporter type, with appliances for collecting, stacking and loading.

   (b) Provision of narrow-gauge tracks with electric locomotives and wagons.
3. Erection of an electric power station of at least 500 kW, using peat-fuelled gas producers, to supply the power required under 2(a) and 2(b), and a chemical plant associated with the power station. (The Committee had a much bigger station in view originally, but they were persuaded to scale this down).
4. Preparation of the bog by:

   (a) Main drainage

   (b) Local drainage for peat winning

   (c) Local drainage for agriculture.
5. Provision of the necessary housing for the employees and of office and laboratory accommodation.
6. Drainage and reclamation of 500 acres of bog for agricultural purposes.

The agricultural parts of these proposals were more or less rejected by the Department of Agriculture on the grounds that they were (for various reasons, in their view) uneconomic. Apart from its considerable influence on later thinking, the work of the Committee did bear fruit in one important respect. Professor Purcell was appointed Peat Investigation Officer to the Fuel Research Department, and he and his assistant, Edward

Duffy, were commissioned to carry out experimental work on the best techniques and approaches to adopt for winning turf by machine. The experimental work got under way at Ticknevin/Lullymore near Carbury in County Kildare, tackling problems such as the best way to dry turf harvested by hand, and testing the latest machinery: in particular the Dolberg macerator. In 1918 the experimental work was moved to Turraun in County Offaly. This early work convinced Purcell and his colleagues of the superior quality of macerated peat, especially for drying. Professor Purcell headed for Canada, Germany and Sweden to study developments there; he was greatly impressed with what he saw.

The findings and recommendations of the Irish Peat Enquiry Sub-Committee were re-worked and presented in updated and modified form in the report on Ireland's turf resources prepared in December 1921 for the incoming Free State Government by a Dail Eireann Commission set up to inquire into the country's resources and industries. This report provides a clear, informative and condensed account of the peat resource in Ireland at the time. It considered all the options for using that resource: hand-cut and machine turf, carbonisation for the manufacture of charcoal and lighting gas, moss litter, alcohol production, the use of cutaway and uncut bog for agriculture, and the various power options: steam engines, steam turbines, pulverised peat for use in rotary kilns and locomotives, producer gas for gas engines, gasification of turf with ammonia as a by-product. It provided a wealth of information on the experience and achievement of other countries. The Turf Committee consisted of Professor Hugh Ryan as Chairman, Joseph Connolly, Thomas Dillon, Maurice Moore, J. P. O'Shea, Roger Sweetman, Robert N. Tweedy, Henry Walsh, and Darrell Figgis as Secretary. But it went significantly further than the Irish Peat Enquiry Sub-Committee in its forthright recommendation that the State should take over all the major bogs and develop them itself:

> ... in order to prevent speculation tending to frustrate enterprise, the State should acquire all the large bogs in the country at bog value, and that it should reserve a small number of the very large bogs, primarily for meeting national wants, and secondarily for carrying out national experiments.

The 1921 Commission also recommended turbo-alternators instead of gas producers for the generation of electricity on a large scale, and it suggested that experimental work should be carried out on the use of pulverised fuel in rotary kilns and locomotives, and on the manufacture of fertilisers and explosives from peat. The 1921 Bog Report formed the basis of government policy on the development of bogs in the newly-independent Irish Free State, but it was some time before its key recommendations were implemented. To begin with, there was little real interest at Government level in the mechanical development of the bogs. Sean Lemass was sceptical of the value of mechanisation, in spite of Duffy's demonstration that the production of machine peat with the Dolberg macerator was economical. According to Todd Andrews (no doubt with some exaggeration) Lemass had never even seen a bog – but then, neither had Andrews himself before 19321. However, he was persuaded to support the establishment of a peat briquette factory by the Peat Fuel Company under Professor Purcell's guidance at Lullymore in 1933, on a bog made available by Sir John Purser-Griffith. The fortunes of that Company have already been outlined in the last chapter.

The Turf Development Board

In 1933 Sean Lemass asked Todd Andrews to join the Department of Industry and Commerce and take the development of the bogs in hand. To start with, a number of bog improvement schemes were undertaken and an attempt was made to introduce quality standards for hand-won turf. Local co-operative turf societies were actively promoted; 180 of these were established over the next few years. Andrews found it difficult to get things done from his subordinate position in the Department, and in the following year (1934) the Turf Development Board, a private limited company financed by the State, was set up. Andrews asked R. C. Barton to become chairman and appointed himself Managing Director. The other members of the Board were Aodhagan O'Rahilly, Bill Quirke and Dr

Kennedy of UCD; shortly after, Dermot Lawlor became General Manager. In the same year the Turf Development Act was passed by the Dáil; among its most important provisions was one which gave the Minister power to acquire land required for the Board's operations by compulsory purchase.

Andrews' first visit to Turraun was an eye-opener: 'the developed section of Turraun bog seemed to me at the time to be vast; the net-work of overhead electric cables, the automatic cutting machines and the peat moss plant driven by electricity inspired me with great hopes for the future. In fact Turraun was a very small installation – no more than a pilot plant – and the area of bog worked was miniscule'. The village of Pullough, on the canal at the edge of Turraun, was an eye opener of a different sort; here he found 'evident squalor and poverty on a scale much worse than I had ever seen even in the Dublin slums of my youth ... It was truly the home of the "bog-man" tradition'.

Andrews and some of his colleagues had further inspiration the following year, when they went on an exploratory visit to investigate industrial peat production in Germany and Russia – the fourth such visit: before this there had been the visit of the Purdon Commission in 1872, the visit by the Fuel Research Committee in 1919, and that two years later by the Dáil Commission. How necessary this was may be open to question. Purdon's account already contained all the data on the development of machine sod peat necessary to proceed, and Turraun was at this time an excellent, efficiently-working production unit with an output of 8,000 tons of macerated sod peat a year. Moreover, two of the greatest experts on mechanical production – Griffiths and Purcell – were living in Ireland. However, Andrews and his colleagues were impressed by the completely different attitude to bogs and their development in Germany as compared with Ireland, and by the level of training, expertise and dedication they met everywhere among turf people. At that time Russia was producing 17 million tons of machine turf, and 10 million tons of milled peat a year, much of it for use in power stations, and the rest for making briquettes and for industrial use. Andrews came home thinking: if the Russians and Germans can do it, so can we. The method they chose to adopt was the excavation, maceration and spreading method they had seen at Klasmann's Works at Meppen in Germany, and they decided that the best way to use it was for generating electricity beside the bog. In actual fact 'we' were already doing it: there were two similar German baggers at Turraun, bought by Purser-Griffith with his own money in 1924, and electricity had been generated here by burning peat since 1924. Andrews was in a position to copy Turraun in 1933 without the need for the German visit, in which case a large supply of macerated sod peat would have been available during the war years.

The conversion to machine peat was not complete. In a letter to the Department in October 1935 the Board reported that 'as a result of the Report by the delegation to the continent to inspect turf enterprises there the Board was now clear that mechanical production of turf is necessary to supply towns and cities – but that it was convinced that at no date in the near future is it possible that mechanically produced turf will be in a position to supplant hand won turf in the small towns and local markets generally or for the use of family communities'.

However, it was decided to begin the mechanised production of sod peat. In 1935 the Board bought John Purser-Griffith's plant at Turraun (1,500 acres, of which 500 had been developed), and in 1939 it acquired the milling and briquetting operation at Lullymore. In 1936 it bought 4,000 acres of raised bog at Clonsast in Offaly and 500 acres of blanket bog at Lyrecrumpane in Kerry. Clonsast was chosen because of its size, because it was in the catchment of the Barrow arterial drainage scheme, and because it was (or so they thought) free of buried timber. Meanwhile, the Government had asked Professor John Taylor of UCD to carry out research on the efficiency of turf as fuel, and by 1937 he had designed an 'improved' stove and range.

The work of development at Clonsast began in 1936 with the digging of 500 miles of drains by hand, and the laying out of many miles of rail and power lines. Two baggers (as cutting machines were known in Germany) and two sod collectors were ordered from

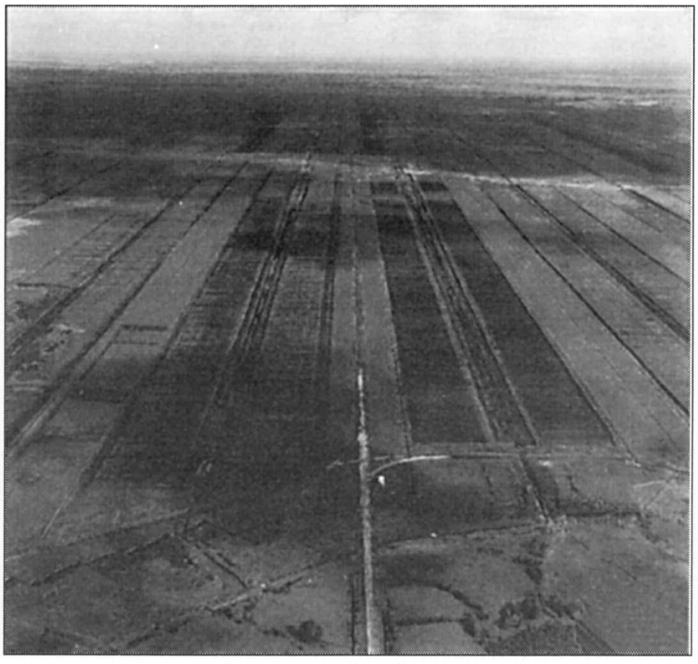


Figure 4.2: Clonsast from the air in 1947. The production area covered 4,700 acres. Mechanised peat developed commenced in 1935. In 1948 there were six baggers in operation, producing between them c.100,000 tons of peat a year; each bagger can produce up to ten tons of air-dried peat an hour. There were 360 miles of drains and 45 miles of cutting trenches. At the peak of the prod uction season 600 men worked on the bog, half of them housed in hostel accommodation.

Germany. It was anticipated that it would cost £200,000 to bring Clonsast into full production (the estimate was up to £263,000 by 1940), and that it would employ 200 men full-time, plus up to twice this number on seasonal work. The Offaly Board of Health built 50 cottages and the Board built its first hostel. Its production target was 100,000 tons a year.

The first Klasmann bagger arrived in 1938-9, and after assembly on site started work at the east side of the bog in Trench 14 in 1939 [Figure 4.3]; it could excavate up to 120 m^3 an hour when it operated smoothly, which in the early years was seldom enough, largely because the bog was not yet fully drained. The Turf Development Board experienced considerable teething problems with Clonsast. The imported machines were ill-adapted for working on the deep and almost undrained Irish bogs. An interval of at least seven years needs to elapse after the commencement of drainage before the surface of a natural raised bog is dry enough for these large 40-tonne sod peat machines to work on them without subsiding into the twelve-foot deep main drains, whence they can be rescued only with skill and the expenditure of a great deal of muscle power. The advice of Herr Mecking, the expert brought from Klasmann's to advise the Board was disastrous. Where local experience going back a hundred years and more could have indicated the folly of such an approach – in addition to the considerable experience acquired in this area at Turraun – he insisted that six-foot deep trenches should be opened in a single operation. This was the practice in German bogs, where the peat drainage properties were very different from Ireland. It took a local man, Pat Gorman, to teach the correct approach. These first Klasmann machines were bog dinosaurs, which evolved into much more efficient and user-friendly machines in the hands of the Turf Development Board and Bord na Móna – and after ten years of drainage had provided a properly firm surface for them to work on. Other makes of turf-cutting machines were also tried at Clonsast: a Dolberg, later re-located to Turraun, and a Lilliput, which was like a small version of the Klasmann, with a spreader arm that was a mere 35m long (compared with 54m on the Klasmann).

Lyrecrumpane went into production in 1938, using a German diesel-driven bagger, while production continued at Turraun. Clonsast started production in 1939. As the new machine turf became available a new problem was encountered: promotion and marketing. There was a decided antipathy to turf as fuel, especially in the cities and in industry. The Turraun Sales Office had found during its fourteen years of operation just how hard it was to compete against cheap coal.

With the advent of War, the full development of Clonsast became more urgent. The shortage of labour forced the Board to recruit from the Dublin Employment Exchange. A hostel was built to accommodate 100 men from Dublin; the first batch of 57 single men left Dublin in April 1940 for what for most of them might as well have been another continent. Many of those originally interviewed refused to go. The hostels which 'operated a benign form of army discipline. Each of the men had a single cubicle, and received meals and a minimum of 4/- a week pocket money on top of their wages, which were paid a week or two after their period of work. Many of the turf workers in the hostels during the war years came from the western counties of Galway and Mayo, many of them Irish speakers. Workers from Kiltimagh gave a new word to the English language as spoken in Ireland, where the word 'culchie' has come to mean (in a derisory sense) a 'bogman'.

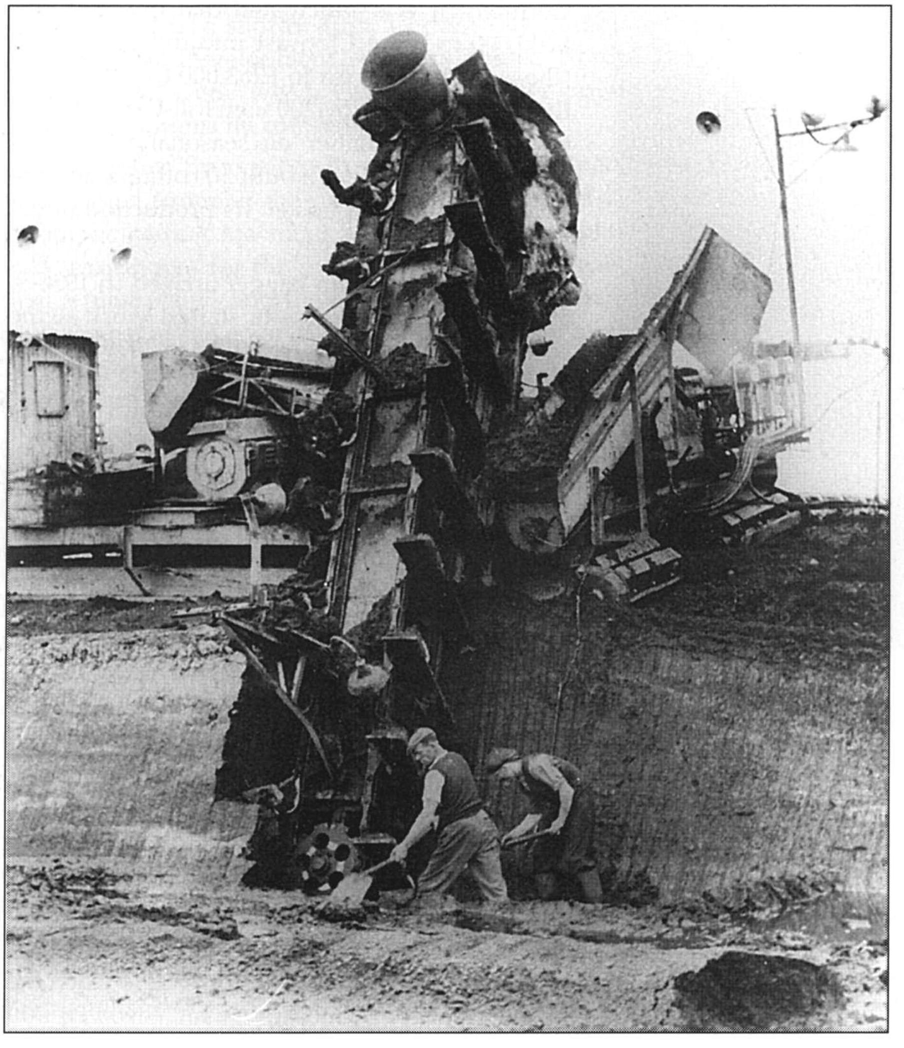
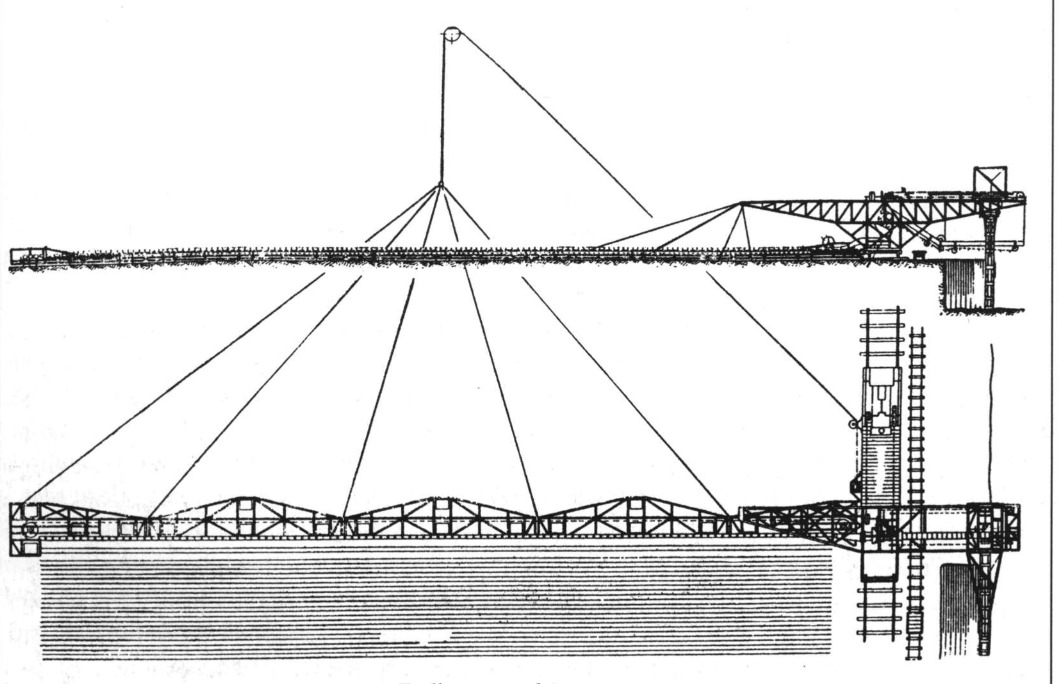
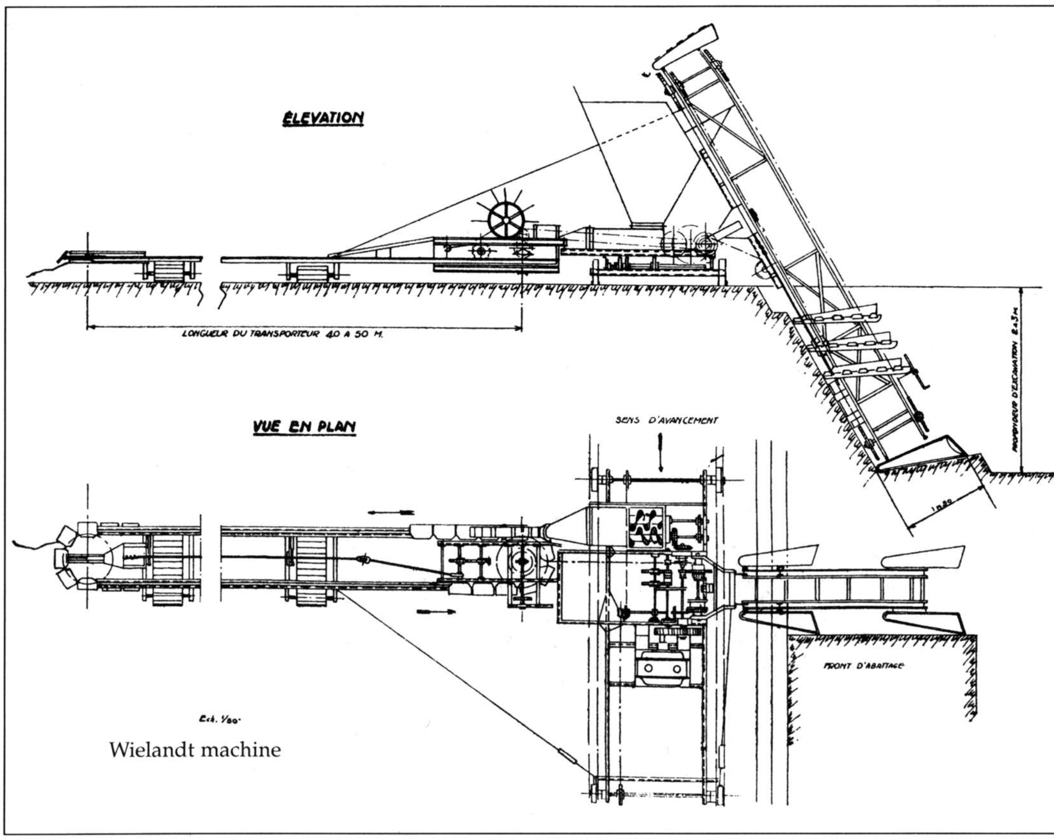


Figure 4.3: Bagger in action. The automatic excavator cuts a 2m wide bank of peat to a depth of 3m. The macerated peat is fed out onto a 54m spreader arm in a continuous 'sausage', and is deposited in parallel rows where it is cut by discs. The diagrams show the general layout and design of the Wielandt and Dolberg machines.



Dolberg machine



Wielandt machine

By 1938 the Board had surveyed Kilberry and Timahoe in Kildare, Blackwater and Shannon Harbour, Hill of Down in Meath, Dallow in Roscommon, Glenties in Donegal and Barrahaurin in Cork, and was at work on Mallaranny and Inny Junction bogs. Surveys of the bogs of the Shannon Basin, the River Suck and the Brosna were being planned.

Because of the teething problems with the machines, labour problems and the difficulty of trying to get the operation started during the War, the Turf Development Board progressed more slowly than the optimists of the 1930s would have liked. Turraun however had no production problems because Purser-Griffith was present on site. The

Figure 4.4: De Valera visiting Clonsast, c. 1938. Also in the picture are Frank Aiken (on left), Todd Andrews (to right of Aiken) and Vivion de Valera (to right of Eamon de Valera).

Turf Development Board had only one briquette factory (Lullymore) during the War years; all its other operations were on semi-mechanised bogs. It played an important role during the War in ensuring a sufficiency of fuel for the whole country when imported coal was unavailable. Between 1942 and 1947 it organised the delivery to Dublin of over half a million tons of hand-won turf.

Only a relatively small amount of turf was produced by the three new machine peat Works during the War, but the spotlight had now shifted to the wartime turf campaign, and the Board was spared the criticism of opponents – including the Department of Finance – that it would otherwise have had to endure. During the War years the Board acquired invaluable experience in the actual business of producing machine turf. The difficulty experienced after the War in procuring suitable machines and components forced the Board to look to its own resources and the engineering skills available in this country, leading very soon to the achievement of a great degree of self-sufficiency in machine design and manufacture. At the same time, new designs of foreign peat machines were bought and tested for possible use here.

The establishment of Bord na Móna

The Board submitted its post-war plans to the Government at the end of 1944, setting out its new ten-year Development Programme for machine peat, costed at £3,870,000; this was introduced as a White Paper in December 1945. The Turf Development Board became a statutory corporation like the ESB (Electricity Supply Board). The production capacity of Lullymore was increased to 20,000 tons of briquettes a year, and Portarlington was joined by a second sod peat power station built at Allenwood in County Kildare in 1952. A new peat moss litter factory was proposed for Kilberry. Konrad Petersen accepted the invitation to become the first manager of Kilberry, in spite of the substantial drop in salary involved in his move to Ireland. Petersen was a Latvian who had taken his degree in Dublin before returning to work in his own country. He had extensive experience in the peat moss industry in the Baltic States, and by the time war broke out he had risen to become head of the Latvian bog development department.

The new plan also proposed the setting up of a peat experimental station at Newbridge. In the years which followed important research work into areas such as machine design, methods of drainage and drying, and the nature of turf combustion was carried out. Research on combustion was important because most of the research and development on the design of combustion appliances for industrial or household use had been done with coal in mind. However, peat needs different kinds of grates or furnaces from coal, because whereas a pound of household coal requires around 200 cubic feet of air to bring about the complete combustion of its carbon and hydrogen, a pound of machine turf needs only half this. If a grate (or furnace) designed for coal is used to burn turf, the excess air will carry much of the heat up the chimney, resulting in a loss of as much as 65% of the thermal efficiency of the turf as against 30% in a properly designed grate.

A long list of new bogs for machine sod peat development was announced **[Table 4.1]**. The new plan anticipated 3,400 full-time jobs, and as many seasonal jobs. A production target of a million tons of machine-won peat a year was set. It was expected that this could be produced at a cost of £1 to 25/= per ton at the bog, at a time when hand-cut turf was about £1 a ton.

In 1948 Bord na Móna took over the running of the County Council turf-cutting schemes at the Government's request, and equipped many of these bogs with de Smithske semi-automatic cutting machines from Aalborg in Denmark. 200 of these machines were purchased. Peat was dug by hand, then raised by scraper chain up into a macerator, from which it was extruded and moved along a chain-operated spreader arm of ten metres length, before being spread by hand **[Figure 4.5]**. However, the scope of the project was severely curtailed by the Coalition Government which came to power later that year. The bogs with the new machines were kept open, and continued to produce around 100,000 tons a year until 1953. The other bogs were closed, causing a substantial rise in the emigration of turf-workers, particularly from the west. Production by the semi-automatic de Smitske machines between 1948 and 1953 (inclusive) was 405,000 tons. During the first year of the scheme these machines worked on 85 bogs in 12 counties, declining to 17 bogs in the final year.

Table 4.1. Bogs for development in the post-war development plan.

Bog	County	Development £	Output £
Clonsast	Offaly	65,000	120,000
Carrigcannon	Kerry	36,000	8,000
Derrycashel and Mountdillon	Roscommon	236,000	60,000
Derraghan	Longford	104,000	20,000
Derryaroge	Longford	161,000	40,000
Hill of Down	Westmeath	109,000	20,000
Attymon	Galway	93,000	20,000
Coolnagun	Westmeath	100,000	20,000
Derryounce	Offaly	78,000	20,000
Glenties	Donegal	65,000	15,000
Littleton	Tipperary	161,000	40,000
Barna	Kerry	69,000	15,000
Boora	Offaly	303,000	100,000
Tomduff	Offaly	323,000	80,000
Derries	Offaly	116,000	20,000
Timahoe North	Kildare	240,000	60,000
Timahoe South	Kildare	454,000	120,000
Codd	Kildare	110,000	20,000
Glashabaun	Kildare	172,000	40,000
Ballydermot	Kildare	160,000	40,000
Black River	Kildare	310,000	80,000
Lodge	Kildare	118,000	20,000
Turraun	Offaly	Developed	14,000
Lyrecrumpane	Kerry	Developed	10,000
		3,763,000	1,002,000

	Development	Output
Lullymore briquetting factory.	£40,000	20,000 tons
Kilberry peat moss litter factory	£37,000	3,500 tons

Total estimated cost of development programme, £3,750.000

Figure 4.5: De Smithske machine at work in the 1950s. In 1948, 200 of these semi-automatic machines were introduced in small areas of bog, each capable of producing c. 2,000 tons of air-dried peat a year.

Comhlucht Siuicre Eireann, the State sugar company, operated a somewhat similar scheme using more advanced machines. These developments using smaller bagger-type (and other) machines were important, because they provided experience of an approach to bog development which became widespread when the Turf Development Act of 1981 made grants available for the development of bogs by private enterprise. This grant scheme was administered by Bord na Móna on behalf of the Department of Energy. These smaller baggers were supplied by Schnittger of Edenderry, and they continue to be used today (See page 27).

In June 1946 the Turf Development Board underwent the final step in its metamorphosis to Bord na Móna. The first board had R.C. Barton as Chairman and C. S. Andrews as Managing Director [**Figure 4.6**]; the other directors were A.Ó Raithile, Prof. T. Wheeler and A. Woods. As much as anything else the change in name was because of the widespread negative psychological associations of bogs and turf in the Irish mind in those days. One of the few objectors to the change of name seems to have been the acerbic *Irish Times* columnist Myles na gCopaleen, who complained about the way 'The Board has arrogated to itself an atrocious neo-decadent Irish title'. His idiosyncratic wit was probably not appreciated by everybody at the time!:

> Móin means, of course, not 'turf' but 'bog' and Dr Dinneen affirms that *Bord* means 'verge'. 'The Verge of the Bog' is simply silly as the name of a great catering house. Assume, however, that the actual words are admissible – the syntax is execrable and quite alien to the genius of the language. I denounce it absolutely and require to be furnished with the mane of the party responsible ... The use of the article with adjectival noun – as in Bord na Móna – is unauthorised, inelegant, and utterly unholy in my sight ... I had intended to advert to the innate questionability of this concern, set up for the purpose of incinerating large sections of your strictly limited national patrimony. *An Bord Losctha Eireann* might be an idea for a title. That big subject must, however, await another day.
>
> 'Cruiskeen Lawn', *The Irish Times,* Monday April 29, 1946.

Figure 4.6: Photograph of Bord na Móna Works Managers, Engineers and HQ Staff in 1949. Front row, from left: A.D. Sheahan (Sec.), Miss B. Flynn (Chief Acc.), C.S. Andrews (Man. Dir.), D.C. Lawlor, (Gen.Man.), M. Maguire (Chief Eng.). Second row, from left: J. Dunphy, W. Stapleton, C.B. Murphy, C. Blair, P. Cogan, E. Redehan, P. Barry, S. O'Donoghue, L. Collins, J. Connolly, J. Lynch, P. Hogan. Back row, from left: C. Petersen, M. Conway, J. Cooney, S. McAllister, W. Green, P. Ó Faolain, E. Glynn, J. Gaved, A. Comerford, E.V. Switzer, McGloin, D. Power, J.J. Kelly, F. Murphy, M. Keane, T. Lee, L. Rhatigan, J. Martin.

Bord na Móna is a commercial company which has to make its own way without help from the State, but it does get its capital in the form of State loans, on which it pays interest, and loans from other sources such as the European Investment Bank. But without this privileged semi-state status a company like Bord na Móna could not survive, because a normal private company could not afford to wait for several years before beginning to reap the reward of its investment. The systematic exploitation of the larger bogs by Bord na Móna represents a massive financial investment which could only have been justified in economic terms by including projected revenues from peat extraction for the entire production life of the bogs. In simple terms, Bord na Móna needs to take out as much peat as possible to justify the level of investment it represents. Whether the same decisions would be taken today is an academic if interesting question, because it is too late to push back the socio-economic tide which will empty the larger raised bogs of their peat reserves.

The next important piece of legislation was the Turf Development Act of 1950, which provided for an expansion of activity that would bring capacity up to two million tons of machine sod peat per annum. It also gave the Board authority to construct housing for the permanent workforce which the increasing sod peat mechanisation made necessary. The need for huge numbers of seasonal workers became less, and the hostel accommodation needed to house them was phased out. Six hundred of these houses were built, in groups of between eight and 150, bringing to fruition an idea which had been dear to the Peat Enquiry Sub-Committee of 1918, one of whose recommendations had been the establishment of an 'agricultural colony' on land adjacent to the bog. The inhabitants of these colonies would devote their labour to the winning of sod peat, while their families would spend their summers helping to harvest it, 'a healthy and not too heavy occupation' in Professor Purcell's words. They felt that this was the only way to ensure a sufficient labour force. In a lecture in 1933, Professor Purcell recalled the vision of the Sub-Committee:

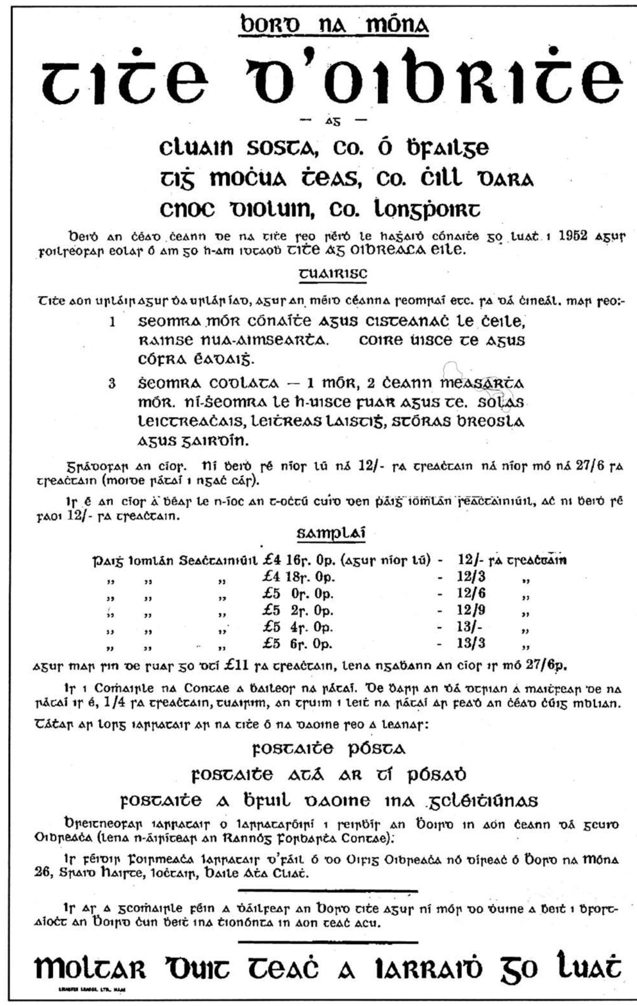
> They visualised the utilisation of the reclaimed land for purposes of agriculture, and they had hopes in this way of getting up peaceful and contented little colonies. It was an ideal scheme, one they had very much at heart, and it distressed them considerably that it was not made operative.

Undoubtedly, here lies the germ of the idea of the Bord na Móna villages of later years [**Figure 4.7**]. In the event, the hostels of the early days of Bord na Móna had more in common with prison camps than the idyllic settlements envisioned by Purcell and de Valera, but as they were established under difficult wartime conditions, this was inevitable. The wide sweep of recruitment was also probably inevitable; when Lar Daly

Figure 4.7: Children at play in the Bord na Móna village at Kilcormac.

(Bord na Móna engineer) sought to recruit 400 workers for the new Boora works in 1946, he received only twelve applications from within a six-mile radius of the works. Such a large number of men from outside the area necessitated the provision of a Camp or Hostel at Boora. With the changeover from sod peat to milled peat in 1952 this was closed down, because enough local machine drivers were available by this time – and the age of travel by car had arrived, widening the local employment catchment considerably.

The change-over from sod peat to milled peat was a key turning point for Bord na Móna. The high cost of sod peat production in the early 19S0s might very well have put the company out of business. When Lullymore was taken over by the TDB in 1940, P. Cogan was appointed as Manager; on the establishment of Bord na Móna in 1946 he moved to Head Office as Assistant Chief Engineer, and in this position he was well placed to argue the advantages of milled peat, having seen its production and progress at Lullymore, where Jim Martin had stepped into his shoes. In 1952 Martin followed him to Head Office, charged with the implementation of the first milled peat programme. This necessitated the purchase of 96 harvesters and disc-ditchers, 182 millers, ridgers, 278 6-cylinder and 4-cylinder Gardner diesel engines, along with over 200 Ferguson TE20 diesel tractors, the construction of maintenace workshops and the installation of large diesel bulk storage tanks. The further expansion projected under the second Peat Development Programme required yet more machines, but by now Bord na Móna had acquired sufficient expertise to manufacture these in Ireland. This enabled an expansion in milled peat output from around 2.5 million tons to some 4 million tons. It was a remarkable achievement, made possible through the ingenuity and dedication of Bord na Móna people whose names and work have already been confined to a neglected archive. The Third Development Programme (1974) planned to acquire a further 63,000 acres of bog; 92% of this was allocated to milled peat (estimated output 2.75 million tons a year), 5.5% to sod moss peat and only 2.2% to sod fuel peat. The Board was in the process of carrying out detailed investigation on a further 43,000 acres (in 115 separate stretches of bog) in 1979.


BORD NA MÓNA

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FOSTAIṪE ATÁ AR TÍ PÓSAḊ
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Is ar a gcomairle féin a ḋáilfear an Bord tiṫe agus ní mór do ḋuine a ḃeiṫ i bfostaíoċt an Ḃoird ċun beiṫ ina tionónta in aon teaċ acu.

MOLTAR DUIT TEAĊ A IARRAIḊ GO LUAṪ

Figure 4.8: *Poster advertising Bord na Móna houses for turf workers at Clonsast, Timahoe and Knockdillon in 1952. The posters were produced both in Irish and in English. The rent charged was one eighth of the weekly wage, with a lower limit of 12/= and an upper limit of 27/6 a week. The houses were only available to married workers, workers about to marry, and workers with dependents.*

Some 130,000 acres of bogland were acquired by Bord na Móna under its First and Second Development Programmes, which spanned the periods 1946-50 and 1951-73. This included all the bogs which at that time were regarded as suitable for economic development. The Third Development Programme (1974) was initiated in response to the oil crisis of the 1970s; with the great increase in the price of oil it became economic to work much smaller bogs, and the Board therefore set out to acquire all raised bogs above 50ha in size which were within reasonable reach of existing works, or could be combined together to form new groups. This meant that Bord na Móna's activities now extended to include intermediate bogs, located for the most part between the Midlands and the west of Ireland. It also meant a lot more work for the Land Acquisition Section, because most of these bogs had been completely divided into large numbers of small Land Commission turbary allottments [**Figures 1.19, 1.20, 1.22**]. A further 90,000 acres have been acquired under the Third Programme.

Bord na Móna is now the second largest peat-producing operation in the world. In 2006, Bord na Móna owned 80,000 ha of peatland, employed approximately 1,800 people

Figure 4.9: Aerial view of Bord na Móna camp at Timahoe, County Kildare, pre-1946.

Figure 4.10:
Life in the camps: Mrs O'Kelly, the President's wife (left of picture), inspecting the hostel kitchen at Robertstown Camp in the 1950s. To her right is Chief Hostel Supervisor W.J. Stapleton; on his left Bord na Mona's accountant, Miss B. Flynn. Todd Andrews stands behind. one hopes their expressions do not reflect their innermost response to the quality of the food being inspected!

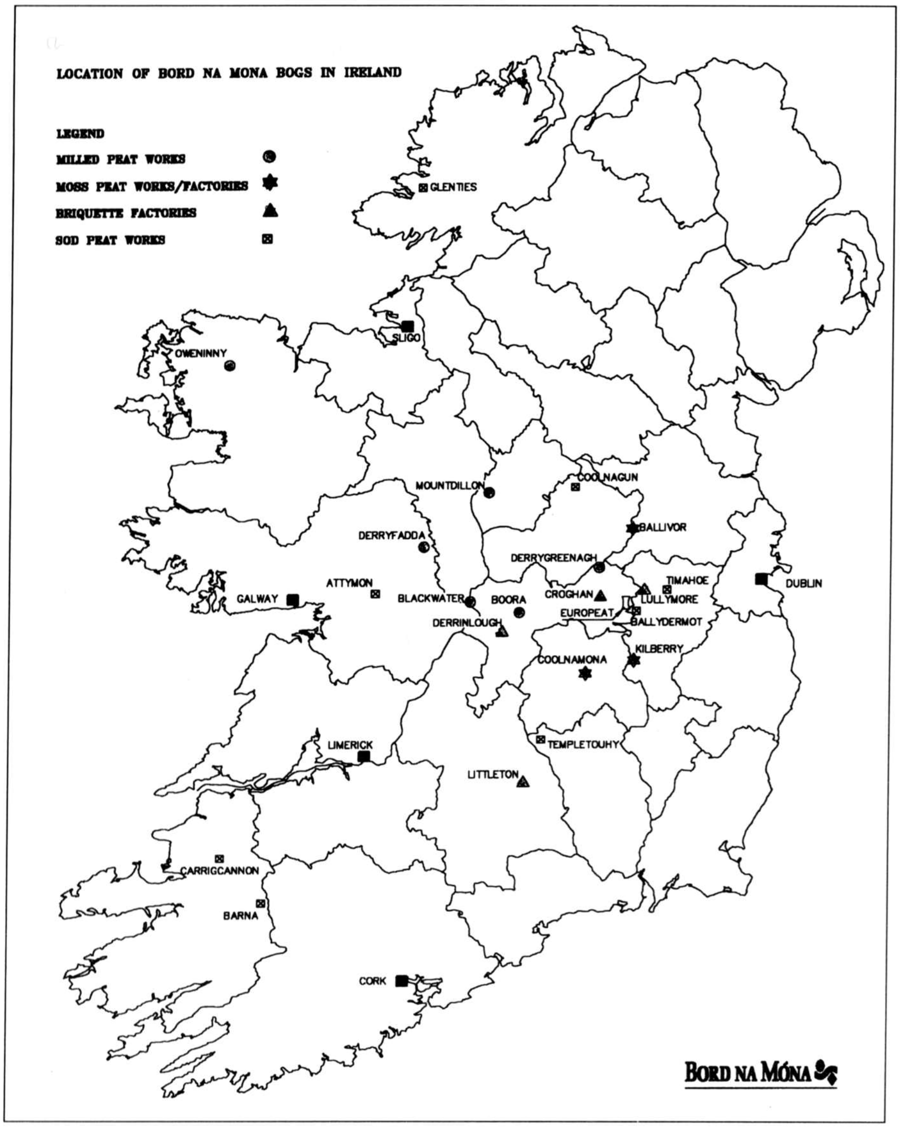


Figure 4.11: Map of Bord na Móna works.

(2000 at peaks with a total annual payroll of €95 million). It has a turnover of nearly €296 million. It operates out of 30 localities mainly in Ireland, but also in the United Kingdom and eastern United States. Bord na Móna harvests 4 million tones of milled peat per annum, the main market for this milled peat being the energy sector (electricity). Based on estimates of volumes harvested by private peat producers it may be inferred that a probable total of 100,000ha is being utilised for peat harvesting in Ireland, i.e. 7.5% of the original total peatland area. Of this, 6.4% is attributable to energy peat; the remainder to horticulture.

Bord na Móna's bogs are organised in work groups, each of which has its own centre. An important change in Bord na Móna's work-practice philosophy took place in the years after 1988, following a fact-finding visit to Finland in that year. Most of the work of harvesting is now done by autonomous or semi-autonomous enterprise groups. From the worker's viewpoint, the new approach has the incentive of greater remuneration. They are given more opportunity to use their own initiative and intelligence, so that the change has resulted in greatly increased flexibility and considerable innovation. From the Board's viewpoint the increased commitment seems to have paid off in terms of increased productivity. Great care has to be exercised in the case of milled peat produced by these groups especially during poor weather years; it is particularly important that correct moisture and quality specifications are strictly adhered to, despite the temptation to ignore them.

Up to the present, the activities of Bord na Móna have largely focused on the large raised bogs, because the irregular contours of low-level blanket bog make mechanical

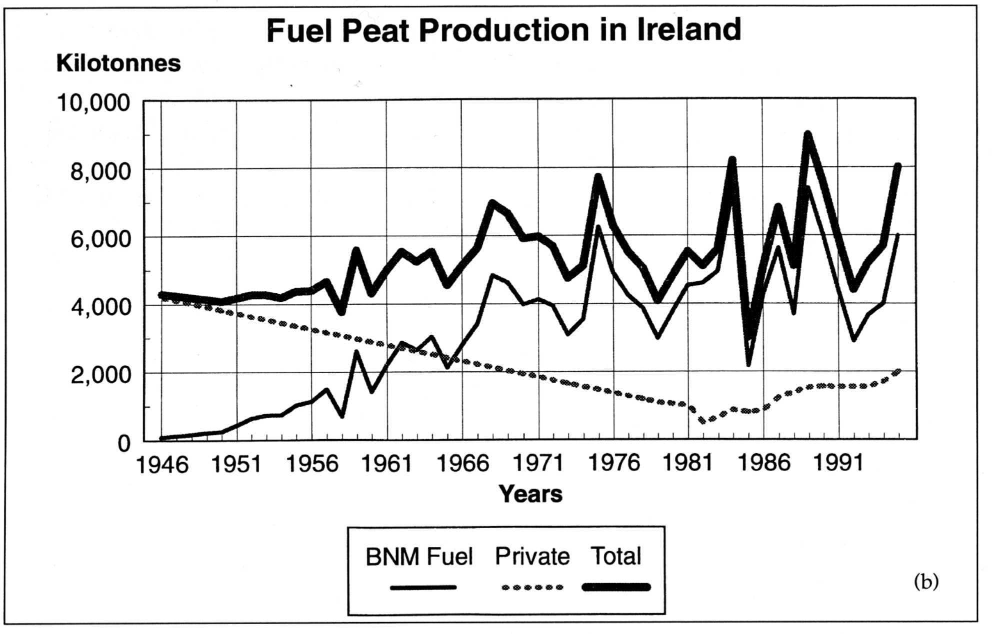
Table 4.2:
Map of Bord na Móna production during the 50 years since its establishment.
(a) Production figures for sod peat, briquettes and moss peat; the figures for peat produced by private operators are included.

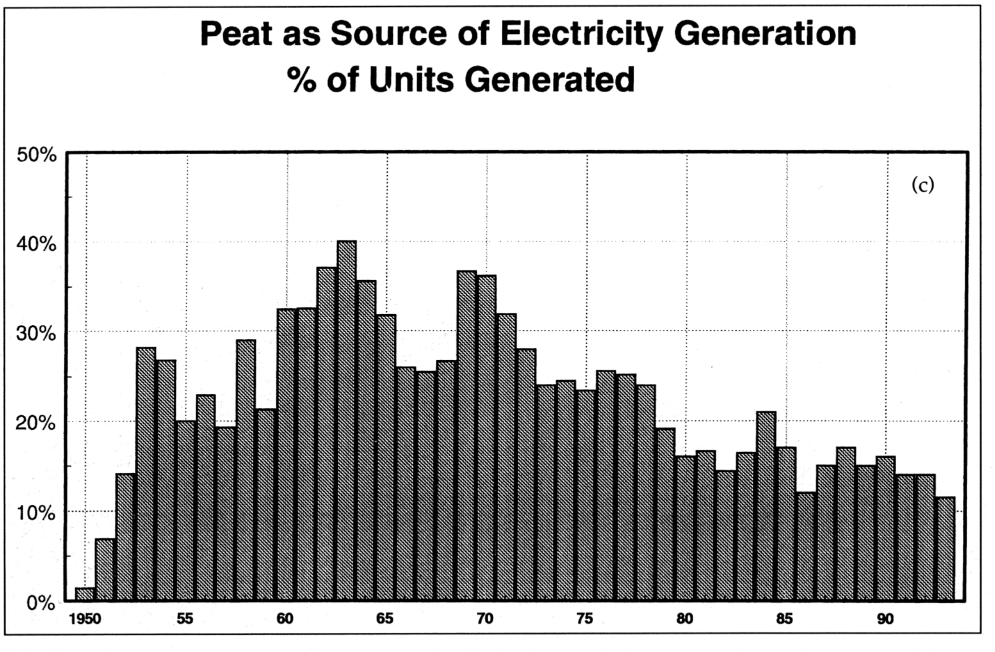
Table 4.2(a). History of Peat Production in Bord Na Móna

Year	Sod Peat Tonnes	Milled Peat Tonnes	Briquettes Tonnes	Moss Peat Cubic Mts	Private Tonnes
1946	97,521	58,193	18,187	-	
1947	86,959	47,993	14,068	24,130	
1948	124,569	50,502	16,913	45,021	
1949	140,410	80,242	14,005	85,616	
1950	197,539	54,574	24,784	76,545	
1951	376,376	68,298	24,525	77,996	
1952	546,633	91,440	30,387	103,871	
1953	636,646	91,592	35,966	125,525	
1954	638,654	101,190	35,634	124,838	
1955	675,557	347,404	41,479	123,759	
1956	841,893	295,051	48,997	150,207	
1957	832,933	662,184	33,125	191,758	
1958	515,435	170,676	32,807	110,590	
1959	918,713	1,687,095	44,285	166,492	
1960	901,113	518,768	124,187	176,988	
1961	1,012,101	1,202,701	210,784	258,746	
1962	938,636	1,915,936	240,635	301,005	
1963	973,135	1,663,965	286,357	347,590	
1964	908,691	2,122,667	295,866	336,798	
1965	728,897	1,401,209	255,491	380,472	
1966	740,915	2,049,536	235,261	434,523	
1967	885,441	2,521.176	249,728	471,473	
1968	903,422	3,927,200	275,314	649,368	
1969	882,825	3,744,466	303,790	739,286	
1970	912823	3,061 102	329,938	737,267	
1971	972152	3,151 246	316,773	828,840	
·1972	878875	3062738	330,660	969,968	
1973	934810	2 153995	315966	1,069,695	
1974	914631	2626568	322406	959,810	
1975	1003420	5.247,911	350801	962,730	
1976	750287	4155555	305614	1.024,624	
1977	965466	3276847	357720	1.181.869	
1978	942699	2914537	318888	1,093,05	
1979	757,145	2,221,588	334,409	1,311,488	
1980	826,220	2,934,393	336,179	1,185,399	
1981	634,409	3,896,515	354,112	1,191,241	
1982	724,606	3,871,748	426,992	1,325,000	350,000
1983	471,007	4,471,510	442,564	1,303,352	463,700
1984	546,324	6,786,850	417,960	1,288,780	680,279
1985	293,926	1,884,076	492,426	1,410,395	607,094
1986	322,367	3,928,153	460,207	1,432,003	663,840
1987	354,000	5,278,000	505,000	1,138,000	1,037,00
1988	230,000	3,465,000	363,000	1,326,000	1,255,600
1989	123,000	7,285,000	355,000	1,170,000	1,389,60
1990	81,000	5,946,000	403,000	1,010,000	1,410,000
1991	84,000	4,318,000	365,000	1,096,000	1,398,000
1992	135,000	2,759,000	394,000	1,216,000	1,300,000
1993	123,000	3,536,000	365,000	1,160,000	1,300,000
1994	94,000	3,646,000	365,000	1,142,000	1,300,000
1995*	60,000	6,500,000	340,000	1,100,000	1,400,000
Totals	**29,640,181**	**127,252,390**	**12,561,190**	**35,136,113**	**14,555,113**

* Estimated

Year	Sod Peat Tonnes	Milled Peat Tonnes	Briquettes Tonnes	Horticulture Cubic Mts
2002	0	2,739,000	269,000	1,896,000
2003	0	5,099,000	284,000	1,799,000
2004	0	4,164,000	209,000	1,822,000
2005	0	3,941,000	230,000	1,701,000
2006	0	3,668,000	231,000	1,803,000





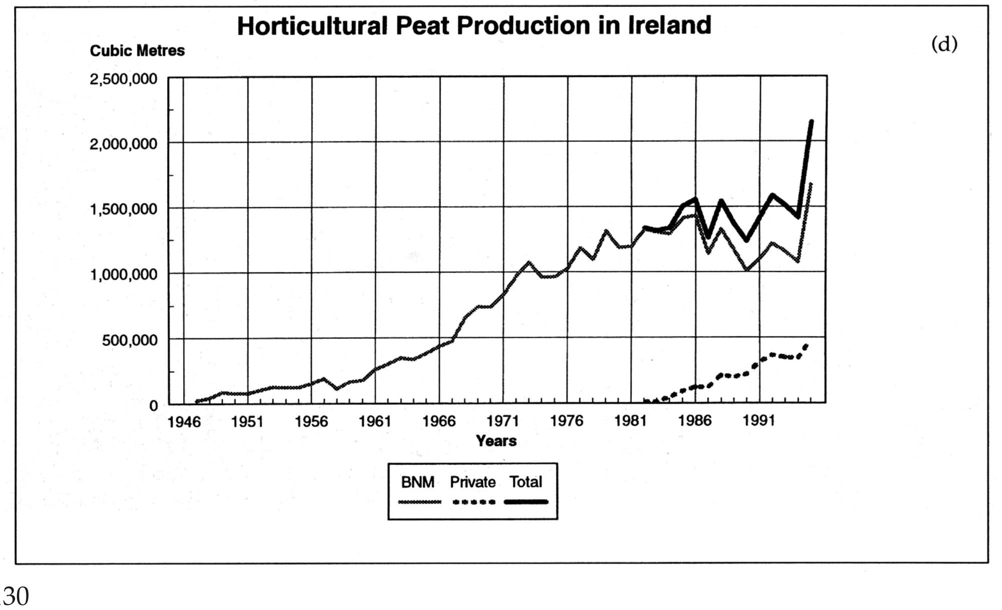


Table 4.2:
(b) Fuel peat production.
(c) The contribution of peat to the production of electricity.
(d) Horticultural peat production, including private operators.

harvesting very difficult, and high-level bog is usually not very deep. Only 8,000ha of blanket bog had been acquired by Bord na Móna by 1981, and of this only 60% is considered to be suited to large-scale development; lakes, steep gradients etc. make the rest uneconomic. It also holds a small amount of midland raised bog (900ha) which it regards as uneconomic. It is in fact unlikely that Bord na Móna will develop its small and scattered western raised bogs. It is much more expensive for Bord na Móna to operate here: as much as 60% higher than in the Midlands, where the capital development costs are about £6,200 to £7,400 per hectare. In addition to this, it is much wetter in the west, with only 50-60% of the number of dry, fine days which the Midlands can expects, and this makes the production of milled peat much more difficult. On the other hand, machine sods from deep peat had a tendency to break into small pieces, making it difficult to harvest as sod peat, though of excellent quality for milled peat production.

Figure 4.12:
The first drains at Oweninny bog were excavated in 1952 by one of the first ditchers to arrive from Garretts after the War. This was first used to ditch Garryhinch bog near Clonsast before making the slow journey westwards - by road! The development of Oweninny bog and Bellacorick power station led to a big reduction in emigration from this part of Mayo.

Preparing the bog for large-scale development

The first task is to identify the bogs which are most suitable for large-scale mechanical harvesting, Up to about 1975 this initial selection was made with conventional maps and fieldwork, but more recently stereo aerial photographs have made the task a good deal easier. When the right bogs have been selected, all the important parameters are measured and recorded: including the type of peatland, the depth, stratigraphy and quality of the peat, its timber content, drainage and communications aspects and so on. Outfalls need to be examined carefully to see if they can be made capable of taking the run-off from the bog during production, down to a level two feet below the bog floor, and to provide settling pond areas to hold back peat fines during heavy rainfall.

Having decided which bogs it wants to develop, Bord na Móna sets about acquiring them. A *Book of Reference* has to be prepared (See **Figure 1.21**). This shows who the owners are, and exactly how much of the bog each owns. This can be a complicated exercise, because as many as several hundred people may have turbary rights on a particular bog, over areas ranging from an acre or two to thousands of acres, and the various records in the Land Registry, Land Commission and Valuation Office must be searched to ascertain who they are. To make things more complicated, one man may have grazing rights and another turbary rights over the same piece of bog (See page 30). The Board has powers of compulsory purchase, but every effort is taken to minimise difficulties to the landowners, who must be fairly compensated. People who want to retain turbary rights are offered alternative turbary elsewhere. All of this can take a long time, but the Board has the power to begin work while negotiations about compensation are still going on. The actual level of compensation depends to a large extent on the use to which the particular bog is being put. If it is just lying idle it is valued today at around £400/ha, but if people are dependent on it for their fuel supply then the price may be several times higher than this. Normally agreement is reached between the owners and Bord na Móna's purchase officer after more or less prolonged bargaining, but if negotiations reach an impasse then an arbitrator appointed by the Minister for Finance is called in to decide on a fair price. In 1982 the High Court declared this approach to be unconstitutional, and the procedures wrong. However, on appeal, the Supreme Court decided that it *was* constitutional, but that the procedures were loose. In future, the Board must examine each case and question it before giving a decision for a CPO (compulsory purchase order).

It takes several years to get the bog ready for production, because it is essential to drain it properly first. This is important for two main reasons: to reduce the water content of the peat which is to be harvested, and to make the bog surface dry enough for the machines to work on and for the spreading of the harvested peat. Undrained peat is 95% water, and this has to be reduced to 90% before the machines can work efficiently. This may not seem like a very significant reduction, but it actually involves the removal of half the water in the raw peat. At 95% the ratio of water to solid matter in the peat is 19:1 which means it contains less solid matter than milk – put at 90% moisture the ratio is down to 9:1 (100kg peat at 90% moisture will reduce to 20kg milled peat at 50% moisture, or 14kg sod peat at 30% moisture). Because of the high rainfall and relative humidity, drying is especially difficult in Ireland. Bord na Móna's annual production of peat is at present approximately 44.5Mm^3 @ 95%, divided between milled peat, moss peat and sod turf as follows:

Milled fuel peat @ 55% m.c.	4.5 Mt	= 40.5 Mm^3 @ 95% m.c.
Milled moss peat @ 55% m.c.	0.3 Mt	= 2.7 Mm^3 @ 95% m.c.
Sod peat @ 35% m.c.	0.1 Mt	= 1,3 Mm^3 @ 95% m.c.
		44.5 Mm^3 @ 95% m.c.

Drainage of Bogs for machine sod peat and milled peat

Figure 4.13: Digging drains by hand. Before the invention of the disc ditcher, bog drains had to be cut by hand, an enormously laborious task. The Photograph shows the making of the first cut on Clonsast Bog in 1937.

Bord na Móna's approach to drainage is a modern adaptation of the old method of tapping the water by surface or 'sheep drains', which are deepened year by year, a method very effectively employed in Galloway in the 19th century. Attempts were often made in the last century to drain bogs by cutting a deep drain to a loughan in the centre of the bog, but this is completely ineffectual: the first winter will obliterate the drain. Instead the drain must be extended bit by bit from the dry ground into the bog, taking several years in the process for sod peat development until eventually the lake is reached. Extensive drainage works were carried out in bogs in 1852 and subsequent years by the Government, but they were a failure because the behaviour of peat drains was not understood. Until the introduction of the disc ditcher in 1936, the drains were dug by hand. Today drainage is usually done by machine, but it's not a one-off operation. If the newly-opened drains were simply left they would be very quickly close in from both sides and from the bottom, so they need to be deepened every year. Sometimes natural drainage may have to be supplemented by pumping, especially in later stages of bog development or on low-level bogs.

This slow deepening of the main drains only applies to machine sod bogs. The great drains for sod peat bogs cannot be dug to their full depth all at once; this has to be done in stages because of the peculiar way peat shrinks as it dries out. In the first year, a criss-cross network of drains 100-120cm deep is opened up across the bog using Cuthbertson ploughs; they are further deepened for several years running using disc ditchers. As the bog dries, the peat in the drain walls dries more quickly than the rest – by around 50%, so that the solid content of a given volume doubles. The whole operation usually takes between five and seven years, after which sod production machines (baggers etc.) can commence work.

The preparatory drainage of an intact bog for milled peat production takes less time than for sod peat production. In the case of milled peat the preparatory drainage by plough, and follow-up disc ditching on virgin raised bog, takes less time than preparatory drainage for sod peat production. This is because milling is a surface operation while sod peat involves very deep excavation. On drier bogs with little Sphagnum, milling can commences as little as two years after the commencement of drainage. Wet sphagnum bogs take several years longer. The idea of the disc ditcher was first suggested to the British Peco Company by Mr G. Owens (workshop foreman at Lullymore) and was made and delivered by Garretts of Leiston (England) as an attachment for a harvester chassis at Lullymore in 1936 **[Figure 4.14]**. The machines used for drainage need to be like gigantic pond-skaters; they must exert a pressure not greater than 1.3 p.s.i. (8.8kPa) – which is less than a third of what an average man would exert walking across the bog. Most machines involved in the production process are designed to bear down on the bog surface with a pressure of about 1.8 p.s.i (12.75kPa). This is achieved partly by spreading the weight by means of tracks, partly by using lighter metals such as aluminium alloys where possible – which do not rust in the wet and acid bog environment. Many of Bord na Móna's production machines have hydrostatic transmission nowadays, which means in practice that their working speed can be varied with greater ease and control, making them much more efficient on the bog.

After it has been drained, the bog is levelled (which is helped by the spore spread from the drains by the dirt ditchers) and given a gently slope towards the nearest drain, to allow machinery to work at maximum efficiency and to encourage rainwater to flow off the surface rather than soak into the bog. Finally, a railway is laid to carry the bog harvest to its destination: the factory or power station, to a tiphead for sale to the public or to await transport by lorry. Bord na Móna maintains 900km of permanent 3-ft narrow gauge railway on its bogs, as well as 240km of temporary railway for taking peat from stockpiles. These temporary rails are lilted and relaid as required, using mechanically-operated rail-lifting equipment.

Figure 4.14: C.S.V. Smith OBE of Garretts, at Lullymore in 1947 during the redesign period of the machines for milled peat Production. Smith was a bog machine designer With Garretts, who were responsible for the design of the machines provided to Lullymore in 1935 and 1947, and for Boora, Derrygreenagh and Blackwater in 1952. Note the flat Wheels and tracks, Which ensure a flat surface on the fields harveted for milled peat. (Photograph J. Martin).

Machine sod peat harvesting method

Sod peat is the Bord na Móna equivalent of hand-won turf, but it is very different in many ways. Unlike hand-won turf, machine turf is not just a slice taken out of a particular level of the bog, but a mixture of peat from different levels. This makes it better in a number of ways; when E. J. Duffy experimented with the Dolberg machine at Turraun in 1920 he found that machine turf dried faster than hand-won turf, and became twice as dense. Of course there was nothing original about this observation. It underlay the recommendation of both the Purdon (1872) and 1918 Commissions to manufacture machine macerated peat, founded on 60 years of European (including Irish) experience and machine development. As far back as 1874 McDonnell had supplied samples of such peat to the GSR for testing on locomotives.

After the bog surface has been drained, cleared and levelled, an area is prepared for the machines to work. The peat, which is now at 90-92% moisture, is dug out from a considerable depth (up to 4m) by a large excavating machine called a bucket dredger or *bagger* (the German word), from near-vertical facebanks. Modern sod peat machines of the bagger type date to the early years of this century, and in particular to the design work of Strenge and Wielandt in Europe, and of Anrep and Jacobson in Canada. Before the bagger starts cutting along the facebank edge it is usual to remove the fibrous top scraw to a depth of a half-metre of so across the width of the bagger; this is disposed of on the cutaway using an Abbunker screw machine.

Excavation starts from deep central drains 220-250m apart, and gradually works outwards. The peat from the different depths is mixed in a macerator, and the mixture is extruded by a spreader arm on the machine in a long line onto the surface to dry. This mixing of peat from all depths means that all the sods have the same quality. Cutting discs behind the spreader divide each line of extruded peat into individual sods. When these are dry enough to move they are gathered up by special plough-like machines into windrows where further drying takes place. When the moisture content is down to 35% the windrows are gathered into long ricks parallel to the drain about 60m back. A diesel-driven loading machine is used to transfer the rick of sods into rail wagons on the temporary railways beside the rick. The mechanical harvesting of sod peat in Bord na Móna was – and still is – confined to the larger bogs (Ballydermot and Timahoe), because long cutting trenches are desirable for bagger operations since they involve less turning; it takes the long, heavy machines several hours to turn when they reach the end of a trench. The baggers each harvest about 25,000 tonnes a year.

Machine turf is more weather-resistant than hand-won turf because it quickly forms a protective skin as it dries, and this protects it from soaking up water during heavy rain. Weather permitting, the production season for machine turf lasts from April to September, which is more or less similar to that for milled peat; two harvests are obtained under favourable conditions (the average has been 1.6 a year). When turf has to be left on the bog over the winter, awaiting sale to power stations or private users, care must be taken to cover the ricks with polythene film against rain and wind, and to store it correctly along well-established lines. Before suitably wide sheets of thin polythene became readily available, the sods in the ricks has to be arranged so as to throw off falling rain in order to avoid penetration of the pile. This was a very laborious and time-consuming job, adding considerably to the cost of production.

For some 60 years these machines dominated mechanised peat winning, though smaller diesel-powered machines with a spread width of up to 22m were also used; these can produce about four tonnes of air-dried peat per hour. Although the entire sod peat production process, from bagger cutting and spreading to collection and stockpiling has been fully mechanised in Ireland since the early 19S0s, the complete replacement of manual labour on Bord na Móna's bogs only came in the mid-1960s; up to this an additional 700 workers were still employed in turf footing at Clonsast. The invention of a plough-type sod lifting and turning machine at Ballydermot works helped greatly in the advance of mechanisation. Other machine improvements came from Germany. Improving the bog surface by levelling greatly facilitated the mechanisation of turf-saving.

Much smaller tractor-attached production machines with an output of 3,000-6,000 tonnes a year of air-dried peat at 35% moisture were also developed; these are extensively used nowadays by private developers, and have already been described in Chapter 1.

The hydropeat method

One of the greatest problems in large-scale mechanical peat excavation is the occurrence of buried timber in the bog, which can wreak havoc with the machinery. In countries where buried timber is more abundant, such as in parts of Russia, an entirely different method of production was formerly used: the peat was sluiced out by high-pressure water jets and the resulting slurry then dried out and cut into sods (of poor quality). Since World War 2 this has been superseded by milled peat methods using high-powered machinery and deep milling/ grinding techniques to reduce the timber to small particles.

The hydropeat method was tried for a time in Derrylea near Portarlington from 1949 to 1953 [**Figure 4.15**]. It was estimated that a hydropeat plant turning out 10,000 tons per annum required 100 acres of spreading ground and 10 acres of cutting pits. The method seemed to offer several advantages. It could be used on bogs which were too small to be worked by the bagger method, and on bogs which were very difficult and costly to drain. The peat slurry produced by washing with jets of water under high pressure was directed onto a drying field on the bog surface, the field edges slightly raised to confine the spread. As the peat dried it was marked into sods by a tractor with special tracks (initially a horse--drawn cutter), and afterwards footed and ricked like machine turf. However, the method was very weather-dependent and the turf produced was very light; moreover, the sand content of the sods was high, so it had a higher ash content, which made it unacceptable for use in Portarlington power station.

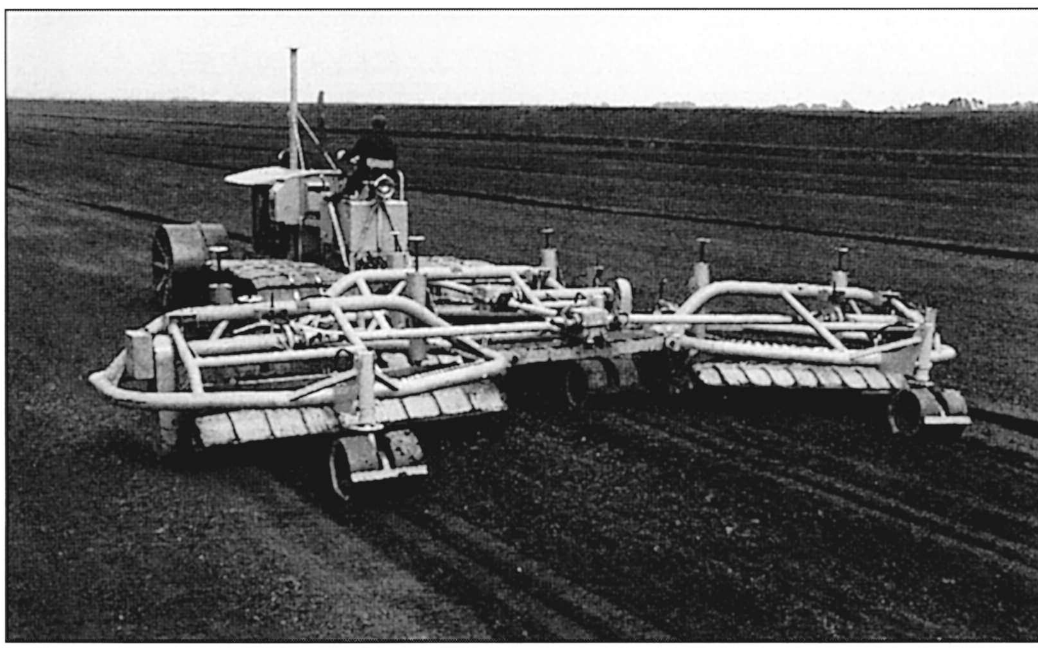
The milled peat harvesting method

There had been considerable experimentation in a number of countries including Ireland during the 1860s with peat mould produced by pin-harrowing, but the early methods were very labour intensive, and involved heavy hauled steam engine equipment. The milled peat techniques in use by Bord na Móna were pioneered by the Russians in the 1920s and 1930s; the first peat miller was produced by Rogoff in Russia in 1924. The basic idea was subsequently further developed by Nyboe at Kaas in Denmark and Sybolts in Holland. In the early 1930s Tomter and Gram refined Sybolts' method for the English firm of Peco Ltd., which then supplied machines for use in Ireland. Milled peat was widely used in Russia during the 1930s for the generation of electricity; by 1937 Russia was generating 1,000MW of electricity in milled peat power stations.

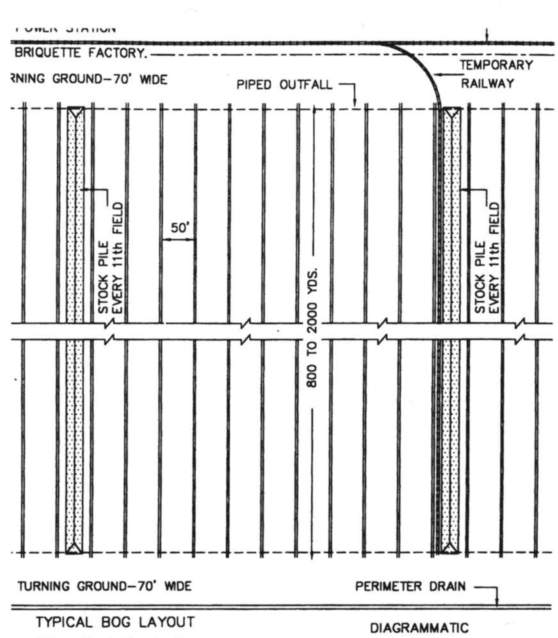
Figure 4.15: In the hydropeat method the bog is sluiced with high-pressure hoses in order to liquify the peat. This frees the peat from buried timber. The photographs show the hydropeat method in use at Derrylea in 1949.

The Turf Development Board took over the milled peat operation for the making of briquettes at Lullymore from the Peat Fuel Company in 1940. However, the Turf Development Programme published in January 1946, and the ensuing Turf Development Act issued in November of that year, were based on sod peat production. Milled peat came to supersede sod peat as the primary method of large-scale production in developed countries during the 1950s, and in 1952 Bord na Móna strongly advocated the use of milled peat for electricity generation, following an influential paper to the Institution of Civil Engineers of Ireland in 1946 by Jim Martin in which he argued persuasively in its favour. Martin showed that the milled peat method was cheaper, and output was much greater than for sod peat production and was fully mechanised. There were experienced Irish bog developers in the 1940s who doubted if milled peat would be commercially feasible either for generating electricity or in briquette making. In 1939 the Chairman of the TDB dismissively compared the milling at Lullymore to hens scratching about on the ground looking for feed!

For milled peat production, the bog is laid out in a series of rectangular drying fields around 800 to 1,200 yds long (c. 2,400′ to 8,000′) and 50′ wide, with drains between. These are 0.5m (18″) deep to begin with, and they are progressively deepened until they are up to 1.5m (3′6″). Special milling machines then work their way along these fields. These have rotating drums fitted with spikes, which scarify or tear up the surface into crumbs to a depth to suit the prevailing drying conditions (about 4mm under poor drying conditions, up to 6-8mm under good to excellent drying conditions) [**Figure 4.16**]. This 'milled peat' is left to dry until its moisture content is down to between 40 and 50%, which takes two or three days in good weather, and is accelerated by harrowing. The dry milled peat is then scraped into long ridges running down the centre of each field; at a later stage the output of every ten ridges is transferred to a larger central pile ('rail pile'), from which it is collected and transported to the power station or briquette factory by railway when it is required. Because it is so light, the milled peat piles have to be compacted by rolling after every two or three harvests. If the stockpiles have to be left on the bog over the winter they are protected against wetting, and wind erosion during stormy weather, by a covering of polythene. This was first introduced in the mid 1960s, after Hurricane Debbie caused great pile losses. If the ridges are left for too long, micro-organisms set to work on the peat. This can result in losses of up to 2% a month, and it also causes a rise in temperature. Under certain conditions (when the moisture content of the peat is over 60% and ambient temperature is low) spontaneous combustion can occur.



(a)

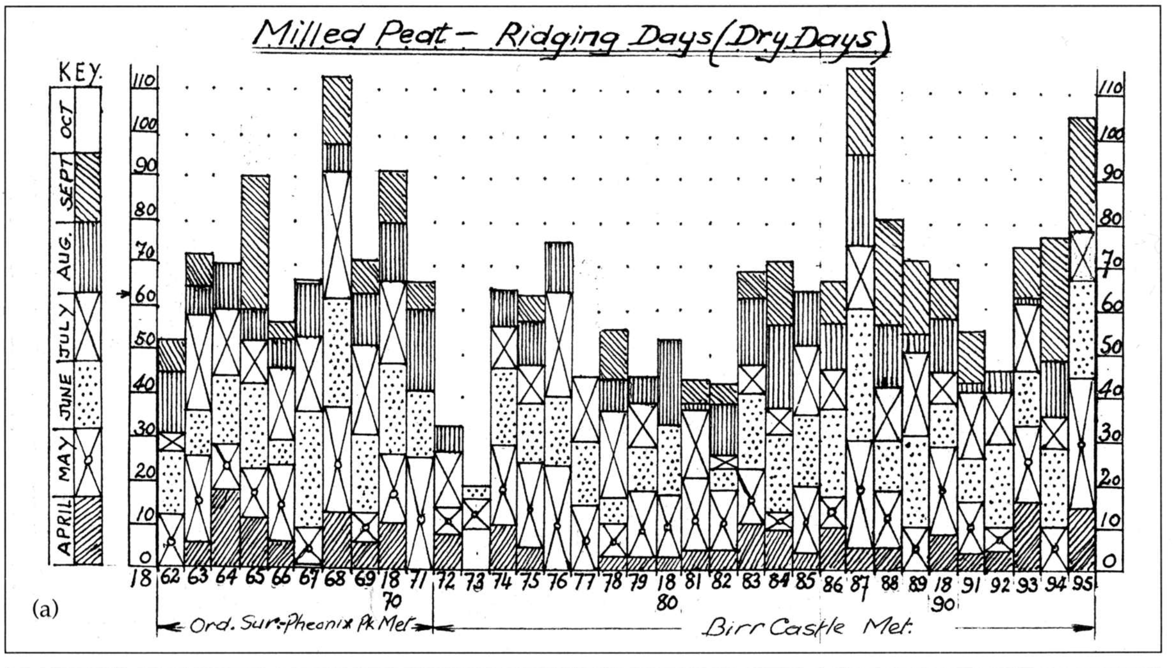


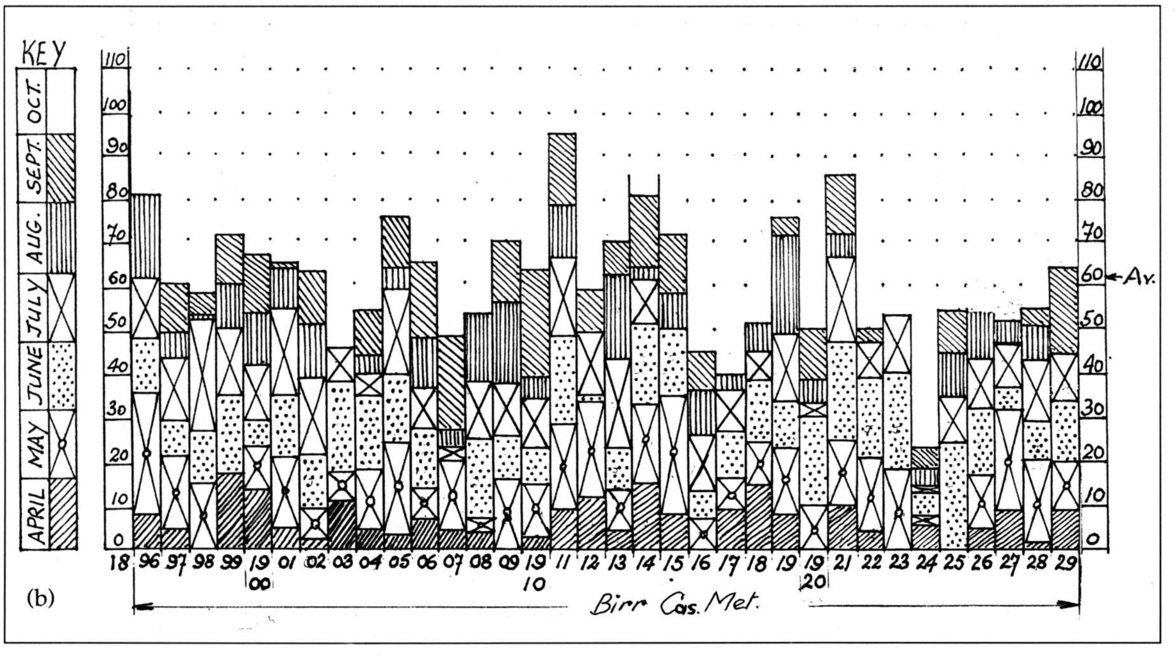
(b)

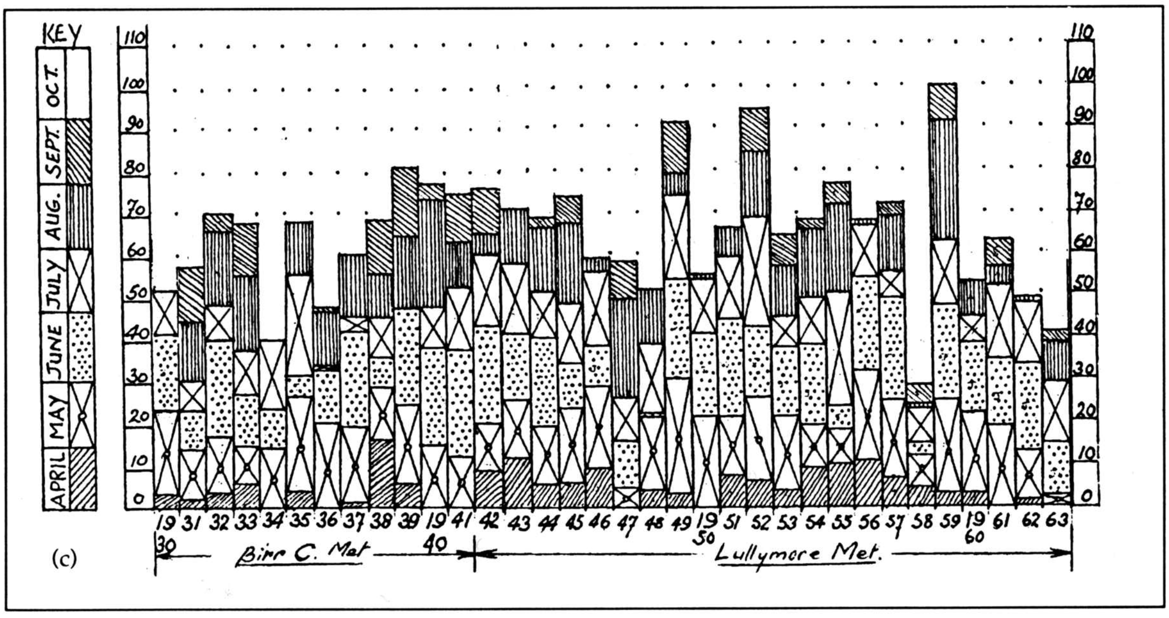
Figure 4.16: (a) Triple attachment pin miller. Pin miller attachments were developed at Sösdala in southern Sweden in the 1940s. Bord na Móna has made all its own attachments since the early 1950s. (b) The layout of a bog for milled peat production.

The harvesting season for milled peat normally runs from mid-April to mid-September, each harvest cycle usually taking two to three days – in good weather. A two-day milling-ridging-harvesting cycle would be the ideal in our unreliable climate; and although a number of experts since Professor Purcell have argued that this is feasible, it has not been attained in practice because the milling depth is often too great to allow rapid drying to take place. The average number of harvests in a year is around twelve, and at this rate it takes about ten years to take a metre of peat from the production surface of the bog, and forty to fifty years to remove the total economic peat reserve. The average number of dry days suitable for ridging dry milled peat was 62.5 days per year from 1862 to 1993 [**Figure 4.17**], but there is great variation from year to year. In 1985 there were only 29 ridging days, but 60 the following year; there were 88 such days in 1984 and 75 in 1989. Enthusiastic deep milling causes the number of days per harvest to increase, which reduces the total output during poor weather conditions. To get the best output under Irish weather conditions milling needs to be shallow in poor weather, with frequent harrowing to increase the frequency of harvesting (For details see Martin, 1991).

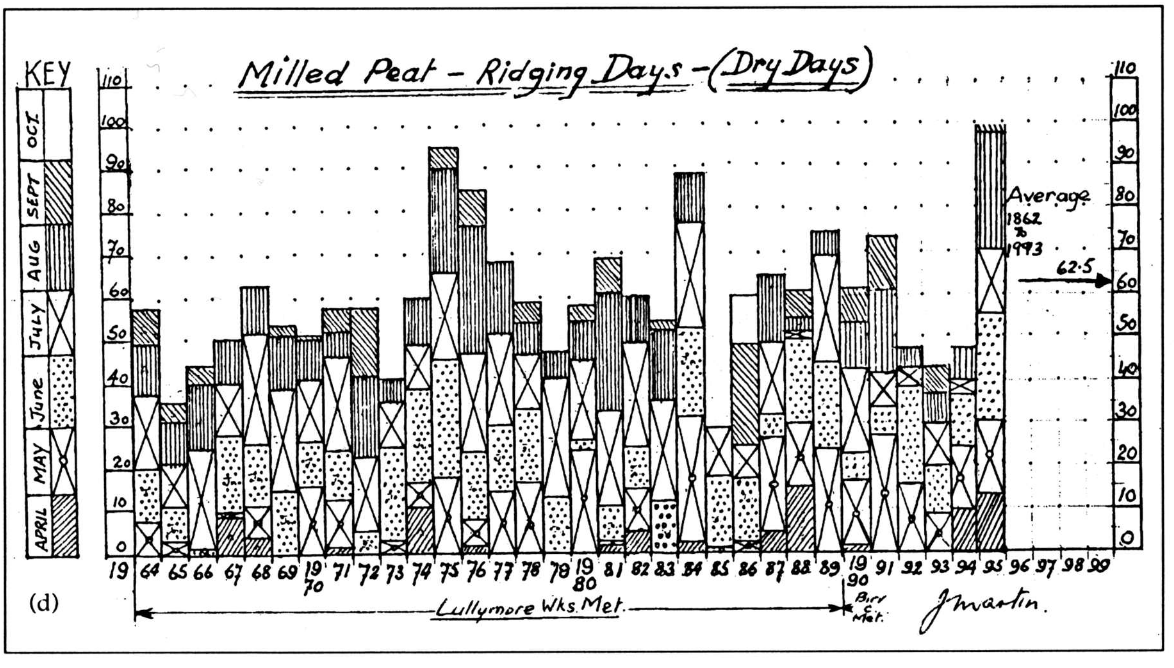
Figure 4.17: The number of days suitable for ridging. milled peat since 1862 (Compiled by Jim Martin). The average number of days down to 1963 was 62.5.
(a) 1862-1895.
(b) 1896-1929.
(c) 1930- 1963.
(d) 1964-1995.







(c)



(d)

The Peco system of bog development is only one of many systems in use, but it has proved to be the one best suited to Irish conditions. The Kaas system, which used small Severin Petersen millers, followed by scraping and push-piling, was tried alongside the Peco system at Lullymore between 1936 and 1943. Although it was used in many European countries – it is named from the Kaas Peat Briquetting Works in Denmark – it was abandoned at Lullymore in 1943. The Finnish Haku collecting system – an upgraded version of the Kaas system, with improved wheeled transport equipment – is now used in areas where there is an undulating bog floor and outcropping subsoil breaks up production areas; it has been in use in Oweninny since 1990. Whatever method is used, the tracks or tyre surfaces of the machines must have minimal impact on the bog surface in order not to interfere with control of milling depth. One of the disadvantages of the Peco system is that it is more suitable for use on large bogs; for efficient operation a machine unit comprising one harvester with supporting millers, ridgers and harrows etc. needs 100ha of bog area.

Electricity from peat

Bord na Móna currently harvests 4 million tonnes of milled peat per annum. The main market for milled peat is the energy sector, both for burning in and for domestic consumption (briquettes). Three new electricity-generation power stations were constructed between 2000 and 2005; two of these stations are run by the ESB (Electricity Supply Board) and located near the Shannon and the third, Edenderry Power Ltd is owned and run by Bord na Móna. All three stations use the latest technology in the form fluidised bed burners.

Peat-fired electricity power stations:

ESB – West Offaly Power (2005)	=	150 MWe
ESB – Lough Ree Power (2004)	=	100 MWe
Edenderry Power (2000)	=	128 MWe
Total		= 378 MWe

The contribution of peat to Ireland's electricity needs reached its peak during the oil crisis of the early 1960s, when it accounted for nearly 40% of the total. In 2006, burning milled peat (378MWe) accounted for 8.5% of total energy used to generate electricity in Ireland, but this was still half the total contribution from indigenous energy sources (renewable accounting for only 4.5 %).

The earliest experiments at using turf to generate electricity in Ireland were made at Sutton Power Station in County Dublin. These showed that turf compares favourably with coal, but that it would be more efficient to convert the turf to power gas first; the 1921 Commission recommended the use of turbo-alternators. Turf was used to generate electricity on a small scale at Turraun and Lullymore, by Hamilton Robb in Northern Ireland by the Marconi Company at Clifden and in a number of other places. Sir John Purser-Griffith had hoped to be able to supply nearby towns from Turraun, and indeed attempts had been made as early as 1908-9 to interest the Government in setting up peat-burning power stations for municipal use.

The decision to use peat to generate electricity was taken in 1938, when Sean Lemass, then Minister for Industry and Commerce, announced that once the hydroelectric plant at Poulaphuca in Wicklow was completed (Sir John Purser-Griffith's brainchild also) all future electrical development would be based on home-produced peat. In an address in December he rounded on Irish engineers for their failure to take a serious interest in the technical problems and opportunities of peatland development, and in particular for their failure to implement engineering solutions better suited to the characteristics of Ireland's bogs – a rebuke which quite remarkably ignored the achievements of Purser-Griffith and Purcell. At the same time the Government announced that it would build its first peat-fuelled power station at Clonsast, near Portarlington [Figure 4.18].

The ESB did not take at all enthusiastically to the idea of generating electricity from peat; it was of course perfectly feasible technically, but the ESB claimed it didn't make economic sense. It took a directive from Lemass, fully converted to the virtues of turf during the War, to force the marriage. Their reluctance was compounded by two further proposals which were made in 1951. The first was Bord na Móna's proposal that milled peat be used instead of machine turf for the power stations in the Midlands, because milled peat production was completely mechanised. The first milled peat power station was commissioned at Ferbane in 1957. The second proposal came from Sean Lemass and the Government: to set up four small power stations along the western seaboard which would be fuelled by hand-won turf. These would be quite uneconomical, but social and political reasons stifled economic considerations for the time being. The stations were forced on a reluctant ESB, and eventually all four (Milltown Malbay in Clare, Cahirciveen in Kerry, Screebe in Connemara and Gweedore in Donegal) went into production. But as economic reality began to bite, they closed one by one.

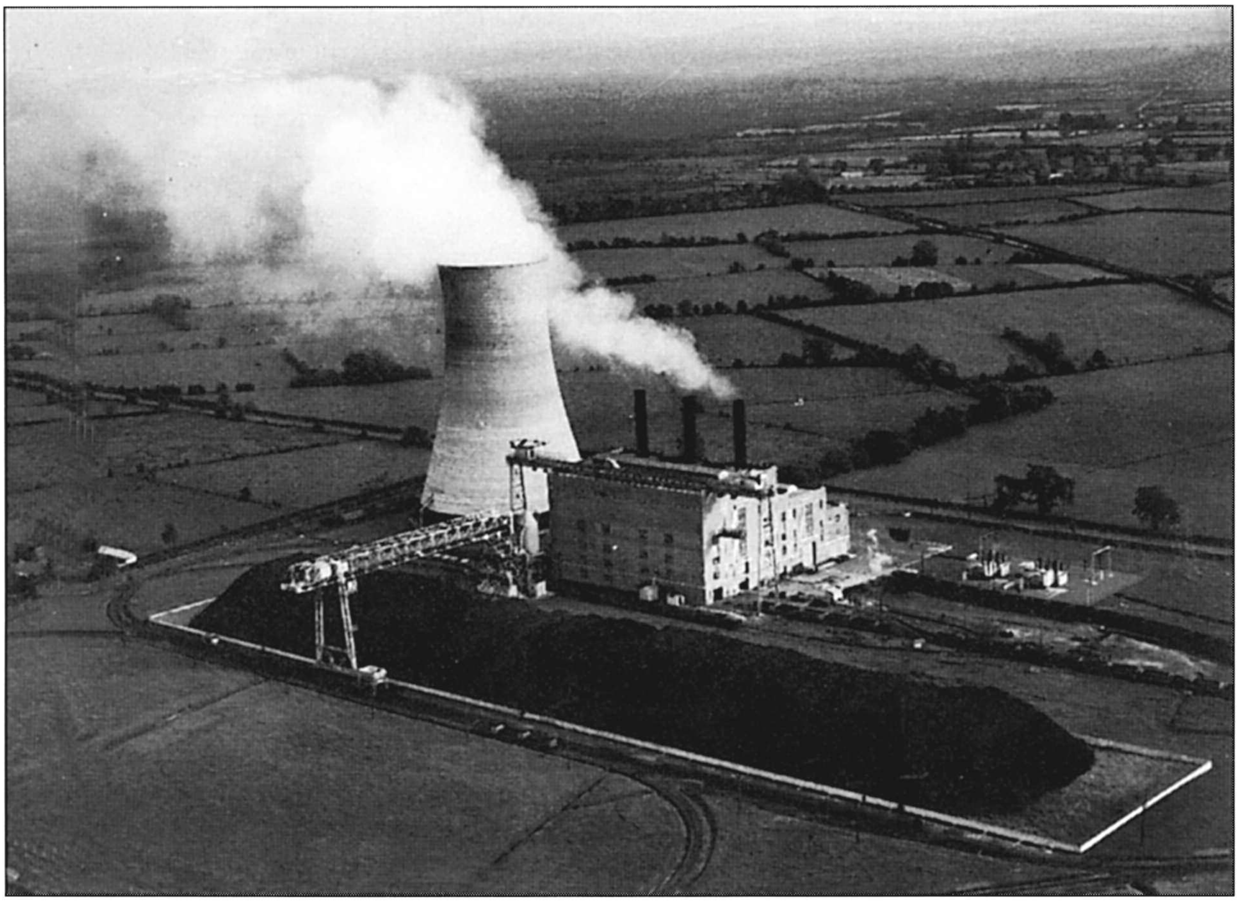


Figure 4.18: Portarlington Power Station. Note the stockpile of sod peat with loading and unloading gantry in foreground.

In 1956 the ESB struck back, declaring its intention to cut back on its plans for increased output. This would have meant a 50% reduction in Bord na Móna's planned expansion on two of the large new bogs it was developing, and the cancellation of two others. And it would have put the jobs of between 600 and 900 workers at risk. The only way to prevent this was to find another outlet for the milled peat by using it to make briquettes. But there was neither a market developed for surplus briquettes, nor was the capital forthcoming from the Government to build the new briquette factories that would be needed to cope with so much milled peat. Help came from an altogether unexpected source. The chief executive of Guinness, Sir Hugh Beaver, was a friend and admirer of Todd Andrews; a loan of a million pounds was secured from Guinness. To seal their marriage, the two groups agreed to fund a Chair of Industrial Microbiology at University College Dublin, initially for research into peat.

The increasing dependency on imported energy sources (90%) together with highest electricity prices in Europe, was one of the arguments behind the decommissioning of five of the old ESB peat-fired power station and the construction of three state-of-the-art plants. The first of this new generation was built in 2000 near Edenderry and has been bought by Bord na Móna in 2006. Briefly, the station was manufactured by Kvaerner and the fluidised bed boiler gives an average efficiency of 38%. The combustion chamber consists of a bed of hot sand which is fluidised by the combustion of air flowing upwards through the sand. The high turbulence in the bed causes the fuel to mix quickly and uniformly with the bed material. The long residence time of the fuel in the combustion zone, and the high heat capacity accumulated in the bed (900°C), result in stable and efficient burning. The steam in the boiler is superheated to a temperature of 540 °C before it enters the two-cylinder reheat condensing turbine, which is coupled with an air-cooled generator. The system can maintain stable operating conditions with a wide variety of fuels, and is less sensitive to fuel moisture content variations than the pulverised fuel system. Possible fuels include wood waste and biomass. As indicated in an Energy White

Paper (2007), 30% co-firing should be attained in each peat-fired stations. Edenderry Power has already been a pilot plant for co-firing trials with wood residues and biomass.

The thermal efficiency of the fluidised bed boiler system means that emissions are low, and concentrations of sulphur dioxide and nitrogen oxides well below permitted limits. The levels of carbon dioxide produced are well below those of existing plants:1.16 tonnes of CO_2 per megawatt hour (MWh) compared with 1.48-2.19 tonnes. In 2006, the Edenderry Power Ltd station emitted 865,552 million tonnes of CO_2. There is no discharge of cooling water since the cooling system is a closed circuit. Waste and purge water discharge will be less than 100 litres/second; this is neutralised and filtered through peat and ground layers. The ash produced is stored in specially designed landfills on industrialised cutaway bogs.

The machinery for peat harvesting is being further refined, and becoming more sophisticated, all the time. Bord na Móna has now developed a fully instrumented and computerised milling machine, and is investigating the possibility of a computerised milled peat harvester. One of the main areas of research now is into the development of production techniques which will make the harvest less subject to the vagaries of the weather. However, a contribution to increased productivity could probably be made by greater attention to the reduction of harvester load by milling less; smaller harvests taken more often would in the end result in higher annual output.

For a time there was considerable interest in the development of the 'wet carbonisation process'. This could be operated in all weathers, and would be especially suited to the western bogs as a supplement to milled peat production. Scandinavian work on the process was examined briefly by Bord na Móna, but it was judged to be uneconomic and environmentally unacceptable. Another area of investigation is the possibility of harvesting wet peat and then drying it: as the previous chapter will have made clear, this has been the Philosopher's Stone of the peat industry from its very beginning! However, the harvesting of wet peat and then drying it is economically unattractive. The main emphasis in research is now on (i) the reduction of product unit cost, through higher machine output and lower capital costs; (ii) the improvement of product quality, through improved peat storage and stockpile protection; and (iii) a reduction in the overall environmental impact of Bord na Móna's operations.

Up until the turn of the 21st century, Bord na Móna had accumulated crippling debts. The costly Littleton briquette factory and the Ballyforan project (said to have been undertaken at the request of Government) must have contributed substantially to this, as did the ill-fated Foidin experiment. Depressed production levels resulting from a tendency towards deeper milling practices than prevailing drying conditions would support may also have been a factor. In 1995 the Government approved a major financial restructuring of the company. Among the more significant elements of this restructuring were a grant of £120 million over 3 years; this enables the Board to payoff 2/3 of its crippling debt, and enables it to seek out new equity partners for development. However, the price of this injection was that Bord na Móna must sell its peat to the ESB at a commercial rate - around £13 per tonne instead of £19 as heretofore. Bord na Móna is now a successful semi-private company making annual profits and growing with many subsidiaries.

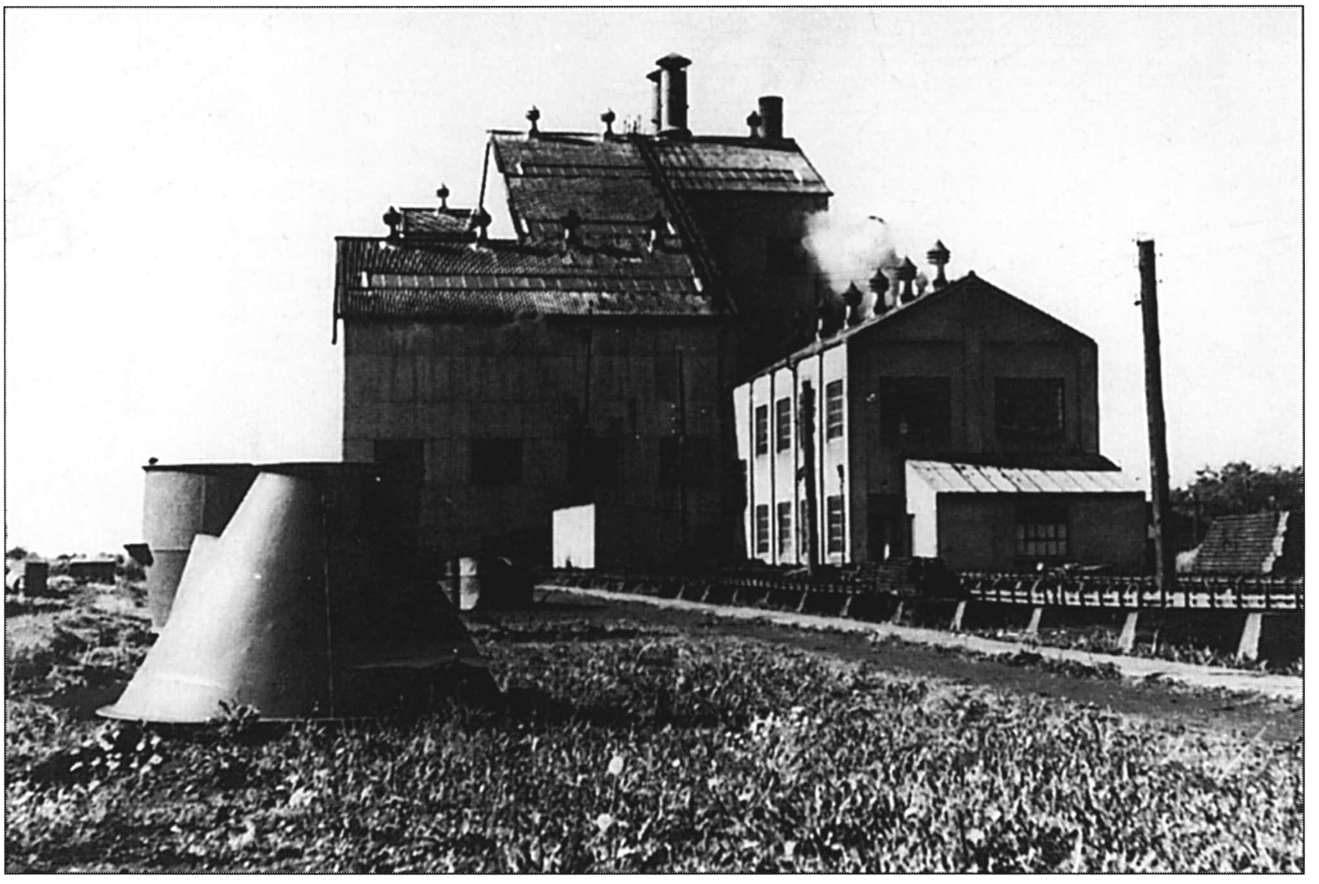


Figure 4.19: The first briquette factory at Lullymore, photographed about 1950.

Briquettes

The basic process of briquette manufacture has changed little since the late 1850s (See page 78). This is a crank-driven open-channel extrusion press similar to those used for briquetting brown coal, without using a binder, in Germany and elsewhere. The briquette presses built by Hodgon at Derrylea in County Offaly around 1858-62 were essentially similar. The milled peat used in the making of briquettes has to be carefully selected so that a product of even standard can be ensured as far as possible, so moisture content, density and ash content are allowed to vary only slightly. Various selected milled peats are blended in a blending bunker holding a full day's factory production, then ground up in a hammer mill and screened to remove bits of fibre, wood and so on. These screened peat 'tailings' are used as fuel in the boilers. The milled peat reaching the briquette factory has a moisture content of about 50%, and during manufacture it is further reduced by hot water and steam driers to 10% before it is compressed to form briquettes.

Drying takes place in the series of five tall, cylindrical steel towers which are the most distinctive external feature of a Peco-type briquette factory. The towers are insulation clad and aluminium covered, and they contain a large number of tubes which are heated by circulating hot water (in two of the towers) and steam (in the remaining three). The screened peat dust is blown through these tubes, up and down through each of the five towers in turn, until it reaches a moisture content of 10% and a temperature of about 100°C. The peat dust is then compressed under a pressure of about five tonnes/ sq. inch by a reciprocating ram, each stroke of the ram forming one briquette **[Figure 4.20]**. When they have cooled down in 90m-long 'runners' they reach the baling station where they are bound in two layers with polypropylene strapping into 12.5kg bales.

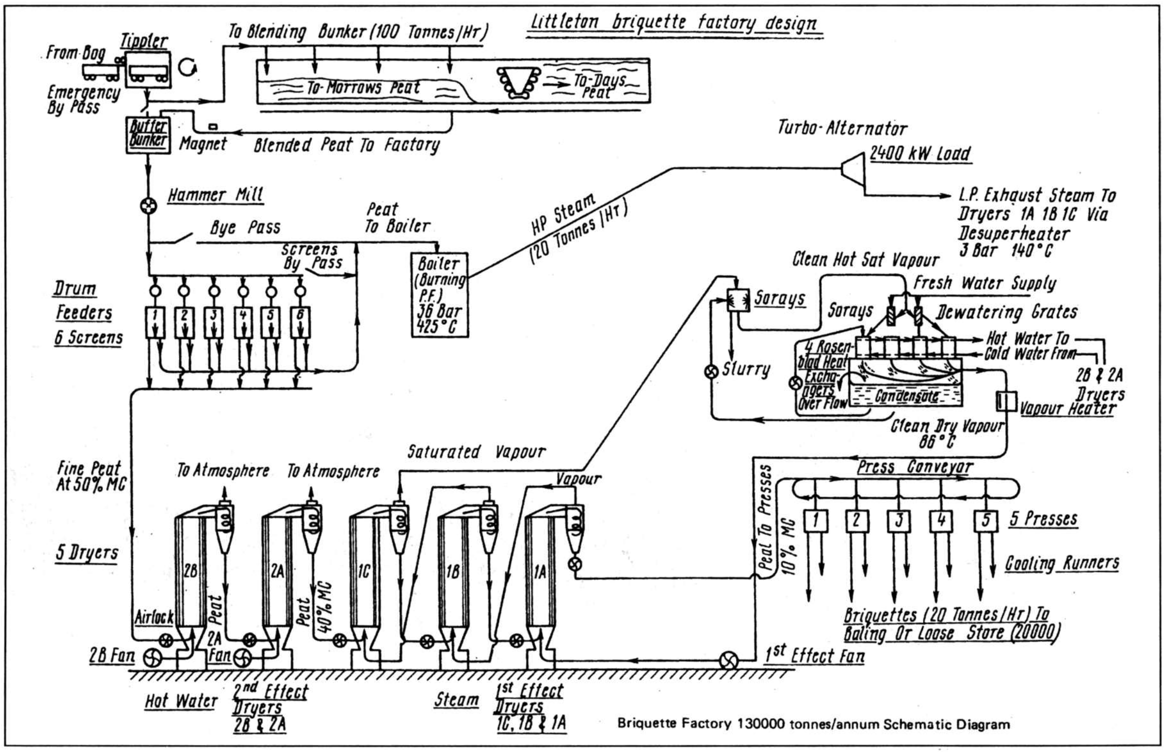


Figure 4.20: The briquetting process.

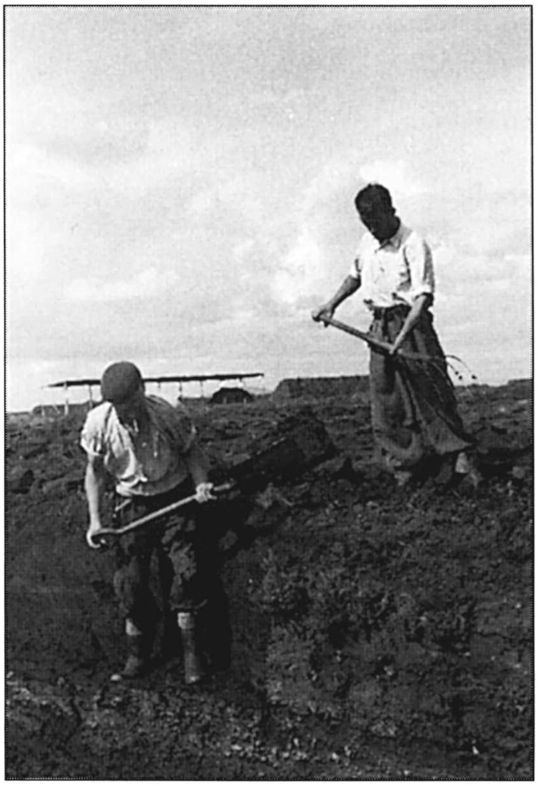
Briquetting in Ireland re-commenced with the Peat Fuel Company at Lullymore in 1935, following the development in Scotland of the fully mechanised Peco system for harvesting milled peat, and building on experience at the Kaas Peat Briquette plant in Denmark. Lullymore was designed as a fully integrated combined heat and power (CHP) plant. Steam raised was used to dry the peat, and also to drive a small turbine to power the plant. During the six months of 1943-4 when Churchill banned all export of coal to Ireland, Lullymore supplied briquettes as a replacement fuel for the railways. Around the same time some 3,000 tons of briquettes were dispatched to Jameson's Distillery in Bow Lane to serve another national need: that of ensuring there would be no break in the Government's revenue from whiskey tax in 1952! Press peat fines were supplied to Drogheda where they were mixed with poor quality coal in order to improve the flame properties in the kiln used for cement manufacture there.

Only two briquette factories remain in operation as of today: Littleton in County Tipperary, and Derrinlough in County Offaly, operating on a round the clock basis on a four-shift rota; Lullymore in County Kildare closed in 1992 and Croghan (Co. Offaly) closed in 2000. A fifth factory was in course of construction at Ballyforan in County Galway but was cancelled by Government in 1982; four large presses, unused, are still in stores. Total production of briquettes is currently around 231,000 tonnes/year. New sorts of briquettes may well appear in the future; briquettes made from a coal-peat mixture are being produced at Littleton.

Moss peat

Moss peat is the younger, only slightly decomposed (unhumified) sphagnum peat. Only those bogs where this peat type is well-developed are suitable for the exploitation of moss peat, but when this has been harvested the underlying peat can often be developed for milled peat production. The peculiar cellular structure of the sphagnum which makes up moss peat gives it an absorptive capacity up to ten times its dry weight, as well as a high air pore space even at 90% moisture. The value of moss peat as a soil conditioner has been appreciated for a long time, in Holland especially. 'Bog stuff' was frequently used to improve ground in the eighteenth and nineteenth centuries, and there was an extensive literature extolling its virtues. Moss peat was first produced commercially about 1850, when it was used as horse stable litter by cavalry and artillery units.

(a)



(b)

Figure 4.21: (a) Cutting moss peat by hand. (b) Moss peat sods drying in clamps.

Moss peat in Ireland is harvested by the Peco system in the same way as milled peat, although the sod moss peat method is also still used. In the sod method the peat is simply cut from the bog in large sods by machine, and these are dried by wind and sun. Walls of these large sods are left on the bog over the winter to improve the texture. They are turned and dried several times during the following spring and summer, and usually collected into ricks between July and September and taken off to the factory as required. Here the sods are disintegrated, then milled, screened and graded. Only the best grade is used in gardening. The moss peat is also pre-mixed with different fertilisers for more specialised purposes in a sophisticated batch mixer and packaging plant which compresses the peat, packs it and wraps the bags in polythene. Bord na Móna is a large market player in the production of horticultural peat with a number of other small horticultural competitors also operating since the late 1950s. In 2003 it was estimated that Bord na Móna and some 30 smaller Irish moss peat producers sold 2.6 million cubic metres of horticultural-grade peat with an estimated total turnover of €48 million. More than 90% of the moss peat is exported, to 27 countries. There are three moss peat factories: at Coolnamona in County Laois, Kilberry in County Kildare and Ballivor in County Meath; there are also a number of private producers, of which Erin Peat is the largest. Moss peat also has other uses, notably in the manufacture of peat pots, for mushroom casing etc. Fibre extracted from the peat also has commercial possibilities – it can be used for removing odours from gases released during industrial processes or from animal manures, for lagging drainage pipes and so on.

Moss peat is very light and bulky, which makes transport a major cost. In 1970 peat moss was compressed on an experimental basis by Bord na Móna in an attempt to overcome this problem. The peat was first dried to 15% in a grass drier and then compressed by briquetting so that it occupied little more than 11% of its earlier volume. A refinement of the method was to crumble the briquettes. Briquetted moss peat had no fibre, as the drying and briquetting process destroyed it. For this reason the crumbled briquettes made excellent casing for mushrooms. However, although patented in four countries these initiatives in the preparation of moss peat compacts have not so far been taken further.

The environmental impact of large-scale development

The removal of the bogs from the landscape through mechanical exploitation of their peat has profound and wide-ranging consequences for the environment. The removal of the living vegetation from the surface of the bog, harrowing of the surface peat and the creation of long stockpiles of milled peat on the open bog allows the production of peat dust in considerable quantity. This dust can be a nuisance for those working on the bog and for households living downwind; in some situations shelter belts go some way towards moderating the effect. An efficient and rapid drainage network results in larger outflows of water from the bog; these carry considerable quantities of peat silt which enter the drains through surface run-off and to a lesser extent through the settling of airborne dust. The suspended silt affects aquatic life, particularly larger animals such as fish, most critically when it settles in spawning areas. In the longer term the silt will settle and become part of the river or lake stratigraphy, although as long as it remains unconsolidated at the bottom there is the danger of remobilisation. Little is known in a quantitative way about either the short or long-term effects of peat silt, and some of the more serious impacts may not be obvious. However, the recent evidence contained in the Environmental Research Unit's Report on Lough Derg suggests that peat silt does not appear to contribute significantly to nutrient enrichment (in phosphorus in particular, as had been feared; peat is responsible for less than 2% of phosphorus input into the lake).

In the early days of expansion by Bord na Móna, Jim Martin had drawn attention to chokage of outlets and streams by peat dust resulting from milled peat operations and the ditching process at Lullymore, but the implications for watercourses further afield were not considered. But once the nature and extent of the problem became clearer, steps were taken to control it. The most important preventative measure is the construction of special ponds at the edge of the bog to intercept the silt and provide somewhere for it to settle [Figure 4.22]. These silt ponds are rectangular 8m-wide sumps l.5m deep, located below the invert of the drainage channels. They work by slowing the flow of drainage water sufficiently for suspended silt to settle out. The silt is cleaned out from the ponds twice a year: at the start of the production season and before annual ditching operations. Some 50m^3 of silt is produced each year by each hectare in production, and it takes a settling area of around 12m^2 to control it. Each works area has its own pond maintenance programme, which is monitored regularly. Under Jim Martin's direction at Lullymore it was standard

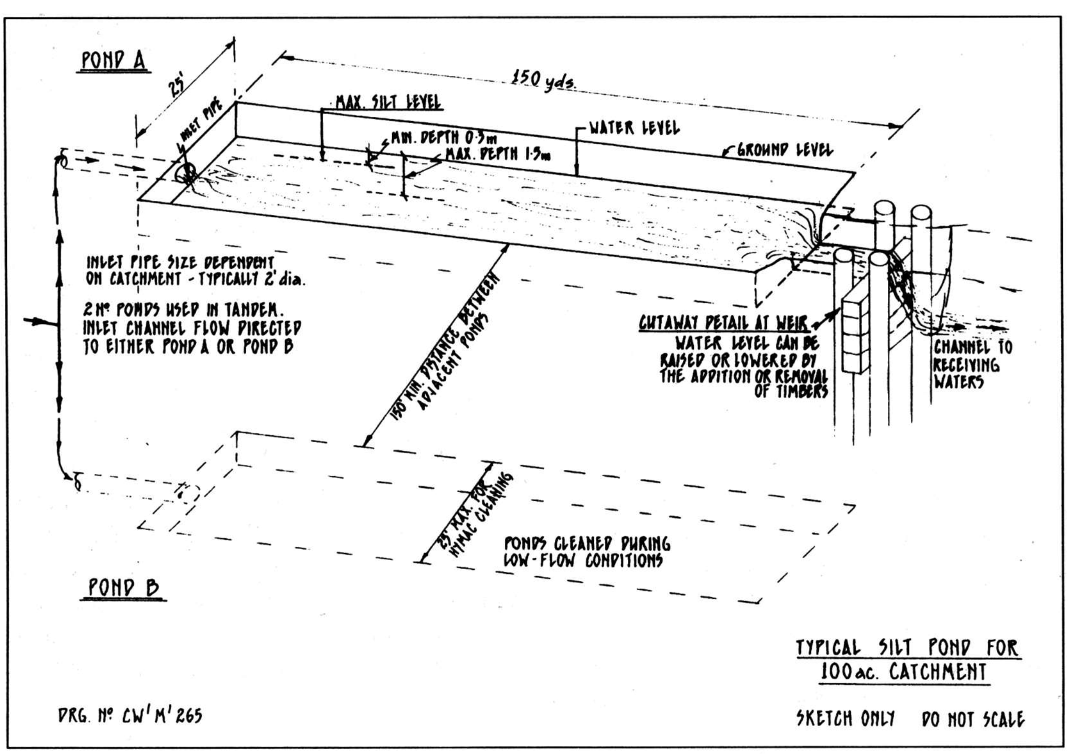


Figure 4.22: Peat silt trap.

practice during the course of ditching to lift the disc every 200 feet for a distance of a yard in order to produce a small dam which would hold back the peat slurry until the next ditcher pass could put it back on the field for re-harvesting. This meant that 8% of the total area under production (the area of the four-foot drain in each 50-foot field) was being used in an economical way as a settling area.

The Lough Derg Report showed that the levels of peat silt in that lake have not changed significantly since 1975, which is an indication of the general effectiveness of the programme. The company continues its research into ensuring clear water at outflows however, partly in accordance with its own code of good environmental practice, but also because it now has to apply to the Environmental Protection Agency for a discharge licence – something it has not had to do up to 1998 – and the EPA has set limits to the level of suspended solids permitted in drainage water.

The importance of the loss of the carbon sink which the bogs represent is discussed in Chapter Five.

Generating stations also have the problem of disposing of large amounts of turf ash. These are disposed of on site, and the dumps are abandoned and more or less forgotten. Briquette factories also produce a considerable amount of ash, which is simply land-spread on site when it dries out. The landscape restoration of the huge ash deposit at Drax Power Station in Yorkshire – a 66ha mound of it – and the subsequent return of the land to a mixture of arable farmland, pasture and woodland could perhaps serve as an inspiration as to what might be done with imagination and determination on these relatively small deposits of peat ash. The EPA is currently banning its use on any land use. Briquette factories also produce aerial emissions of steam and combustion gases. Dust in emissions was a serious problem which has been tackled through a long-term investment programme in electrostatic filters etc. The large amounts of water used in the drying plant and boiler pick up peat silt and ash, which is removed in settlement ponds.

A problem which has not been satisfactorily solved is the disposal of the large amounts of waste plastic used to cover rail-piles of milled peat; when this is removed, it is simply bulldozed to the side and buried or else burned. One solution may lie in ongoing research into the development of biodegradable plastics of sufficient strength, but a simpler solution is to remove the bundles of waste plastic in an organised way for re-cycling. The plastic can be melted at about 130° and poured into moulds, possibly for the manufacture of machine swampshoes which are normally made of native oak. Thousands of these shoes are broken each year and left lying on the bog. It could also be used to make large-bore plastic pipes for bog drainage, replacing the concrete pipes which are used at present.

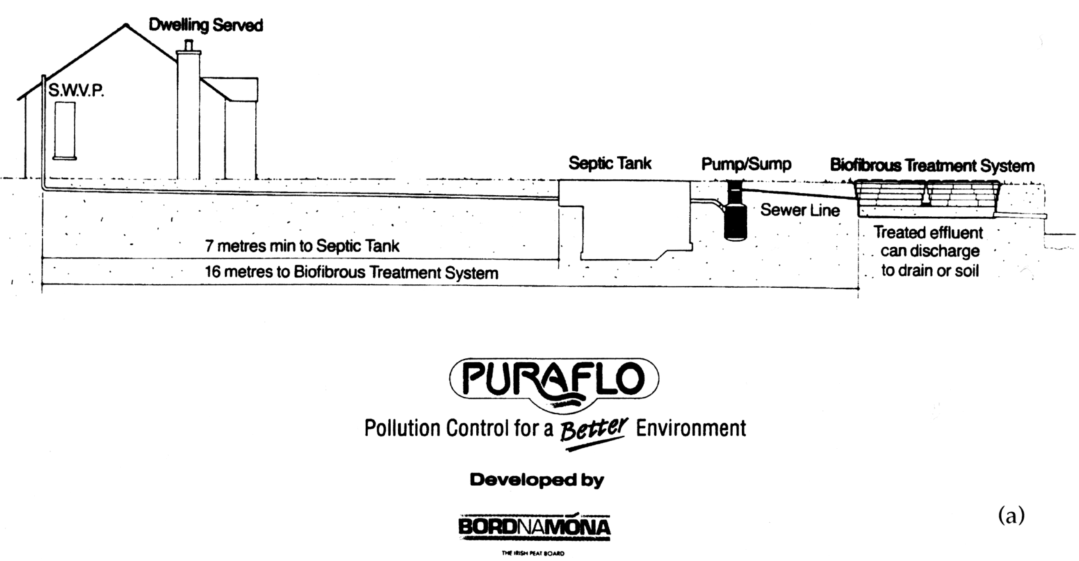
The most profound long-term environmental impact is the replacement of the bogs with other ecotopes; this aspect is analysed in detail in the final chapter. Up to now there has been a dramatic contrast between the detailed, accurate, intelligent and realistic planning which has characterised exploitation of the peatland resource and the rather vague vision which has dominated discussion of the future landscape, especially in relation to areas that cannot be made 'productive' in the conventional sense. This has begun to change in recent years (See Chapter 16).

On a wider front, large-scale exploitation has had a major environmental impact because of its socio-economic consequences: the growth of new villages and an expansion of population and wealth in areas which had been severely disadvantaged. It should be mentioned, at least in passing, that the rise to supremacy of football and hurling in Offaly was due in no small measure to the development of the bogs! On the other hand, when Bord na Móna has discharged its development brief, the communities which it has supported will be severely stressed. This stress might be moderated if adequate resources were applied at an early stage – now – to plan for alternative economic uses, and in particular for proper development of the considerable rural tourism potential of bogland landscapes. All of these issues are discussed more fully in Chapter 16.

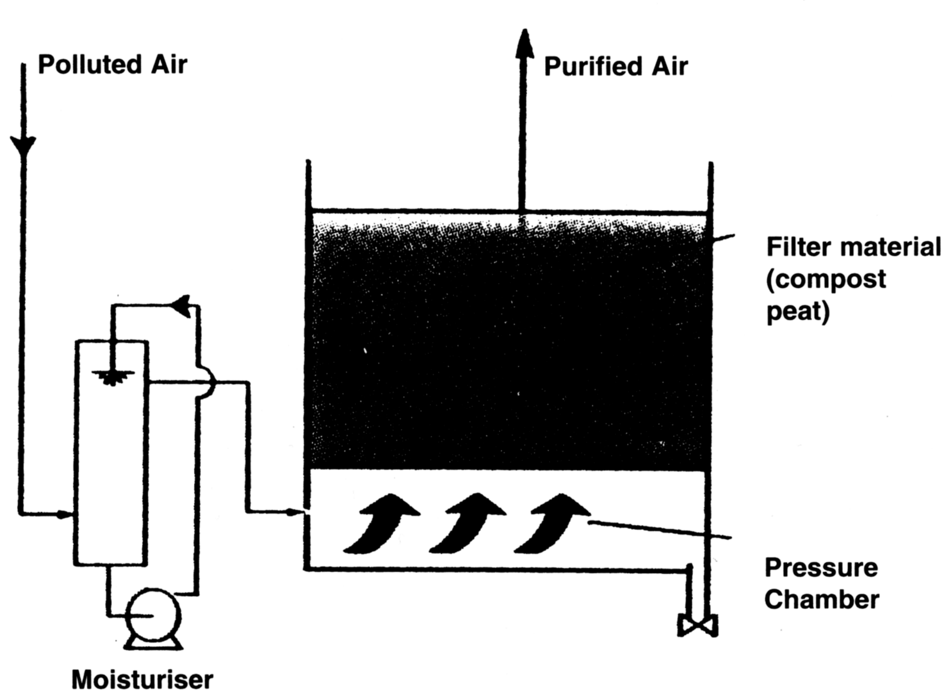
Environmental applications today

Research on alternative uses for peat continues today, especially in Finland, though research is also active in other countries, including Ireland. Russian research has faltered considerably since the break-up of the Soviet Union. New industrial applications for peat are still appearing, particularly in the area of pollution control. Activated carbon from peat is used to absorb trace impurities in liquids or gases in the chemical and pharmaceutical industries. The potential of peat mops for absorbing oil and binding toxic metal ions has been exploited by the Japanese in particular.

Figure 4.23: Operation of (a) the Puraflo system; (b) BioPhore biofilter.



(a)



(b)

Construction principles of a biofilter

In 1946 the (at the time very substantial) sum of £120,000 was provided for experimental and research work on peat production by the Turf Development Act. This allowed the establishment of a well-staffed and equipped Research and Development Centre at Newbridge under Miller and Gillespie. Work on the extraction of wax from peat was carried out by Dr J. Reilly of UCC in the late 1940s, and this was continued in the wax production section at Newbridge under Dalton's direction. The laboratory was under the direction of Pat Coffey. In 1990 the Centre received an injection of finance, equipment and personnel and re-opened as the Peat Research Centre. One of the successes of the Centre has been its research into peat-based biofiltration systems for treating septic tank effluent and polluted gases. Bord na Móna's first biofiltation systems are known by the trade names BioPhore and Puraflo **[Figure 4.23]**. No chemicals are involved in their operation. In the BioPhore system the, peat fibre simply provides a large surface area for the attachment of the microbes of the natural microflora; noxious chemicals are adsorbed onto the peat surface and oxidised by the microbes to simple and harmless compounds like CO_2 and water. The system can be used for effluent purification in such enterprises as pig and poultry units, meat and fish processing plants, waste water and sewage treatment and industrial activity. Puraflo is used for the treatment of septic tank effluent. Here the peat constitutes an enormous sponge-like aerated surface where E. coliphobe microbes can establish themselves, lying in ambush for the *Escherichia coli* bacteria which contaminate the effluent. On a different front, the use of peat briquettes – a low smoke fuel – is making an important contribution to the reduction of smoke levels in Dublin and other cities. The Research Centre has also carried out extensive research over the years on the most energy-efficient designs for industrial and domestic cookers, stoves, furnaces, boilers and open fires. On the other hand, the Centre has had its problems down the years. Many experiments were initiated at Works rather than Research and Development Station level. Machines were imported from abroad for test, sometimes with no obvious benefit, or eventual reporting on success or failure. For instance, 25 huge machines were built for the Foidin experiment at a reported cost of £50,000 each, only to be scrapped within a year or two. Admittedly, they were developed during the very wet production seasons of the mid 1960s and worked fairly well, but with the better production weather of the late 1960s milled peat won by the Peco system again became much more economic.

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Chapter Five

The nature of bogs

Unless there were peat-mosses, many a bare mountain ridge, many a high valley of the temperate zone, and large tracts of the northern plains, would present an uniform watery fiat, instead of a covering of flowering plants or shady woods. For just as the Sphagna suck up the atmospheric moisture and convey it to the earth, do they also contribute to it by pumping up to the surface of the tufts formed by them, the standing water which was their cradle, diminish it by promoting evaporation, and finally also by their own detritus, and by that of the numerous other bog-plants to which they serve as a support, remove it entirely and thus bring about their own destruction. Then, as soon as the plant-detritus formed in this manner has elevated itself above the surface water, it is familiar to us by the name of peat, becomes material for fuel, and all Sphagnum vegetation ceases.

Schimper: *Versuch einer Entwickelungs-geschichte der Torfmoose.*

Carbon sink function in peatlands

In recent years, global warming and human-induced climatic change have been the focus of considerable research. There is now a general consensus among the scientific community that the earth has warmed significantly over the last 200 years and the large increase in the atmospheric concentration of greenhouse gases (GHGs), such as carbon dioxide, methane and nitrous oxide has been central to this rise in temperature. Although they occur at relatively low concentrations in the atmosphere, GHGs are highly effective at absorbing long-wave thermal radiation and thereby ensure that mean global temperatures remain at around 15°C rather than –19°C in their absence.

Since the last Ice Age, peatlands have accumulated a vast store of atmospheric carbon and in the process acted as a regulatory mechanism to the global climate. However, there is considerable difficulty in ascertaining the exact quantity of carbon stored globally, due in part to uncertainties in the areal coverage of the global peatland resource, as well as a lack of information in regard to physical-chemical properties, such as peat depths and bulk density measurements. In 1980, Hugo Sjörs, assuming an average peat depth of one metre and a bulk density of 0.1g cm^{-3}, estimated that there is around 300 billion tonnes of carbon contained in global peatlands. In 1990, Eville Gorham suggested that the average peat depth was closer to 2.3m and he estimated that there was around 450 billion tonnes of carbon contained in the peatlands of the northern latitudes alone, a figure equivalent to almost half the amount of carbon contained in the atmosphere (IPCC, 2001). The largest peat (and therefore carbon) deposits are found in Russia, Canada, U.S.A, Indonesia, Sweden and Finland. The peatlands of Ireland cover around 16% of the land surface and contain an estimated store of around 1230 million tonnes of carbon .

The position of the water table within the peat profile is central to the ability of the peatland to act as a carbon sink insofar as it acts as the interface between the oxic and anoxic zones where differential rates of decomposition can be expected. The peatland vegetation fixes carbon dioxide during photosynthesis and a high proportion is released back to the atmosphere from above- and below-ground plant (autotrophic) respiration **[Fig. 5.1]**. Root exudates and litter added to the oxic layer above the water table are quickly decomposed by microbial action (heterotrophic respiration), releasing further carbon dioxide to the atmosphere. A small proportion of the plant material is deposited below the water table where anaerobic decomposition processes are much slower. The peatland also loses carbon as methane emissions (see below), through the leaching and surface runoff of dissolved organic carbon and from combustion during periodic fire events. If the amount of carbon sequestered is greater than losses, the peatland becomes a net carbon sink. Using techniques such as macrofossil analysis and radiocarbon dating investigators have been able to document the development of a peatland and estimate the rate at which carbon has been sequestered in the past. Not surprisingly, carbon has been sequestered at different rates with larger amounts stored during the early stages of peatland development. In recent years, much experimental work has been carried out to determine the current rate of carbon accumulation. Eddy covariance towers and chamber methodologies have been widely employed by researchers investigating the ability of present-day peatlands within different climatic regions to actively sequester atmospheric carbon. Values typically fall within a very large range and are subject to considerable temporal and spatial variation driven by changes in abiotic and biotic factors.

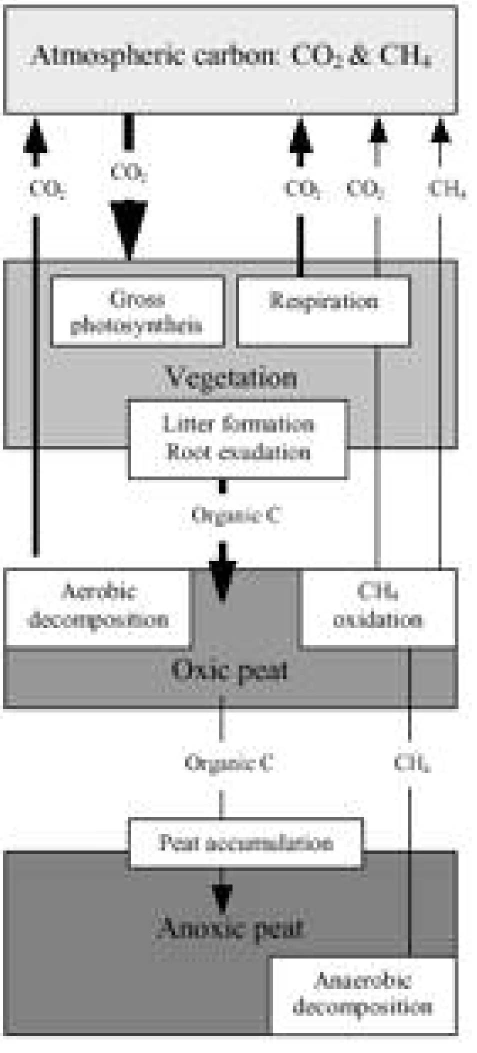


Figure 5.1: Carbon exchange dynamics in pristine peatlands (after Tuittila, 2000)

Temporal variation in carbon dioxide exchange

The capacity of a peatland to act as a sink for carbon dioxide varies considerably over different time scales. Two processes, photosynthesis (carbon dioxide uptake) and respiration (carbon dioxide loss) vie for ascendancy but are strongly controlled by a range of abiotic and biotic factors that are themselves subject to variation at diurnal, seasonal and interannual scales. As photosynthesis is strongly influenced by irradiation levels and the phenological status of the vegetation, the highest rates of carbon dioxide uptake by the vegetation during the day are likely to occur around midday in conjunction with maximum daily irradiation and the lowest rates of uptake at night-time. Seasonally, the highest rates of carbon dioxide uptake occur in mid–summer when annual irradiation levels are at a maximum and plant biomass is optimum. Uptake is lowest during winter, although some uptake can still take place particularly under the mild climatic conditions found in Ireland.

Autotrophic respiration is closely tied to the photosynthetic capacity of the vegetation, and the diurnal and seasonal flux of carbon dioxide to the atmosphere follows the same general trend as photosynthesis. Heterotrophic respiration (the microbial breakdown of litter, root exudates and peat) is strongly controlled by the temperature at or near the peat surface. Therefore, the highest losses of carbon dioxide are likely to occur in mid-summer in conjunction with the maximum peat temperatures. As we have seen earlier, the relationship between respiration and the moisture content of the peatland has been well established. Changes in the position of the water table driven by changes in evapotranspiration rates and the frequency and distribution of precipitation and /or ground water supply can have a major impact on carbon dioxide dynamics within the peatland.

Interannual variations in both photosynthesis and respiration rates have been widely reported for peatlands. For example, Shurpali and colleagues in a two-year study in a Minnesota peatland noted that the ecosystem transformed from a carbon dioxide source to a sink in successive years. They attributed this to lowered water table levels and increased soil temperatures during the drier year of their study, which resulted in greater soil carbon dioxide emissions. In a modelling study, Timothy Griffis and Wayne Rouse observed that the timing of precipitation events and changes in air temperature strongly affected photosynthesis in a sub-arctic fen.

Spatial variation in carbon dioxide exchange

Within a peatland, variation in the rates of carbon dioxide uptake (or loss) has been widely documented by peatland scientists. Differences in microtopography and vegetation composition result in differential rates of carbon dioxide exchange. For example, Anna Laine and colleagues in a study in an Irish blanket bog observed considerable differences between hummocks, lawns and hollows in their ability to act as sinks for carbon dioxide, with the drier microforms being the most effective. There are also considerable differences between peatlands in how much (or indeed how little) carbon dioxide is sequestered. These differences are driven by differences in the trophic status and hydrology.

Peatlands and methane emissions

Although pristine peatlands act as a sink for carbon dioxide, they are also a significant source of another greenhouse gas: methane. Methane emissions from peatlands account for around 23% of total global emissions. Both methane production (methanogenesis) and oxidation (methanotrophy) are strongly influenced by environmental factors such as moisture, temperature, nutrient status and microbial composition. Methanogenesis is a microbial process requiring absolute anoxia and redox conditions of less than -200 mV. The bacteria responsible for methane production (methanogens) belong to the domain Archaea but depend on other anaerobic bacteria for the degradation of the complex organic material released by plants, with several groups of microbes being necessary for the conversion of organic matter to methane. As with carbon dioxide, the position of the water table is central in determining the magnitude of methane emissions. As the water table becomes deeper, the aerobic zone also becomes larger with the result that more methane is oxidised by methanotrophic bacteria. Conversely, as the water table comes closer to the surface, the aerobic zone is constricted and less methane is oxidised.

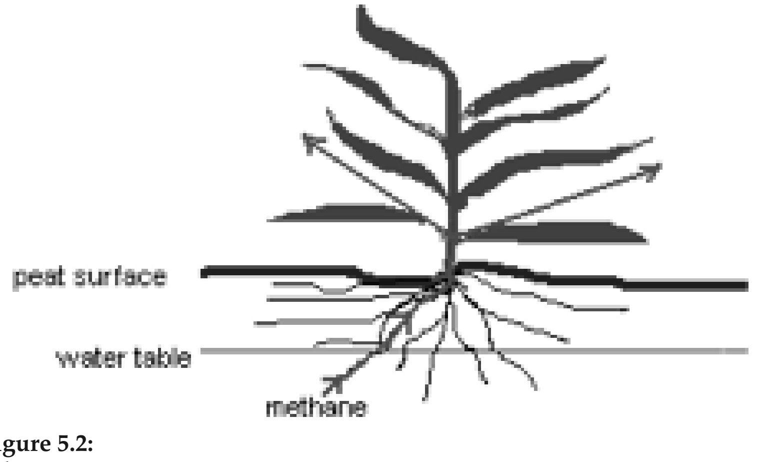


Figure 5.2: Schematic presentation of plant-mediated transport in a peatland plant. Methane produced in the anoxic peat moves through the aerenchymatic structures of the plant to the atmosphere.

The importance of vegetation to the production and transport of methane has been well established. The link between the production of methane and net primary production is strong, with a high proportion of the methane produced resulting from the breakdown of recently sequestered carbon in root exudates and plant litter. Carbon isotope studies have also highlighted the correlation between plant production and methane emissions, in particular the quantity and quality of fresh organic matter. In addition to providing substrates for the methanogens, peatland plants also provide a means whereby the methane produced in the anoxic zone can diffuse to the atmosphere, bypassing the oxic zone at the surface where methane is oxidised to carbon dioxide by methanotrophic bacteria. Plant- mediated transport is the most important pathway for methane movement from the anoxic peat to the atmosphere (diffusion and ebullition are of lesser importance) accounting for up to 97% of the total methane transported. In deep-rooting wetland plants, the development of specialised internal gas transport structures, such as aerenchyma, facilitates the diffusion of oxygen from the leaves to the roots [**Fig. 5.2**]. However, this interconnected column of large air spaces also provides a conduit for methane movement from roots deep in the anoxic substrate to the atmosphere and in the process minimises oxidation in the aerobic zone.

Peat extraction and carbon

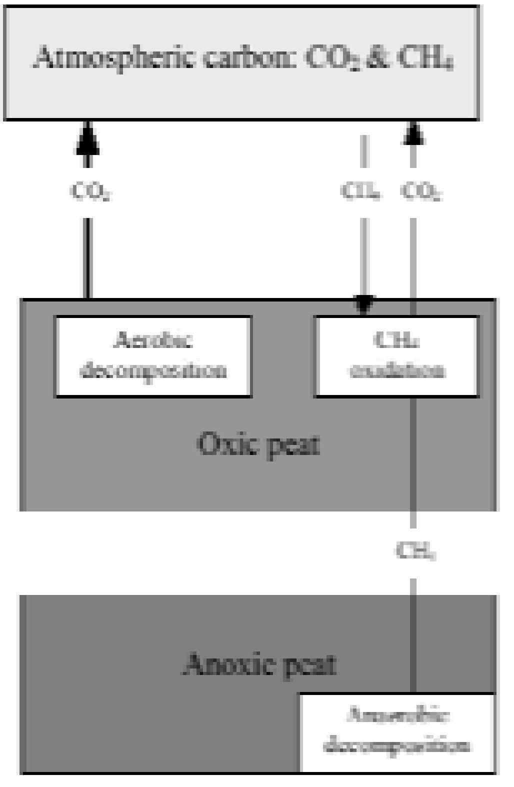


Figure 5.3: Carbon exchange dynamics in a cutaway peatland (after Tuittila, 2000)

Research has shown that both carbon dioxide and methane dynamics undergo significant changes when a peatland undergoes a change in land use. In Ireland, around 7.5% of peatlands are utilised by Bord na Móna, who extract around 4 million tonnes of peat annually. In order to facilitate industrial extraction of the peat, drainage ditches are installed to lower the water table and reduce the moisture content of the peat. The installation of drainage ditches increases the depth of the oxic zone in the upper layers of the peatland resulting in higher losses of carbon dioxide [**Fig. 5.3**]. Even a small change in the position of the water table can have considerable impact in determining how much carbon dioxide is produced. For example, Jouko Silvola and colleagues in Finland reported that a decrease of only 1cm in the position of the water table would result in an additional 9.5g carbon per m^2 being released to the atmosphere each year.

After a number of years, the vegetation layer and the more fibrous peat layers at the surface are removed in order to facilitate the extraction of the more highly decomposed peat deeper within the profile. This action has a number of important effects on the system. Firstly, it disrupts hydrological processes, adding to the changes brought about by drainage, i.e. peat shrinkage, compression, reduced hydraulic conductivity and pore size etc. More importantly, however, it removes the carbon sequestration capability of the system. Peat extraction transforms the peatland into a significant source of carbon dioxide, but conversely results in a significant reduction in emissions of methane from the bare peat surface, although the drainage ditches may remain a significant methane source . The amount of carbon lost from domestic peat extraction (hand-cutting and mechanised) in Ireland remains poorly quantified. Peter Foss and his colleagues in the Irish Peatland Conservation Council have suggested that domestic cutting has affected up to 46% of the original peatland area in the Republic of Ireland over the last 500 years. Domestic cutting significantly affects the vegetation and hydrology at the margins of the peatland and also has severe indirect effects on carbon exchange in the main part of the peatland (Wilson, unpublished data).

The loss of the carbon sequestering function through peat extraction is a cause for concern and policies to reduce the net carbon loss need to be implemented. The technology of peat utilisation should be the most efficient possible; hence the importance of fluidised bed technology and the potential for co-firing of the peat with a suitable biomass crop.

Restoration of the carbon sink function

The ending of peat extraction offers an opportunity to recreate new ecosystems that may have some of the characteristics of pristine peatlands. Two main criteria are required in order to create conditions conducive for peat formation and, therefore, carbon accumulation. Firstly, there is a requirement to ensure that the water table is maintained close to the surface in order to (1) minimise the losses of carbon dioxide from the heterotrophic decomposition of the residual peat substrate and (2) establish conditions for the recolonisation of the peatland by suitable vegetation species. Blocking of drainage ditches and the creation of bunds are techniques commonly employed to raise the water table. However, maintaining a persistently high water table is a major challenge due to the irreversible changes in the structure of the residual peat caused by the original draining of the peatland. For example, compression and compaction of the peat has a marked effect on pore size and hydraulic conductivity, leading to large fluctuations in the position of the water table. Secondly, once the appropriate hydrological conditions have been created, the recolonisation of the bare peat surface by vegetation is necessary to restore the carbon sequestration component.

As with the restoration of the hydrological component, this can be problematic, particularly in the case of industrial cutaway peatlands where a lack of seed bank in the residual peat and the large distance from a ready source of seeds and spores may result in the peatland remaining bare for some time. In cases where the restoration of both hydrology and vegetation has been successful, the results have shown that the return of the carbon sink function can be achieved relatively quickly although the same peatland may lose carbon as it develops over time. Mike Waddington and Kevin Warner noted that although the restored peatland in their study was still a carbon source, the losses were considerably reduced with the return of the vegetation.

In Ireland, the restoration approach has not been widely pursued in industrial cutaway peatlands. Instead, other land use options such as afforestation and natural regeneration have received more attention. The potential of these new ecosystems to act as carbon sinks has revealed contrasting results. For example, Kenneth Byrne and his colleagues reported that a 19-year-old Sitka spruce-afforested cutaway peatland was a sink for carbon dioxide but that a naturally regenerated birch / willow woodland of the same age was a large source. In both those studies and in others in Finland, large annual emissions of carbon dioxide were measured from the residual peat, offsetting somewhat the carbon sequestered by the tree stand.

Climate and peatlands

The effect of increasing atmospheric concentrations of GHGs on the global climate was discussed earlier. Carbon dioxide is the most important GHG, but as the global warming potential (GWP) of methane is 23 times that of carbon dioxide over a 100-year horizon its role is highly significant. Carbon uptake by the peatland has a net cooling effect on the climate while methane emissions result in a net warming effect. A modelling study by Steve Frolking and colleagues described the impact of sustained fluxes of carbon (both carbon dioxide and methane) on the global climate over the lifetime of a peatland. In the early stages of development (i.e. the fen stage), the peatland is likely to have a net warming effect on the climate as a result of high emissions of methane. As the peatland develops towards the ombrotrophic bog stage, emissions of methane decrease, resulting in a net cooling effect on the climate.

The Intergovernmental Panel for Climate Change (IPCC) have envisaged that the global climate will undergo significant change in the future. In the absence of significant reductions in GHG emissions, they have predicted that the global mean temperature will increase by 0.2°C per decade and that widespread changes in precipitation patterns are likely to take place around the globe. Globally, there is considerable uncertainty in predicting the effects of future climate change on the carbon stores within peatlands. Some predictive models suggest an increase in peat accumulation as a result of warmer and wetter conditions and a decrease if there were a drought during the growing season. Other studies have suggested that increased atmospheric carbon dioxide levels may lead to both increased plant productivity and a subsequent increase in soil respiration and methane emissions . Warmer drier climates have also been predicted to result in a general lowering of water table levels within peatlands, and subsequently lead to a decrease in the amount of methane emitted to the atmosphere from the peatland . Furthermore, Chris Freeman and colleagues have suggested that predicted higher temperatures from global warming may also lead to higher losses of dissolved organic carbon (DOC) from the peatland as a consequence of increased activity of the enzyme phenol oxidase . Changing climate may result in successional changes in vegetation within the peatland. Some studies have shown that as a result of water drawdown caused by higher rates of evapotranspiration there could be increased coverage of woody shrubs at the expense of graminoid species in both bogs and fens.

In Ireland, Regional Climate Models (RCM) have predicted that the climate will continue to undergo changes over the next 100 years with warmer, wetter winters and warmer, drier summers more likely . The effect of these changes on carbon gas exchange in Irish peatlands is difficult to predict, as there has been only a limited number of carbon exchange studies undertaken to date and even fewer climate change experiments have been carried out . However, recent work by Mike Jones, Alison Donnelly and Fabrizio Albanito in Trinity College Dublin has suggested that if the climate changes in Ireland as predicted, then a very large loss in present day functioning peatlands could be expected by 2075 with a subsequent diminution of the carbon stored therein.

Kinds of mires

Many different kinds of mires occur in different parts of the world, but they can be grouped into six major mire type complexes:
Tundra mires are shallow mesotrophic mires which cover vast areas in permafrost regions (Alaska, Canada, Siberia, Antarctica).

Palsa mires are characterised by ombrotrophic peat mounds several metres high with permafrost cores, separated from each other by minerotrophic flushes. They occur in the zone of discontinuous permafrost in Canada, Fennoscandia and Siberia.

Aapa mires are flat or concave complexes, mostly minerotrophic, which often occur in a characteristic 'string-flark' patterns. (Flarks are linear pools or hollows, generally transverse to water flow). They are found in the boreal zone of Fennoscandia, the western part of the former Soviet Union, and in North America.

Raised mires are deep ombrotrophic complexes with elevated centres. They occupy an almost continuous belt across Northern Europe, the former Soviet Union, the northern part of Japan and North America.

Blanket mires are ombrotrophic, forming a continuous 'blanket' across the high-rainfall terrains where they occur. They occur mainly in low-lying coastal regions of Western Europe, the Kamchatka peninsula, Canada and Newfoundland in the northern hemisphere; and in southern Chile and south-west New Zealand in the southern hemisphere.

Southern limnogenic mires are alluvial swamps and river-side marshes, and the sedge and reed beds of lake margins and wet depressions. They include the *Papyrus* and *Raphia* swamps of Africa, the Florida Everglades and the Ukraine reed-sedge fens. They are highly minerotrophic.

Words for bogs

'Bog' is an Irish word, derived from the word for 'soft'; *bogach* is soft ground. It made its way into English around the beginning of the 16th century. The older English word for a bog was *moor* or *mire,* which corresponds to the German word *moor,* a bog or fen. The fuel which comes from a bog is called *peat* in England but in Ireland it is *turf,* a word which can be traced back to the Medieval *turbarium.* Peat is also a Celtic word, from *puit* or *peuit,* which means a soft, miry substance; the usual word in modern Irish for a turf bog - or for turf itself - is *móin;* a turf bank is *portach.* Today, moor in English has come to mean *heath,* but the word *mire* is now generally accepted as the proper word in English to describe peat-producing ecosystems in general. Those mires that are fed by surface water or groundwater are described as *minerotrophic,* while those that are fed by atmospheric water are called *ombrotrophic.*

Ancient bogs

Bogs also formed in the geological past, wherever and whenever conditions were favourable, and in exceptional circumstances they survived to become rocks. The earliest plant life on land became established 450 million years ago, and one of the earliest rocks with abundant land plant fossils, the Scottish Rhynie Chert of Silurian age, is an ancient peat.

The most notable example of fossilised peats are the Coal Measure rocks of the Upper Carboniferous period, which (together with the limestones which accumulated in the oceans of the Lower Carboniferous) locked up a very large percentage of the world's carbon at that time. It has been estimated that the level of carbon dioxide in the atmosphere dropped to less than twice its present level during the Carboniferous. The earth's surface temperature is criticially dependent on the amount of CO_2 in the atmosphere; it is not surprising therefore that the low concentration 300 million years ago occurs at the time of the only major ice age in this era.

In the more recent Tertiary epoch, vast bogs existed around Lough Neagh (and perhaps elsewhere) that formed the lignite deposits of that area. Under different circumstances, the post-glacial peats, which are the subject of this book, might have survived to become the lignites or coals of some future age of the earth.

Irish bogs

Four categories of rain-fed or ombrotrophic peatlands are found in temperate areas: upland blanket bog, lowland or oceanic blanket bog, raised bog and wooded bog. The first three of these occur in Ireland. (The great English plant ecologist Tansley also recognised three types of Irish bogs: raised bog, blanket bog and valley bog, 'where water, draining from relatively acidic rocks, stagnates in a valley bottom or depression, so as to keep the soil constantly wet').

Upland blanket bogs cover large expanses of mountainous country. In the wet west of Ireland, great areas of bog very similar to the bogs of the mountains occur right down to sea level; these are the low level or western oceanic blanket bogs. The wet climate is responsible for the presence of these bogs, which is why the peat in them is referred to as climatic peat.

Oceanic blanket bog undulates with the topography, and is nourished by relatively high-nutrient precipitation, giving the flora a somewhat mixed character. It is a very rare habitat type; only about 10 million hectares occur world-wide, and most of this is in Europe, particularly in northern Scotland, the west of Ireland, west Norway and the Pyrenees. Raised bogs are different from blanket bogs in a number of ways, but there is one key difference: they do not owe their existence so much to the wetness of the present climate, as to the peculiar history of the landscape in which they formed. Each one started its development as one or several separate small bogs to begin with, growing on postglacial lake sites; these outgrew their original boundaries with time and eventually fused. These raised bogs often extend over enormous areas; they attained their greatest development in the Irish Midlands, in north-west Germany and the Netherlands. Where the bog remains confined to its original basin, it is classified as a lens raised bog. Most of the large bogs of East Germany, Poland, Southern Sweden and Western Finland are of this kind, though there are also examples here in Ireland. The fourth category of ombrotrophic peatland, the one not represented in Ireland, is continental wooded raised bog; this is found in more continental areas such as Russia, Finland, the Czech Republic and Slovakia, where the continental conditions allow the bog surface to dry sufficiently for pines to grow on them. Various other kinds of bogs occur in the colder northern parts of Europe, and on high mountains. Irish bogs are significantly different from their mainland European counterparts; the Midlands raised bogs differ from those on the Europe mainland in having fewer trees growing on them – under present climatic conditions anyway – and in having a profile which is not as domed. Though Irish bogs are very similar in most ways to bogs elsewhere in Europe, they do have their own special plants. The commonest of these special plants are bog asphodel and cross-leaved heath, great sundew and many-stalked spike rush. The higher saltwater content in Irish rain has a significant effect on the flora of western blanket bogs. Some of our bogs plants would be more properly classified as low-nutrient fen species in countries such as Sweden.

Different kinds of bogs are associated with different rainfall regimes. Raised bogs are found mainly in the Midlands and towards the east of the country where yearly rainfall is 750-1,000mm [**Table 5.1**].

TABLE 5.1: THE RAINFALL REGIMES OF THE MAIN TYPES OF BOGS IN IRELAND

Type of bog	**Mean annual rainfall**
Raised bogs	750-1,000mm
Intermediate bogs	1,000-1,250mm
Blanket bogs	> 1,250mm

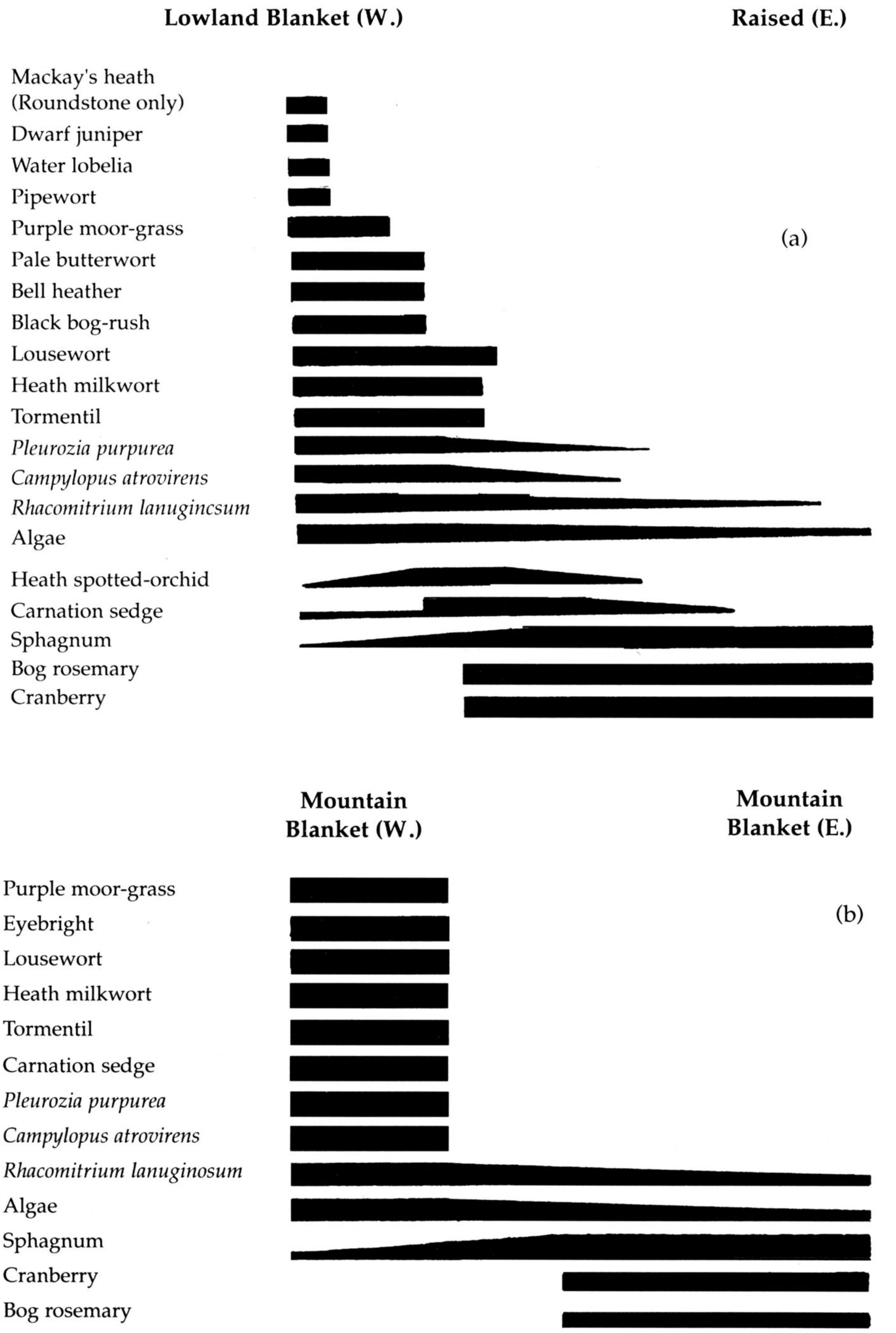
Raised bogs vary in thickness from 3m to 12m; depths of 8m (25’) are not uncommon but the average depth is about 7.5m. Peat density, calorific value and degree of humification all increase with depth. The average depth of low-level blanket bogs would be about 3m, and mountain blanket bog less than half this. Low-level blanket bog tends to have very irregular bottom contours, which makes mechanical working very difficult.

Raised and blanket bogs each have their characteristic species. What distinguishes oceanic blanket bog is the dominance of purple moor-grass and black bog-rush, and the minor role played by shrubs of the heather family. On blanket bogs, sphagnum mosses do not play the dominant role they play on raised bogs, and there is often a much greater cover of the algal complex *Zygogonium ericetorum* which grows on bare peat. The upper peat comprises mostly sedges and grasses, is more compact and more poorly aerated, and this has a major influence on the composition of the vegetation: plants like heather cannot grow under these conditions, and the low diffusion rate makes it difficult for plants to make use of the relatively high levels of nutrient provided by the enriched precipitation. Nevertheless, a number of species of plants which are characteristic of blanket peat vegetation - purple moor grass, heath milkwort, lousewort, tormentil – reflect this higher nutrient status: in raised bogs these plants are characteristic of cutover situations, but not of the intact raised bog surface [**Table 5.2**].

Mathias Schouten has also described other aspects of this ‘eco-geographical gradient’ in ombrotrophic Irish bogs. As well as the variation in overall morphology, there are differences in surface pool-and-hummock patterns, in the kind of tearing that may result from topographically-related pressures exerted on the peat body, in peat slippage pattern and frequency, in the nature and extent of erosion, and in the structure as well as the composition of the vegetation. These structural differences (height, proportion of woody stems, root profiles etc.) are partly related to the more compact structure of the upper peat, and to the relatively poor aeration of western blanket peat: the oxygen diffusion rate here may be only half what it is in raised bogs for the upper 5-50cm.

The lowland bogs of the Midlands are called raised bogs because of their characteristic domed profile. The continued upward growth of the bog mosses and other plants, and the accumulation of their undecayed remains, elevates the bog surface above the level of the surrounding countryside. The dome of the bog is flat on top, and very wet, pools of standing water alternating with drier cushions and hummocks, but towards the margins the bog slopes downwards and is drier. At the very edge there is more movement of groundwater, where the bog comes under the influence of water from the area surrounding it, so that the vegetation here is quite different, forming a belt of marginal fen or *lagg*. These areas of lagg are seldom seen nowadays, because centuries of exploitation have modified the edges of most bogs: they have been reclaimed, colonised by, or planted to woodland, or altered as a result of drainage. However, areas of old cutover sometimes develop vegetation similar to lagg fen.

Table 5.2: The floristic gradient
(a) between lowland blanket bog and raised bog; and
(b) between mountain blanket bog in the east and west of the country
(Schouten, 1984).



The raised bogs began their development in circular basins or longitudinal flood plains, and on the sites of lakes or low-lying wet hollows between the glacial drift, situations which acted as 'templates' for peat formation: wherever water accumulates on its way down from the catchment to the sea there is a template for peat formation. Raised bogs are characterised by a basal layer of fen peat overlain by two layers of bog-moss or sphagnum peat: younger slightly-humified sphagnum peat on top, and a better humified layer beneath. But although to begin with the bogs were confined within lake basins, when the climate became wetter they were able to extend laterally, swamping the woods which grew on the margins of the ancient lakes and fens. Two processes are involved therefore in the formation these bogs: *terrestrialisation,* which is the classical sequence by which shallow lakes go through a process of ecological succession that ends with the development of a bog, and *paludification,* which is the term applied to the process by which restricted drainage at the

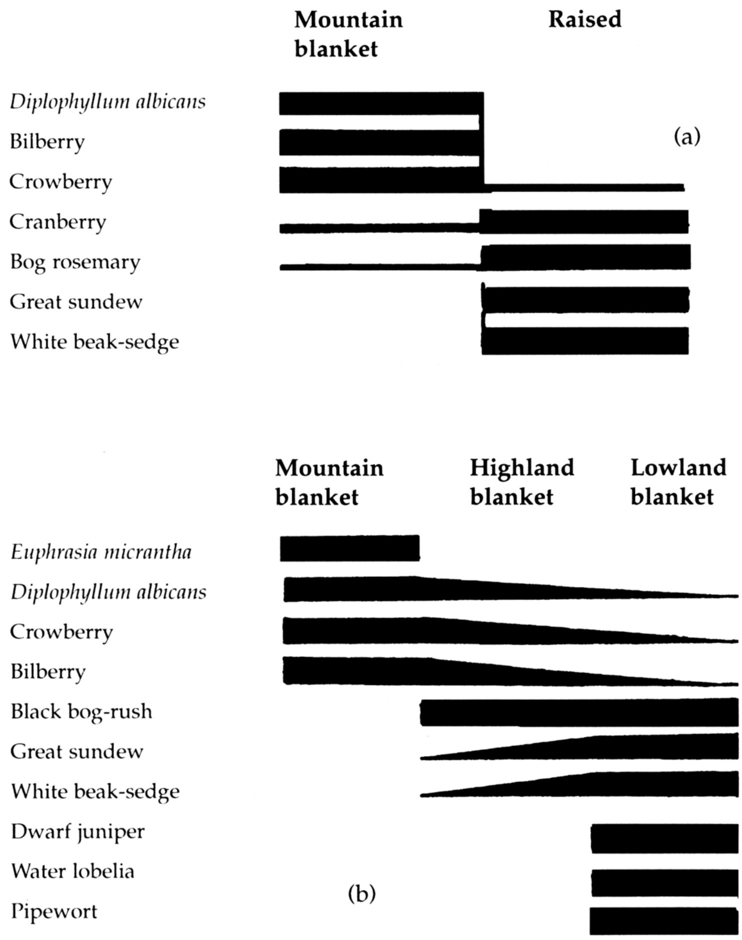


Table 5.3: The floristic gradient (a) between western lowland blanket bog and midland raised bog; and (b) between mountain and lowland blanket bog (Schouten, 1984).

margins allows a bog to encroach over adjacent mineral soil. Areas of raised bogs which have swollen out beyond the boundaries of their original lake basins are called *intermediate* bogs, and they tend to occur in areas where precipitation is between 1,000 and 1,250mm [**Table 5.1**]. These intermediate bogs are really raised bogs which, because of higher rainfall and humidity, managed to grow out of the depressions in which they formed, although the critical distinction between them is based on the flora; they are also intermediate in their geographical distribution, for they occur for the most part in central Galway and central Mayo. Bogs which have spread out from their original lake basins to engulf intervening ridges of mineral ground are sometimes referred to as 'ridge raised bogs'. Small raised bogs of distinctive character formed in the kettle holes which are such a characteristic feature of the Midlandian end moraine which is so splendidly preserved in County Wexford. Because these little bogs were the only source of turf in lowland Wexford they have now more or less disappeared [**Figure 5.4**].

From the botanical point of view there are two sorts of raised bogs in Ireland: these will be discussed more fully in the next chapter. The *Midland Sub-type* is characterised by cranberry and bog rosemary, but as one goes west and climate becomes wetter there is a subtle change in the composition of the plant communities, which take on a botanical character closer to blanket bog. Beyond the 1,000mm isohyet there is a distinct change. The indicator species of the Midland Sub-type are no longer prominent: they are replaced by the indicator species of the *Transitional Sub-type* of raised bog: the mosses *Pleurozia purpurea* and *Campylopus atrovirens.*

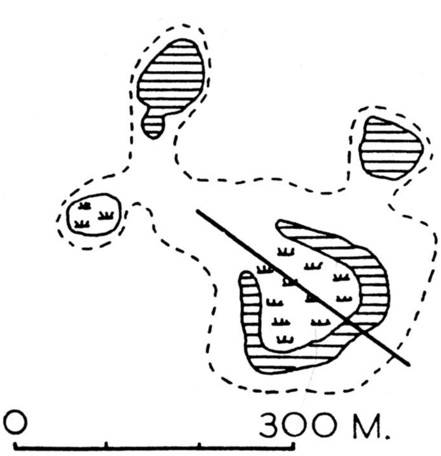


Figure 5.4: Doo Lough, a kettle hole in Kilmacoe townland in County Wexford. The lake was drained around 1850, shrinking as a result to four small areas of open water and marsh. The wet peat was then dredged from the basin and mud turf made from it (From Mitchell, 1951).

Oceanic blanket bogs have most of the characteristic plants that grow in raised bogs - cotton grasses, white beak-sedge, *Sphagnum rubellum* and *Sphagnum papillosum.* But they also have their own special plants: purple moor-grass, lousewort, bell heather, black bog rush, the bryophytes *Campylopus atrovirens* and *Pleurozia purpurea.* These are not absent from the Midland raised bogs, but they only occur as a rule around the edges, where ecological conditions resemble those typical of oceanic bogs.

The productivity of ombrogenous bog vegetation is in the region of 250-600 g m^2 &1, which is low by comparison with most other ecosystems. One of the most striking differences is the important role played by algae and mosses in the energy budget. Bogs are one of the few ecosystems surviving on earth where mosses are often dominant over vascular plants, and in Atlantic blanket bog the most important contributors to annual productivity are the algae. Another notable feature of blanket bog is the huge chunk of the total resource budget locked up in the underground stem bases of black bog rush and purple moor grass. Peak phytomass occurs towards the end of July (1,624 g/m^2), and annual production has been calculated as over 360 g/m^2, about a third of the productivity of grassland growing in reclaimed peat.

What is peat?

Peat is a *biogenic* deposit - a deposit produced by living creatures - which has accumulated under conditions of impeded drainage and oxygen deficiency during the 10,000 or so years since the end of the last glaciation. These anaerobic and waterlogged conditions inhibit the activity of the micro-organisms (fungi and bacteria) that normally bring about the decay of dead plant and animal remains, so they accumulate as peat. Another factor inhibiting decay seems to be the very low level of nitrogen in the plant material in peat - less than 1% of dry mass - particularly where this is dominated by the remains of sphagnum. The roots of the plants which grow on the bog surface are no longer in contact with the mineral soil beneath: and because the nutrients locked away in the peat are not being recycled, a very limited supply of nutrients is available to these plants, and they often resort to special devices and strategies to secure them. More than 90% of peat consists of water - a higher proportion than milk. In a 5m column of fibrous peat, no more than 30cm is solid plant matter. The physical properties of the different kinds of peat are summarised in Table 5.4.

Table 5.4: Physical properties of Irish peats (Galvin 1976).

	Type of peat[a]					
					Woody-fen	
	Blanket	Y.S.	O.S.	Reed-fen	B	B/C
Natural moisture content (% dry weight)	1,057	1,607	995	894	821	929
Natural moisture content (% by volume)	88.9	91.3	88.9	85.7	90.9	91.0
Degree of humification	H8	H2	H8	H8	H6	H7
pH	4.1	4.2	4.7	6.0	5.4	4.5
Ash content (%)	1.5	1.6	1.0	7.3	7.8	7.4
Specific gravity	1.31	1.36	1.36	1.38	1.38	1.36
Void ratio	17.8	23.0	15.0	14.5	12.7	14.8
Porosity (%)	94.7	95.8	93.7	93.5	92.7	93.7
Unit weight at saturation (kg/m^3)						
Natural	1,021	1,006	1,023	1,027	1,030	1,023
Dry	70	56	85	89	101	86
Hydraulic conductivity (mm/day)						
Laboratory	13	208	5	49	8–183	6
Field	6	209	28	126	564	648
Infiltration (mm/day)	4	61	3	13	29	2
Moisture content at pF 2 (% by volume)	78.6	57.6	76.5	79.8	84.5	83.1
Drainable porosity (ml/ml)	0.16	0.38	0.17	0.14	0.08	0.11

[a]Y.S. = Younger Sphagnum; O.S. = Older Sphagnum

The actual material of which bogs are made can be classified in different ways. It can be classified on the basis of the plant remains in it - sphagnum peat, sedge peat etc.; it would be better to base a classification like this on the whole peat-producing community, but this is not easily accomplished. The *degree of decomposition*, which is reflected by the colour, is an important criterion used to classify peat types because it is directly related to several important physical and chemical properties of the peat: its water-holding capacity and hydraulic conductivity, the bulk density and fibrosity, and its value as a fuel. It was first classified in this manner by the Swedish bog scientist von Post. In the 1920s von Post devised a ten-point scale to classify peat types, and this is still the most widely-used practical system. The system takes account of the botanical composition of the peat, its degree of decomposition (humification) and nutrient status, and is an attempt to synthesise and simplify the multitude of systems of classification that had developed independently in many countries [**Table 5.5**].

Table 5.5: The von Post humification scale.

Colour	*Degree of decomposition or humification*
LIGHT	H 1-3
DARK	H 4-6
BLACK	H 7-10

The degree of decomposition can be assessed more quantitatively by measuring the proportion of 'rubber fibre' in the peat, or by determining the solubility in sodium pyrophosphate.

Peat is also classified on the basis of colour and degree of humification by the traditional turf cutter, particularly in raised bogs where there is much variation in density and colour at different depths in the peat profile. Three distinct strata of peat can easily be recognised in these bogs on the basis of the variation in colour, density and other properties, which are due mainly to variation in the botanical composition and the extent of decomposition and compression of the peat. The white turf of which the top metre or two of the bog is made up is composed predominantly of different species of sphagnum mosses; the black turf at the bottom of the bog is made up of the remains of plants which grew in the fens which preceded the bogs, and the brown peat in between the two is dominated by the woody remains of heather, but still with much sphagnum and other plants. The difference between the basic kinds of peat was well appreciated in earlier centuries. Writing in the seventeenth century, Gerard Boate recognised two kinds of turf:

> That which is taken out of the Dry-Bogs, or Red-Bogs, is light, spungy, of a reddish colour, kindleth easily, and burneth very clear, but doth not last. The other on the contrary, which is raised out of the green or wet Bogs, is heavy, firm, black, doth not burn soon, nor with so great a flame, but lasteth a long while, and maketh a very hot fire, and leaveth foul yellowish ashes.

This was the basic classification adopted by the reclaimers of the 18th and 19th centuries. Arthur Young summarised the practical classification of his time as follows:

> Bogs are of two sorts, black and red; the black bog is generally very good, it is solid almost to the surface, yields many ashes in burning, and is generally admitted to be improvable, though at a very heavy expense; the red sort has usually a reddish substance, five or six feet deep from the surface, which holds water like a sponge, yields no ashes in burning, and is supposed to be utterly irreclaimable.

A most important criterion in the classification of peat types is the source of the nutrients for the plants growing on the bog surface. Minerotrophic peatlands (fens) are under the influence of percolating or oscillating groundwater, whereas ombrotrophic peatlands (bogs) have become cut off from groundwater influence, and their only source of nutrient supply is the atmosphere. The nutrients available in minerotrophic peatlands may be abundant *(eutrophic)*, or poor *(oligotrophic)*, or somewhere in between *(mesotrophic).* The nutrient levels in ombrotrophic peatlands are always poor.

The definition of the soil scientist is rather more cautious and particular. For the soil scientist peat consists of organic soil materials that are saturated with water for prolonged periods, or are artificially drained, and have 30% or more organic matter if the mineral fraction is 50% or more clay, or 20% or more organic matter if the mineral fraction has no clay, or proportional intermediate organic matter contents if the clay fraction is intermediate. In practice, a soil qualifies for classification as a peat if it is more than 45cm deep in the case of undrained land, or more than 30cm on drained land.

Irish soil scientists assign different bog soils to a number of different soil *series.* Atlantic blanket peat is assigned to the Glenamoy Series, montane blanket peat to the Aughty Series. Although botanists recognise two different sub-types of raised bog, this is not apparent in the peats below them, and so they are all grouped by the soil scientist in the same soil series, the Allen Series. The peats which underlie old cutover areas in the Midlands are placed in a sort of soil limbo called the Turbary Complex. Reclaimed turbary complex soils are assigned to the aptly-named Gortnamona Series *(gort na Móna* in Irish means 'the tilled field of the bog').

In certain areas during the nineteenth century uncut raised bog was reclaimed by drainage and the spreading of marl or other forms of lime. These special bog soils are placed in the Garrymona Series. Reclaimed fen peats are placed in the Banagher Series, and reclaimed low-level (Atlantic) peats are assigned to the Gweesalia Series.

A special kind of peat forms in and around long-standing loughans and sloughs (the lakes and pools so characteristic of western blanket bogs). When drained, these are found to have a greenish-yellow soap-like peat, often very gaseous, known in Kerry as candle peat. When dry it fragments into small bits which used to be placed in small heaps in saucers and burned in place of candles. Lewis' *Topographical Dictionary* (1846) describes it as follows:

> One species of bog, found chiefly in the barony of Corkaguiney, peculiarly deserves notice; it is called in Irish Meagh Vone, which signifies 'flat turf'. In its natural state it is of a glutinous or saponaceous quality, lying upon the gravel under shallow peat-bogs, which are of a black and brittle nature, with a grassy surface, often producing rushes. It occurs about three spits deep, in a stratum from eight to twelve inches thick, and is of a light-brown colour, mixed with a clayey white. When found, it is carefully laid aside, not for fuel but for light; two or three sods of it, broken small and placed successively on the top of the fire, supply light for the family during the longest night. If kept it is carefully dried, in which case it is nearly as light as cork and has a similar smell when burning. A chymical analysis showed it to be wood, much decayed, and highly impregnated with bituminous matter: when distilled it yielded a considerable proportion of a thick oily inflammable matter, with a residuum of soft charcoal.

This woody 'kippeen' turf is overlain by woody or reed peat, and often burns with a sweet, aromatic smell. On the other hand, some loughan peat contains a lot of iron sulphide and has a very unpleasant, rotten-egg smell. It gives off great heat and sulphurous fumes when burned, and leaves a red ash behind. When stacked it can ignite spontaneously because the iron sulphide changes to sulphuric acid, giving off heat in the process.

The chemistry of peat is highly complicated. At its simplest it can be expressed in terms of elemental composition - the percentage of different elements to which it can be reduced [**Table 5.6**], but in the peat these building blocks make up a complex assemblage of compounds of plant origin: resins and waxes, tannin, small amounts of cellulose and pentosanes, but mainly what the 19th century chemists characterised as humic bodies: ulmic, humine, ulminic and humic acids and their salts. The amount of nitrogen is relatively high: 0.5 to 3% and not all of this comes from the plants in the bog. Some of it is of animal origin, and it may even be supplemented by absorption of ammonia from the air by humic acid in the peat. The amount of ash reflects the amount of inorganic material in the peat, and

Soil profile descriptions and analytical data for organic soils derived from ombrotrophic parent materials of raised and blanket bog origin

Profile 1 - Midland Type

Location:	Clonawiny Td. Co. Westmeath Grid Ref. N: 49.52
Classification:	U.S.D.A. classification Sub-group Typic Sphagnofibrist
Series:	Allen Series
Parent Material:	Ombrotrophic peat of *Sphagnum* origin
Vegetation: Main Species:	*Calluna* and *Sphagnum* spp.
Topography:	On cut edge of bog – slope of 1°
Drainage:	Poor
Permeability:	Poor
Altitude:	99m O.D.
Root Distribution:	Roots to 58 cm

Horizon	**Depth (em)**	**Description**
0i1	0-27	Dark reddish brown (5YR3/4); *Sphagnum Calluna* peat; fibric; poorly humified; on washing *Sphagnum* with *Calluna* remains twigs and flower heads etc., clear wavy boundary to:
0i2	27-58	Dark reddish brown (5YR3/4); *Sphagnum* peat; fibric; poorly humified, on washing dark colour well preserved *Sphagnum;* dear, slightly wavy boundary to:
0i3	58-87	Dark reddish brown (2.5YR2/4); *Sphagnum-Calluna* peat; fibric; poorly humified; on washing dominantly dark-coloured *Sphaglllllll* remains; abrupt wavy boundary to:
0i4	87-118	Black (5YR2/I); *Sphagnum-Calluna* peat; fibric; poorly humified; on washing *Calluna* debris with *Sphagnum imbricatum* dominant and S. *cuspidatum* with *Eriophorum.*

Profile 2 – Blanket bog – low level Atlantic type

Location:	Glenamoy, Co. Mayo. Grid Ref. F 89.34
Classification:	U.S.D.A. classification Great Group Medisaprist
Series:	Glenamoy
Parent Material:	Ombrotrophic peat of cyperaceous origin
Vegetation:	Natural Blanket Bog
Topography:	Gently undulating
Drainage:	Poor
Permeability:	Very slow
Altitude:	20m O.D.

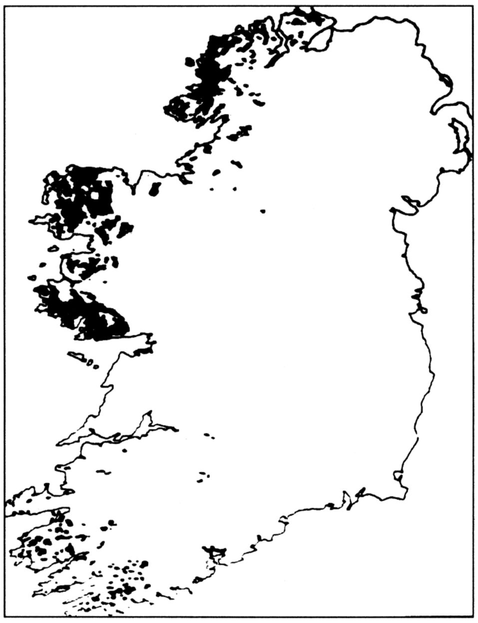
Horizon	**Depth (em)**	**Description**
0.11	0-40	Reddish brown (2.5YR2!2); sapric; finely fibrous; somewhat dried out, liberates only turbid water on squeezing; matrix moderately to well humified; greasy; plant residues, rootlets material and fine amorphous debris with charcoal fragments and *Cenococcum geophilim* fruiting bodies; clear smooth boundary to:
0.12	40-52	Dark reddish brown (5YR32/2); sapric; well humified; greasy; greater than one third of the peat material passes through the fingers on squeezing; plant residues, leaf and rootlet debris and amorphous material; abrupt irregular boundary to:
0.13	52-120+	Dark reddish brown (2.5YR3/2 to 2/2); on exposure; hemic to sapric; well humified; greasy; half peat material passes through fingers; some *Cara* residues; plant residues, *Calluna* rootlet material. occasional charcoal and *Sphagnum* leaf.

Profile 3 – Blanket bog – Montane type

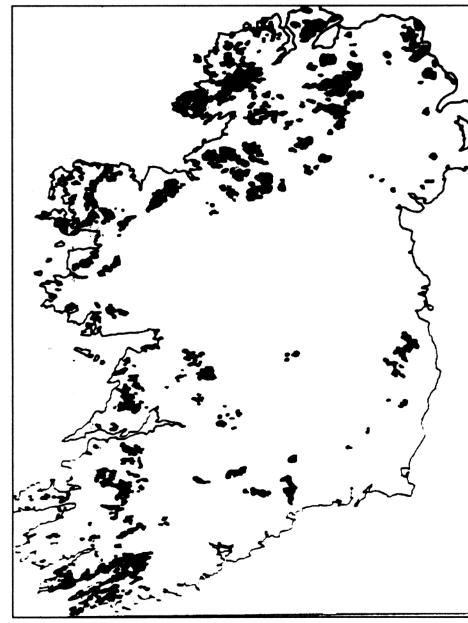
Location:	Slievenakilla Td., Co. Leitrim
Classification:	U.S.D.A. classification Sub-Group Medisaprist
Series:	Aughty Series
Parent Material:	Ombrotrophic peat of cyperaceous origin
Vegetation: Main Species:	*Calluna vulgaris, Polytrichum spp., Eriophorum spp., Vaccinium oxycoccus, Potentilla spp.*
Topography:	Mountainous
Slope:	3-4°
Altitude:	280m 0.0.

Horizon	**Depth (em)**	**Description**
0.11	0-60	Dark reddish brown (5YR3/2); peat; sapric; well humified greasy; humification 7; strong recent and fossil cyperaceous fibres; recent roots to at least 50 em; plant residues, mostly cyperaceous root and leaf material; *Sphagnum* and *Calluna* leaves and leaflets, *Calluna* flower heads; *Juncus* seeds; clear, boundary to:
0.12	60-90	Dark reddish brown (5YR32/2); peat; strong in cypearaceous remains; sapric; well humified; greasy, humification 7/8; increases towards base of layer, plant residues, mainly fine divided rootlet material with amorphous organic maller, charcoal fragments (earbonised *Calluna* leaflets), many remains of carabid beetles, clear boundary to:
0.13	90-110	Black (5YR2/1); peat; sapric; very well humified; few fine fibres; greasy; plant residues, finely divided leaf and root material, woody remains of birch, much charcoal debris, *Juncus* seeds common, some fine quartz grains; abrupt smooth boundary to:
lC	110+	Glacial till, Namurian shale with yellow sandstone.

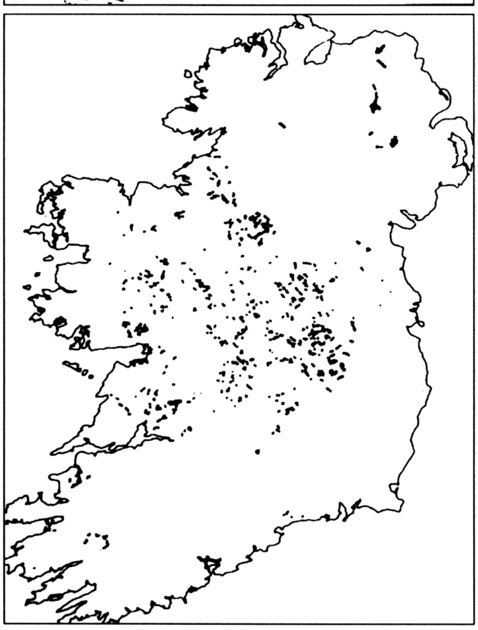
Figure 5.5: Typical profiles of peats belonging to the three unmodified peat soil series (Hammond, 1981).



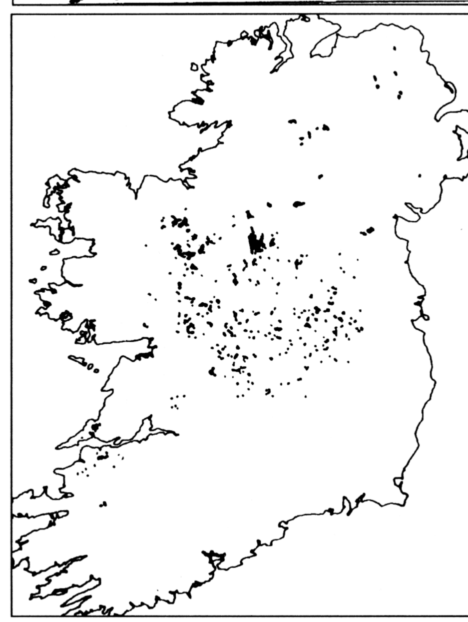
(a) Distribution of blanket bog – Atlantic sub-type.



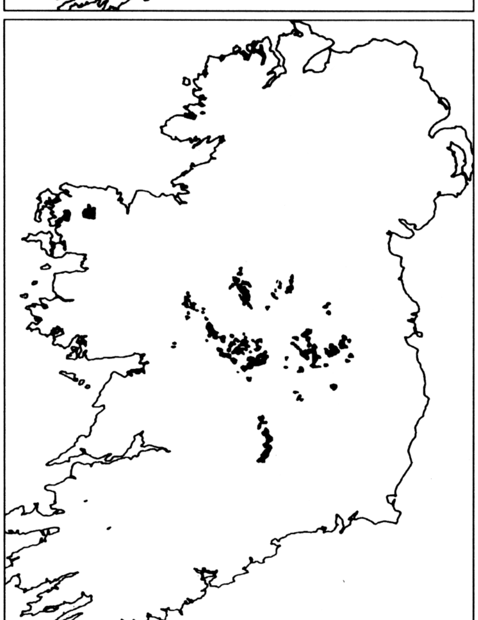
(b) Distribution of blanket bog – montane sub-type



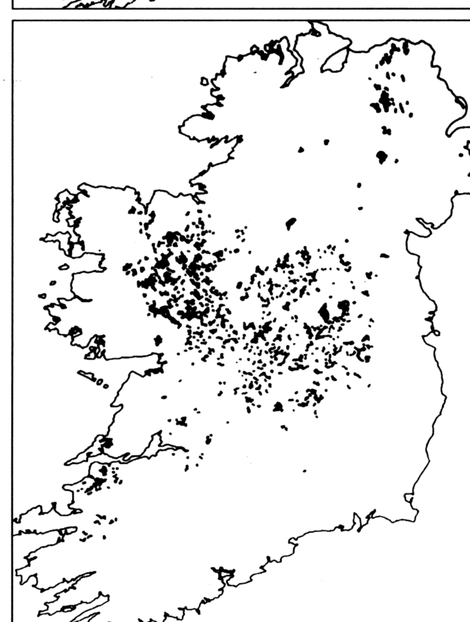
(c) Distribution of fen peat – man modified.



(d) Distribution of raised bog – unmodified



(e) Distribution of industrial peat areas.



(f) Distribution of raised bog – man modified

Figure 5.6: Distribution maps for the different peat types (Hammond, 1981).

Table 5.6: The chemical composition of some Irish peats (Walsh and Barry, 1958).
1. Western blanket bog at Glenamoy, County Mayo.
2. High-level blanket bog at Liffey Head in the Dublin Mountains.
3. Raised bog at Cloncreen, County Offaly.
(a) General chemical analysis. (b) Major elements. (c) Trace elements.

(a)

GLENAMOY

General Analysis

Depth (cms.)	% H_2O	pH	% N	% Ash	(Ps) p.p.m.	Ca(s) p.p.m.	K(s) p.p.m.	% Decom-position	Density gms./ccm.
0–20 }	91·2	4·6	1·44	2·4	16	4	177	38	0·80
20–50 }					2	3	22		
50–100	93·8	4·5	1·20	1·2	4	4	50	47	0·91
100–150	93·0	4·6	1·08	1·2	0·5	3	33	46	0·91
150–200	92·5	4·8	1·00	2·6	0·5	3	56	44	0·90
200–250	92·2	4·8	0·84	2·6	0·5	3	83	38	0·87
250–300	91·0	5·0	0·72	2·6	0·5	3	61	59	1·04
300–350	90·1	5·1	0·76	12·6	0·5	2	45	57	1·03

LIFFEY HEAD

General Analysis

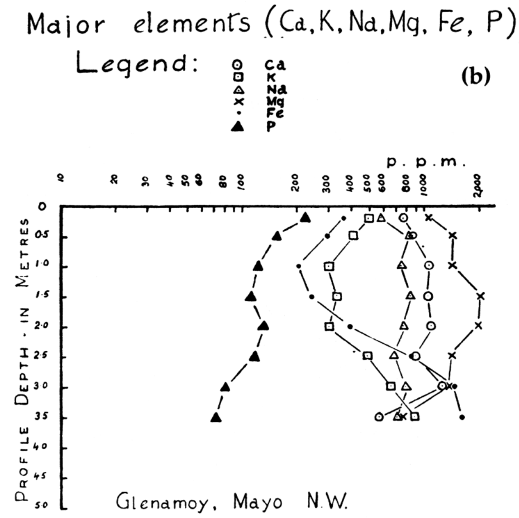
Depth (cms.)	% H_2O	pH	% N	% Ash	(Ps) p.p.m.	Ca(s) p.p.m.	K(s) p.p.m.	% Decom-position	Density gms./ccm.
0–20 }	93·2	4·4	0·90	2·4	16	5	130	35	0·80
20–50 }					9	3	73		
50–100	93·3	4·5	1·24	1·2	5	3	61	34	0·80
100–150	92·0	4·3	1·04	1·2	2	3	39	36	0·90
150–200	91·9	4·6	1·08	1·0	0·5	2	22	36	0·91
200–250	91·6	4·6	0·72	1·0	0·5	2	17	40	0·95
250–300	89·2	4·7	1·12	1·2	0·5	2	22	49	0·99
300–350	88·3	4·7	1·10	2·0	0·5	3	34	64	1·03
350–400	88·2	5·0	1·52	2·2	0·5	2	17	51	0·90

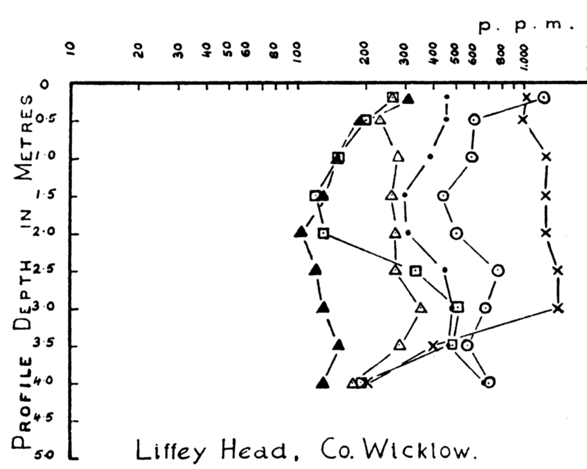
CLONCREEN

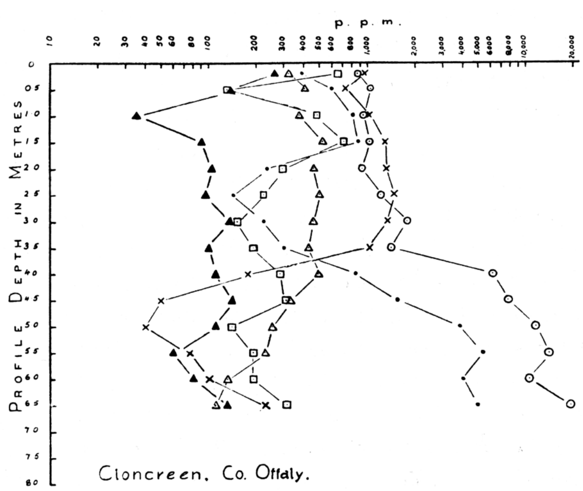
General Analysis

Depth (cms.)	% H_2O	pH	% N	% Ash	P(s) p.p.m.	Ca(s) p.p.m.	K(s) p.p.m.	% Decom-position	Density gms./ccm.
0–20 }	93·7	4·5	1·36	1·9	17	4	130	14	0·4
20–50 }					7·5	5	88		
50–100	94·2	4·6	0·92	1·4	2	4	77	10	0·35
100–150	95·0	4·3	0·72	1·0	3	4	67	8	0·34
150–200	95·1	4·5	0·76	1·0	0·5	3	33	5	0·36
200–250	94·5	4·7	0·76	1·2	0·5	3	33	8	0·36
250–300	93·3	4·7	0·80	2·4	0·5	3	33	48	0·80
300–350	92·7	4·6	0·72	1·6	0·5	3	27	40	0·79
350–400	92·8	4·8	0·72	1·8	0·5	3	17	35	0·60
400–450	91·2	5·0	1·64	3·8	0·5	4	22	38	0·78
450–500	90·2	5·3	1·40	5·0	0·5	6	12	51	0·82
500–550	91·4	5·2	1·68	6·0	0·5	7	33	58	0·92
550–600	90·1	5·5	1·44	19·2	0·5	8	27	42	0·80
					0·5	8	57		

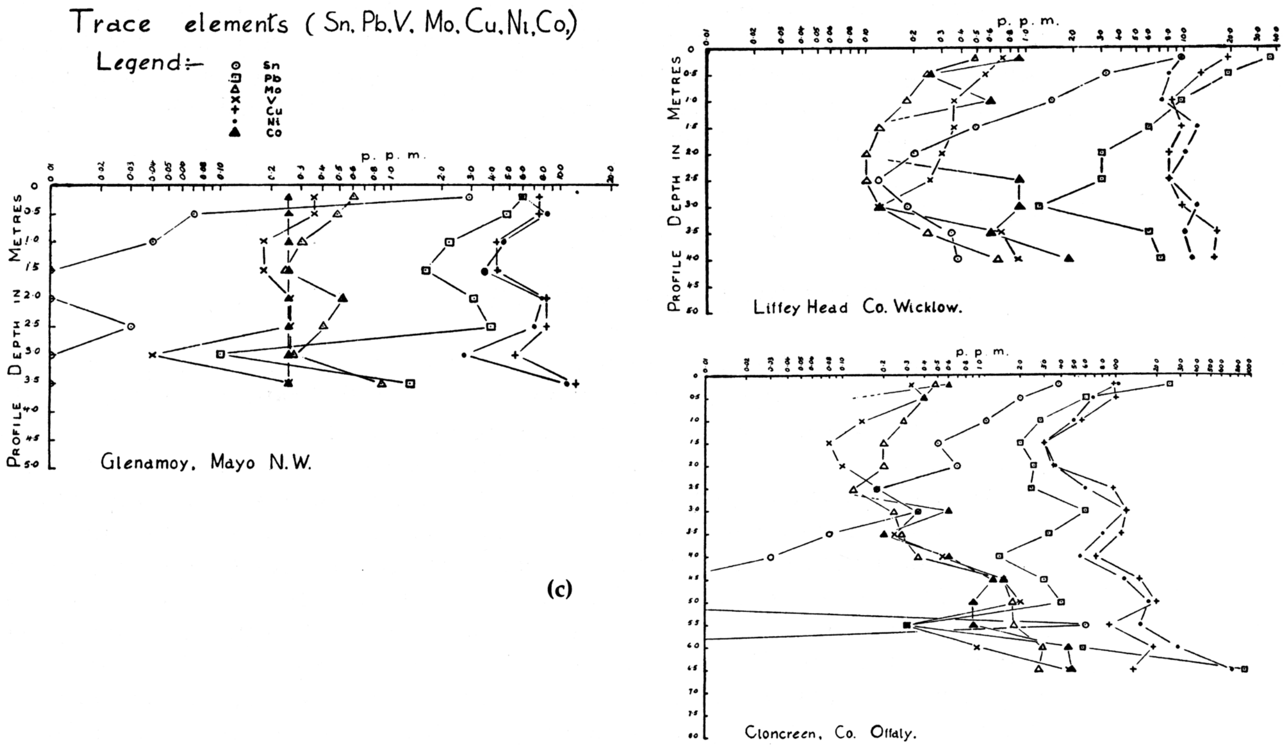
(b)







was traditionally a measure of turf quality. Five percent was regarded as satisfactory, but if the amount of ash went above 25% the turf was considered to be unsuitable for fuel. The ash content of ombrotrophic peats is low – 1-5% – whereas it is high in minerotrophic peats. The nature and amount of the ash is an important factor in processing; the average fusion



(c)

point of peat ash is around 1,250 C, but $5i0_3$ and Al_2 03 raise this, whereas CaO and Fe_2O_3 lower it. Sulphur content is usually very low – 0.1 to 0.4% of dry weight – an important point when considering the potential pollution caused by the use of peat as fuel. The calorific value of air-dried peat is about 7,200 B.Th.U./lb (20-22 MJ/kg) compared with around 12,000 for coal. The acidity of the peat is due largely to ionisable phenolic and carboxyl groups derived from the breakdown of peat plant constituents, while acidity in the acrotelm is due in large measure to cation exchange by sphagnum, the presence of organic acids, sulphate reduction and dissolved CO_2. Much of the sulphate which falls on the bog surface in rainwater is reduced to sulphide, part of which enters the peat, while part is precipated as FeS.

Figure 5.7: One of the many attempts to picture the Water Sheerie: from an old Irish book illustration.

The Water Sheerie

The gas emanating from peat is largely nitrogen (54% or so), methane (about 43%) and some carbon dioxide (3%). The spontaneous combustion of gas escaping from pockets of trapped methane has generally been accepted as the explanation for the strange, pale lights usually known as 'will o' the wisp' which hover over bogs and other marshy places.

From a distance, the will o' the wisp generally has the look of a candle or taper seen through a window at a distance; sometimes it is still, sometimes in motion. When viewed close up it has a white, cloudy appearance, but is usually very luminous and brilliant. Sometimes it takes the form of globes of fire that appear suddenly above the marsh, and then explode like fireworks. It burns continuously, but is clearly visible only by night. In Ireland, the lights were believed to be carried by a malevolent spirit known as the Water Sheerie or Bog Sprite, which sought to lure people to a watery grave in the bog. According to Canon O'Hanlon, the spirit is related to the *sowlth,* a bodiless or misshapen ghost that wanders lonely places in search of rest [**Figure 5.7**].

However, there is a problem with spontaneous combustion as an explanation for the will o' the wisp: there is no plausible way to explain why methane should ignite *spontaneously.* It is now believed that the 'match' that ignites methane is diphosphane (P_20_4) which is also produced by anaerobic micro-organisms and which *does* burn spontaneously when it meets air.

THE ORIGIN OF THE RAISED BOGS

Setting the scene: the pre-bog landscape

Before the most recent Ice Age, a few million years ago, our part of Europe enjoyed a warm and wonderful climate. For tens of millions of years the landscape had been slowly moulded by the surface processes of weathering and erosion. The eroded sediment was carried off to the sea by rivers. A mature drainage network had long established itself; ancient rivers meandered slowly across the lowlands to the sea, having removed or reached a compromise with any obstacles in their path millions of years before. The landscape of the Midlands now hidden beneath the bogs and glacial drift is an ancient lowland *karst* landscape, shaped primarily not by the forces of glacial erosion, but the product of perhaps as much as 40 million years of denudation processes during the Tertiary Era. The Central Lowland has been in existence probably since late Miocene times (7 million years ago). It would have been completely destroyed by erosion had it not acquired a protective capping of clay in the later Tertiary, which was only removed by the Pleistocene glaciers.

The Ice Age put an end to this idyllic world. As the approaching Great Cold tightened its grip on the land, plants and animals retreated slowly southwards, each century a bit further and further, as the ice and snow remained progressively longer on the mountains, and then advanced inexorably to extend its cold and lifeless rule across the lowlands, until eventually the whole country lay in its icy grip for long periods. The country was not glaciated for the entire duration of the Ice Age, however, because in reality 'The Ice Age' was a succession of ice ages, separated by periods when things returned more or less to 'normal' – and the Cold Stages which separated these warm interglacial episodes varied greatly in intensity and duration.

But in fact, the landscape was anything but 'normal' when the Ice Age ended - or when the most recent Cold Stage of the Ice Age ended: we are very probably in the middle of an interglacial period at the moment. When the glaciers melted they didn't leave the lowland landscape all clean and polished. Instead, it was littered with great hummocks and ridges of glacial debris: bouldery clay, sand and gravel – all the stuff the moving ice and meltwater had eroded and carried with it on its journey. As a result, the mature drainage patterns of the pre-glacial landscape were disrupted in many areas. Rivers found their channels blocked with glacial drift or *till,* and had to set about finding new routes. Moreover, drainage was impeded by widespread permafrost during the last years of cold, when frost still held the land in its icy grip.

The sediments in the postglacial lakes

The late glacial and early post-glacial landscape was, therefore, a very watery landscape. It was covered with shallow lakes, large and small, the biggest of which was the Shannon, which was swollen for much of its length into one enormous lake. The lakes, which gave rise to many of the bogs close to the Shannon, were part of this larger Shannon lake/lagoon complex in the early Postglacial. The low-lying bogs in these areas require pumping to drain them today; when this is abandoned, they will revert to lakes.

Sedimentary material was often washed into the lakes from the cold hinterland, or blown in from the bare surface of the windswept glacial drift in early postglacial time. This material was usually fine-grained, now generally blue or grey in colour, very heavy and sticky, and sometimes finely laminated *(varved),* with layers of fine sand, silt and clay repeating at intervals, each varve probably representing a single season's deposit. These sediments comprise a mixture of mud of mineral origin, often with much material of biogenic origin, including the siliceous frustules of diatoms, bits of chitinous insect skeletons, and the skeletons of rhizopods, all mixed with abundant droppings of small lake animals. The most extensive areas of blue clay seem to be near the Shannon, around the edges of the post-glacial lake network that then existed in its basin; they are especially widespread (under the Mountdillon group of Bord na Móna bogs) near Lanesborough, and under many of the Offaly bogs. Sometimes these blue clays are overlain by lake marl, but they may be followed directly by reedswamp peat deposits, or – as at Mountdillon – by organic muds. The lake marls are much less widespread than the blue clays, and the transition from one to the other, where it does occur, is sudden. This points to a rapid drop in lake level preceding the onset of marl deposition about 9,000 years ago, and corroborates the evidence provided by a thin layer of sand which occurs almost everywhere in the Shannon valley, which is believed to have been left behind as the water drained away from the edges of the floodplain, taking the finer sedimentary material with it.

The blue-grey bog clays have been widely used in the making of bricks, especially in Holland, where they were manufactured on a large scale using black turf as a fuel. In 18th and 19th century Ireland blue clays quarried around the edges of the midland bogs were widely used for brick-making also. These bricks can be seen in buildings of the period all over the country, especially in the Midlands, but they were of poor quality and texture. There was seldom any preparation of the clay, the quality of which could have been much improved by purification.

Marl

Shell marl and chalk mud (or *lake chalk protopedon* in the impressive language of some soil scientists) are white to buff-coloured chalky clays which formed in the clear waters of the calcareous lakes, once abundant life had returned. Snails, ostracods and other creatures which built their shells from lime extracted from the water were abundant in these lakes, and are very common in the marls, but the chalky material which accounts for between 70 and over 90% of their composition is carbonate sloughed off the stems and leaves of stoneworts, on which it is precipitated by the plants as a crystalline crust. The reason for this is that stoneworts utilise $HC0_3$ (bicarbonate ions) for their photosynthesis; they take these out of solution, and precipitate calcite ($CaCO_3$). Stoneworts are an isolated and ancient group of green plants intermediate between bryophytes and algae [**Figure 5.8**]. When the plants die back each year, their remains contribute further to the marl. Some of the material in the marl is also probably due to the activities of snails and microorganisms.

As time went by, the marl accumulated on the floors of the lakes to a thickness of between a few centimetres and a metre or so, though they occasionally reach thicknesses of several metres [**Plate 1**]. The marl is often layered, because deposition was seasonal, each individual lamina recording a year's deposit. Marl was widely used as a source of lime for land reclamation of the 18th and 19th centuries (See Chapter 2).

Deep marl is by no means confined to the midland raised bogs. It also sometimes occurs under the deep bogs of south Mayo. In postglacial times this was also a land of impeded drainage, with extensive lakes surrounded and dammed up by drumlins and other glacial deposits. Up to a metre or more of marl accumulated in these lakes, and tufa was

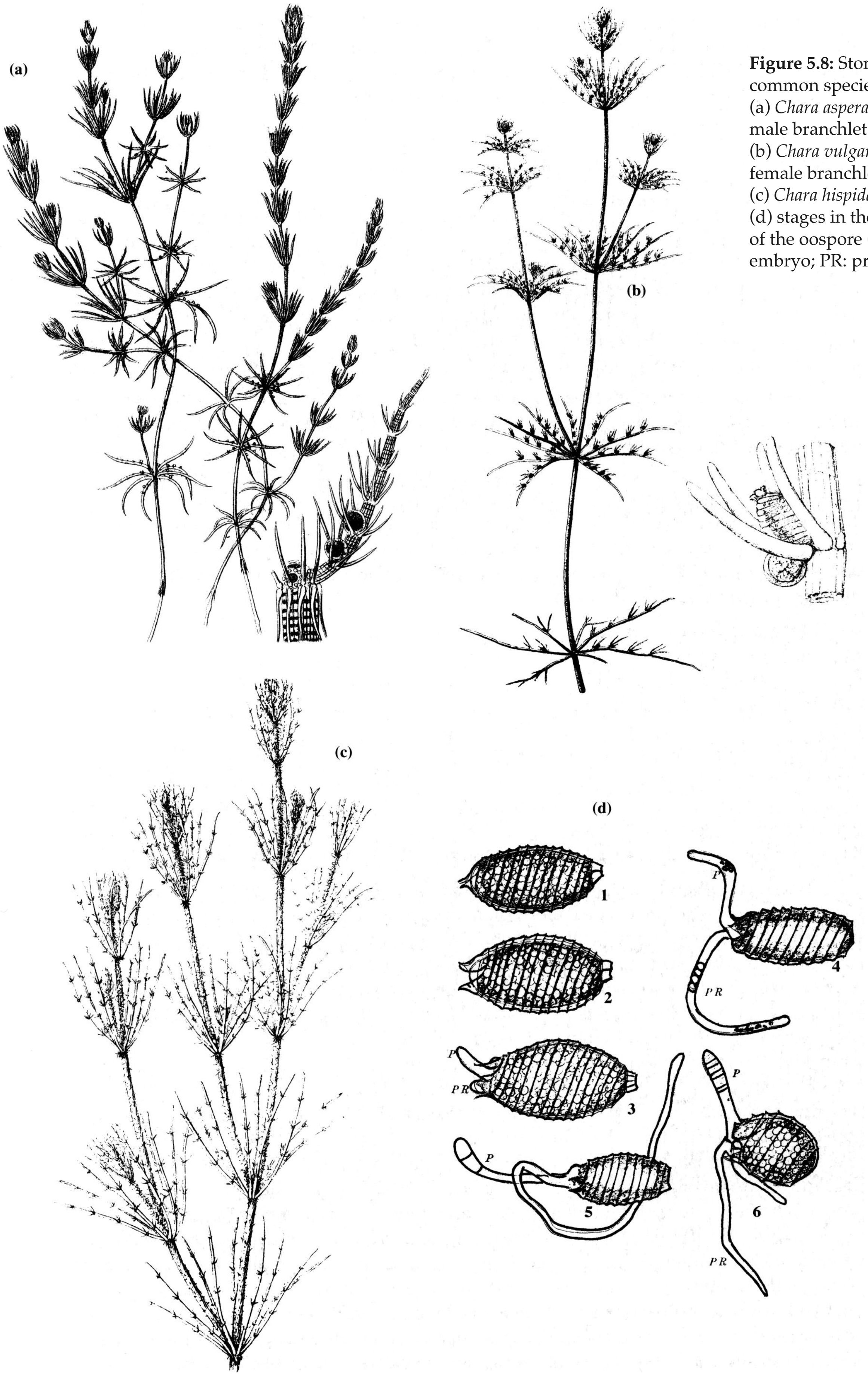


Figure 5.8: Stoneworts. Three common species:
(a) *Chara aspera* (with fertile male branchlet node);
(b) *Chara vulgaris* (with fertile female branchlet node);
(c) *Chara hispida*;
(d) stages in the germination of the oospore ('egg'). P: proembryo; PR: primary root.

sometimes deposited along their margins. The bogs are often long and narrow, and follow the local drainage pattern as well as the pattern of inter-drumlin hollows. Along the Manulla River, for instance, deep bog rests on a metre of marl, which in turn overlies boulder clay, showing that the course of the Manulla river was formerly the bed of a lake. Large stumps of pine and hazel, with occasional oak, lie between the bog and the marl. As with the raised bogs of the midlands, a sudden drop in the regional water table drained the shallow lakes of most of their water, catalysing the onset of bog development, and leaving the tufas as benchmarks of a higher water table.

Creatures of the marl and clay

The last cold stage of the Ice Age reached its peak around 15,000 years ago, and Ireland finally began to recover from the grip of the ice around 13,000 years ago. The climate improved rapidly, and plant and animal life began to make its way back into the country, the larger animals using the land bridges that connected Ireland to Great Britain and mainland Europe. Even at the height of the last glaciation, which was ending around 11,000 years ago, there was still plenty of life on the tundra that extended southwards across much of Munster in front of the great ice field.

Then, for a short space of around 500 years, between 10,600 and 10,000 years ago, there was a brief return of the intense cold; small corrie glaciers reoccupied their recently abandoned nests high in the mountains. Before that final cold spell of 500 years (which geologists refer to as the Nahanagan Stadial) much of lowland Ireland was covered with lake-studded tundra grassland, broken here and there by woods of pine and birch. Although there had been early Stone Age communities in Europe during most of the two million years of the Ice Age, moving northwards as the ice retreated at the end of each cold stage, and falling back in front of every advance, there is as yet no evidence that there were people in Ireland at this time.

But if there had been, there would have been much for them to wonder at: and the most wondrous sight of all must have been the herds of enormous deer which wandered the vast grasslands of Ireland between 12,000 and 10,600 years ago, when the returning cold brought an end to the rich grazing and the herds of herbivores which depended on it. Enormous is not an exaggeration. These deer were huge in every sense; they were up to 2m in height at the shoulders, but their most amazing endowment were the antlers of the stag, which could have a span of up to 4m and a dry weight of as much as 35kg. These were the largest deer which ever lived, and although they roamed most of Europe, the densest populations seem to have been in Ireland - at least this is where most of its fossils have been found - so it is appropriately referred to as the giant Irish deer [**Figure 5.9**].

Fossil giant deer have been recovered from lake clays beneath bogs all over Ireland, but one place, which has yielded more than any other single locality, is the small bog at Ballybetagh in south County Dublin. Actually, Ballybetagh Bog is a bit misleading now, because is not a bog any more; it was drained and the turf cut away long ago. Thirty giant deer skeletons were found here in the course of work on a famine relief scheme during the 1840s, when a channel was being dug across the bog to provide water for a cotton mill and lead works. By the end of the century Ballybetagh had yielded 120 skeletons. But strangely, almost all belonged to old male animals – there were no females or young. It used to be thought they had met their deaths through becoming trapped in the muds at the edge of the lake that was here before Ballybetagh Bog began to form, but it is now generally accepted that they had died of weakness or hunger. The skeletons do not belong to a single group of deer which all perished at the same time; the collection of 120 is probably made up of animals which died at different times over a long period. The reason only males are found is that the giant deer had habits similar to many living deer: males and females congregated together only during the rutting season in the autumn; during winter the stags gathered along sheltered valleys and around lakes while the females and young were out in more open country. The animals that died and were buried in the mud at Ballybetagh were those that were unable to survive the rigours of the early postglacial winter; we know they died in winter from the poor condition of their antlers, which were shed and re-grown every year. Today the giant deer of Ballybetagh are in a different final resting place. Most of them are in the National Museum: dark as bog oak – not as a result of their long immersion beneath the bog, but from the preservative wax rubbed into them in the last century.

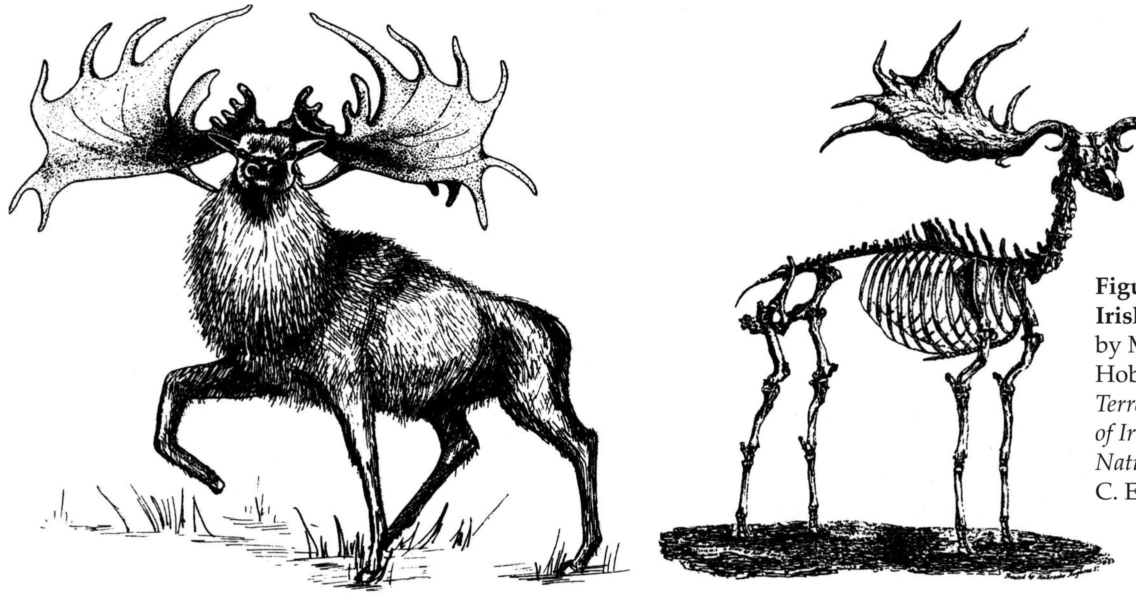


Figure 5.9: Giant Irish deer. (Drawing by Margaret Doyle Hobbs in *Extinct Terrestrial Mammals of Ireland in the National Museum* by C. E. O'Riordan).

The massive antlers of the giant deer were used for display and to determine social rank among the stags, but in spite of their size, it appears likely that they were used also in combat. Having to grow a new set of those enormous antlers every year made enormous demands on the animal's resources – they must have grown at a rate of several inches a day in big animals – so it could only be done in spring and summer when there was an abundant food supply. Spring was also the time of year the fawns were born, which gave them plenty of time to build up their strength for their first Irish winter. Only the male deer had to carry this burden. The female was a rather more graceful animal; the absence of the antlers meant that the vertebrae of the neck didn't have to support all the extra muscle needed to hold up the antlered head.

Almost all giant deer remains have come from the lower clays underlying the raised bogs, which formed during the warm Woodgrange Interstadial between 12,100 and 10,600 years ago. Observers in the last century commented on the fact that where giant deer occurred most frequently the peat was different, giving rise to friable, black peat that could not be cut into sods; these 'rotten parts' were called 'black holes' or 'elk holes'. There is one intriguing report of the occurrence of giant deer in the peat *overlying* the marl which is worth recounting in full, if only because it raises again the perennially intriguing question of whether there is any possibility that giant deer could have survived somewhere on the island until the earliest human communities arrived. The writer is the usually reliable and observant G.H. Kinahan:

> An interesting bog is the environ of Lough Mentrim near the N.E. mearing of the Co. Meath. This lake lies in the valley of the river Dee, and fifty years ago or thereabouts **it** was surrounded by a peaty shelf or morass that in general was under water. This lake was lowered during the Arterial drainage, and the shelf thereby made available for turf cutting. Over the good peat there was from two to four feet of 'black stuff', the bottom mud of this lake shelf. In this were numerous heads and bones of the elk and other animals, but so rotten that when the stuff was thrown up they rapidly decomposed into a ferriferous stuff; below, however, in the good peat, where they were also numerous, they were sound, but those under the peat in the mud were more or less friable or eaten away. Human remains also occurred, but these pagans were given Christian burial, and thus lost to science.

Other grazing animals shared the rich postglacial grasslands with the giant deer; there were reindeer, and elk or moose, perhaps great herds of them. The reason we have so few fossils may simply be because their seasonal habits were not as conducive to animals being buried in the lake muds. Although we don't have the fossils to prove it, there were very probably bears and wolves, lemmings, foxes and hares as well. Reindeer have been found in many localities in Ireland. More than half of these are caves, and only a few have been found in bogs. Reindeer bones are almost invariably found together with bones of giant deer; most are of the 'barren ground' variety - the kind that lives on the open tundra - as distinct from the woodland variety.

The bones, which are found in caves, are often what were left over after the brown bears *(Ursus arctos),* which lived in these caves in postglacial Ireland, had finished their meals. The remains of the bears themselves are often found in the caves too, and there are even a few records of bears found in bogs, including one from Donore Bog near Mountrath in County Laois, where several teeth were found about 7 feet (c 2m) below the surface in 1903. Two jaws, six teeth and an atlas vertebra were recovered from Derrykeel Bog near Birr in 1914. Sometimes deposits of disintegrating bones rich in phosphate and lime have been turned up in the marl; their most attractive component is the mineral *vivianite* (hydrated iron phosphate), which is deep blue in colour.

The mammals of the tundra are certainly the most dramatic of the creatures entombed in the clays. But they are few and far between and few of us are likely to find them. But every handful of marl is packed with fossils of the creatures that lived in the postglacial lakes. Many species of water snails occur, their shells perfectly preserved. Many of the species encountered are shown in Figure 5.10.

Rather less common species include *Planorbis crista* and *Acme lineata.* Smaller sub-fossil remains occur too - the resistant oospores of stoneworts, ostracod shells, and the frustules of such common freshwater algae as *Pediastrum, Tetraedron, Botryococcus* and *Gleotrichia.* Although the sub-fossil fauna of the midland marls still awaits study, work elsewhere in the country shows that the snail fauna towards the base of the marl includes species which only live in the Arctic today.

At the same time as the marl was accumulating on the bottom of a lake, it would have been the rooting floor for underwater meadows of stoneworts, water-milfoil and pondweeds. The marl often contains remains of these plants: winter buds of pondweed and fossils of water-milfoil, the occasional seed of white water-lily and horned pondweed. Stray bits and pieces of sedges and grasses are often found. The chalk mud also contains remains of some plants, such as holly-leaved najas, which have since become extinct in Ireland.

Under many bogs grey-green organic muds of freshwater origin can cover a very high percentage of the mineral fooor, especially in the low-lying bogs along the Shannon. These muds, known as *sapropel,* are largely of algal origin; they are non-calcareous, with a strong smell of hydrogen sulphide, and often streaked with limonite and other iron compounds. They are almost always succeeded by reedswamp peat. They have found uses in other countries in agriculture, in bath therapy (balneology), and as a source of minerals and vitamins (especially B12) for animal foodstuffs, and in the chemical industry.

From open lake to swamp

In time, vegetation began to encroach from the margins of the lakes, choking out more and more of the open water, until eventually *reedswamp* colonised much of the lake area. Reed swamps cover large areas of open water today, but they covered even bigger areas in the past. In some places there would also have been locally extensive areas of large sedges (tufted sedge or great tussock sedge). Colonies of bulrushes grew in deeper water. Fringing marsh surrounded the reedswamp; here plants such as gipsywort and great spearwort grew.

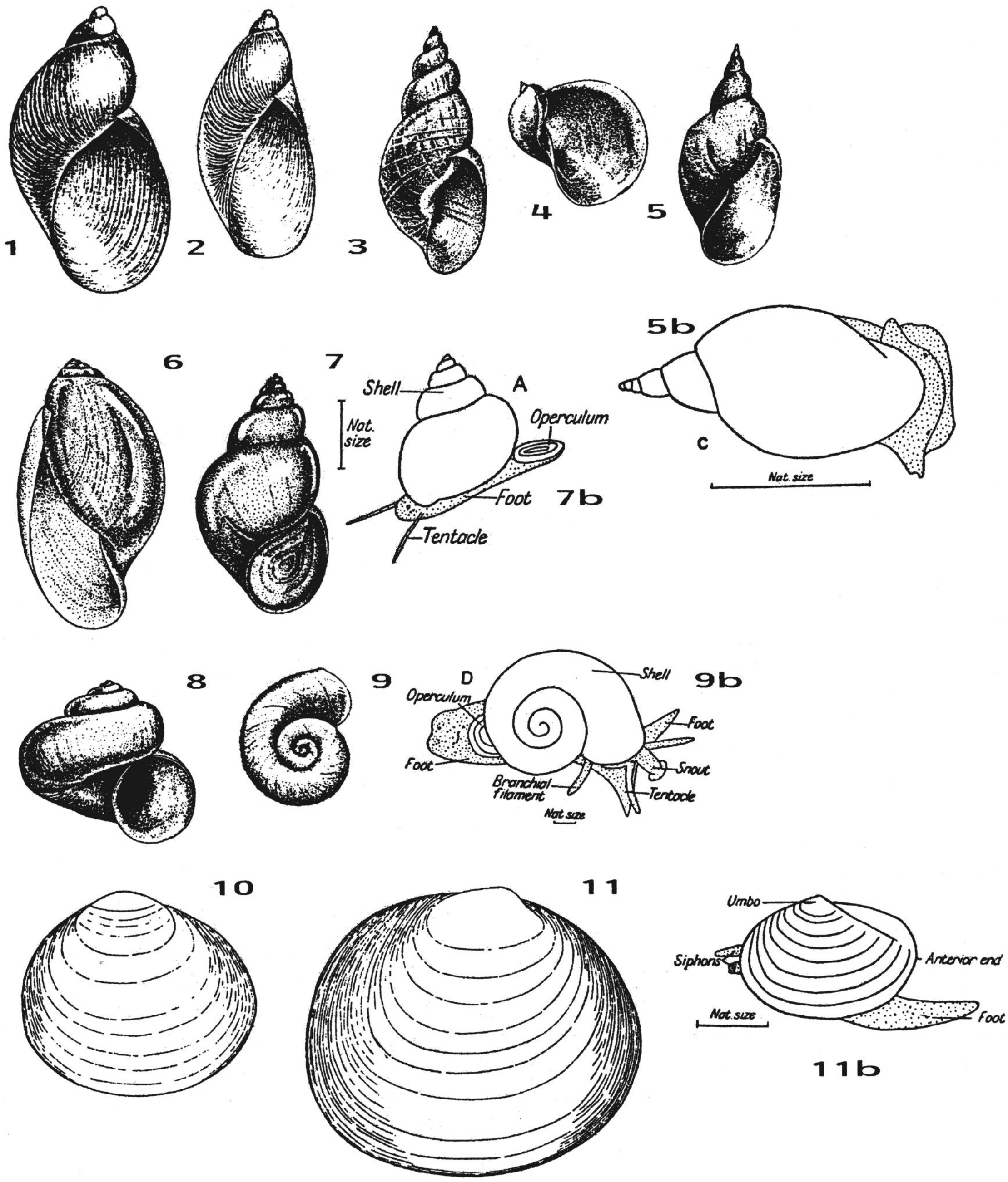


Figure 5.10: Post-glacial snails from the marl.
Because each species occupies its own ecological niche, the relative concentrations of different snails at different levels in marl can provide information on changing conditions in the lake over time, especially in relation to such factors as temperature, water depth and distance from shore. The drawings show a selection of snail species commonly found in lake marl.

(1) *Succinea putris* (about 15mm high).
(2) *Oxyloma sarsi* (15mm high).
(3) Marsh or bog snail *Limnaea palustris* (11mm high).
(4) Wandering snail *Limnaea peregra* (11mm high).
(5) Great pond snail *Limnaea stagnalis* (50mm high); (5b) great pond snail in life.
(6) Bladder snail *Physa fontinalis* (10mm high).
(7) *Bithynia tentaculata* (9.5mm high); (7b) *Bithynia* in life.
(8) Valve snail *Valvata piscinalis* (5mm high).
(9) Valve snail *Valvata cristata* (4mm across); (9b) Valve snail in life.
(10) Pea-shell cockle Pisidium, 3.5mm long. Several species of freshwater cockles are common, including *Pisidium pusillum*, *Pisidium milium*, *Pisidium nitidum*, *Pisidium hibernicum* and *Pisidium obtusale*.
(11) Orb-shell cockle *Sphaerium corneum* (5mm long); (11b) Orb shell cockle in life.

The midland bogs therefore developed on the sites of the post-glacial lakes that covered the floodplains of the major river systems. As we have seen, the Shannon lakes formerly covered a much greater area, because the lake level was considerably higher than it is today. More than 70,000 hectares (176,000 acres) of bog along the river and its lakes, between Lough Allen and the sea, have developed on the fringes of this formerly much more extensive system of rivers and lakes. The distribution of marl and other lake clays can be used to map the extent of these post-glacial lakes. Frank Mitchell's map [Figure 5.11] shows the great area of the lakes in the Shannon and Erne basins, and C. Delaney has produced a similar map for Lough Corrib. On the shores of Lough Ree and other midland lakes can be seen water-worn limestone blocks eroded up to the old postglacial lake level, showing clearly that here lake level once stood 3-5m higher than it does today. Upper Lough Erne is also only a fraction of what it once was; before the growth of the bogs, the lake was more than twice its present-day width of 5km, and the deepest parts of the bogs along its shores are much lower than the present day level of the water.

From the geological perspective, lakes are temporary features of the landscape in the normal run of things. Given enough time, the processes of weathering, erosion and deposition will level out any landscape; the high places will be worn away and the low places filled in. As time goes by lakes will gradually get shallower as sediment is washed in by the rivers feeding them. As soon as the water becomes shallow enough, water plants begin to grow in the sediment, binding it, slowing down currents, and acting as a trap for further sediment. *Colonisation* has begun, and as the lake gets smaller and shallower, a *succession* of different kinds of vegetation follow one another, keeping pace with the change.

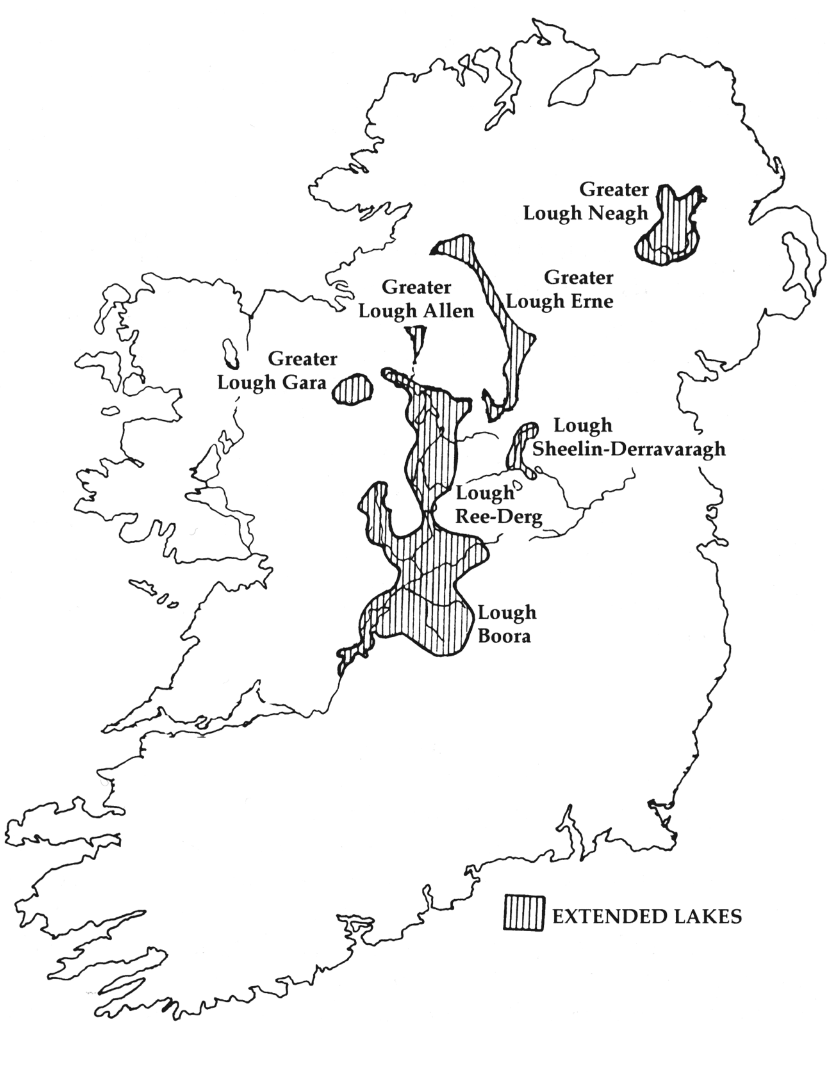


Figure 5.11: The map shows the extent of the great lakes of early post-glacial time in the Midlands and north of the country. In addition to these great lakes, the landscape was studded with a galaxy of smaller lakes which acted as nuclei for the growth of raised bogs. Note in particular the location of Lough Boora on the south-east edge of the Shannon lakes (See Chapter 15). (After Mitchell, 1986).

At first open water plants predominate, plants like water lilies that have unwettable floating leaves and long lifelines of leaf and flower stems going all the way to the bottom. As water depth decreases, more conventional plants with long spear-like leaves and slender stems move in. The most important are reeds, reed-maces and bulrushes. Once these *emergent* plants have taken hold events move rapidly, because their root systems spread through the mud, often resulting in very extensive cover by a few species. An abundance of plant debris is trapped and rots away among the ranked masses of upright leaves and stems, further contributing to the build-up of the lake bottom. Eventually the lake becomes shallow enough to support the weight of someone walking across - though one would get very muddy feet in the process. A lowering of the water table would of course also hasten the disappearance of the open water.

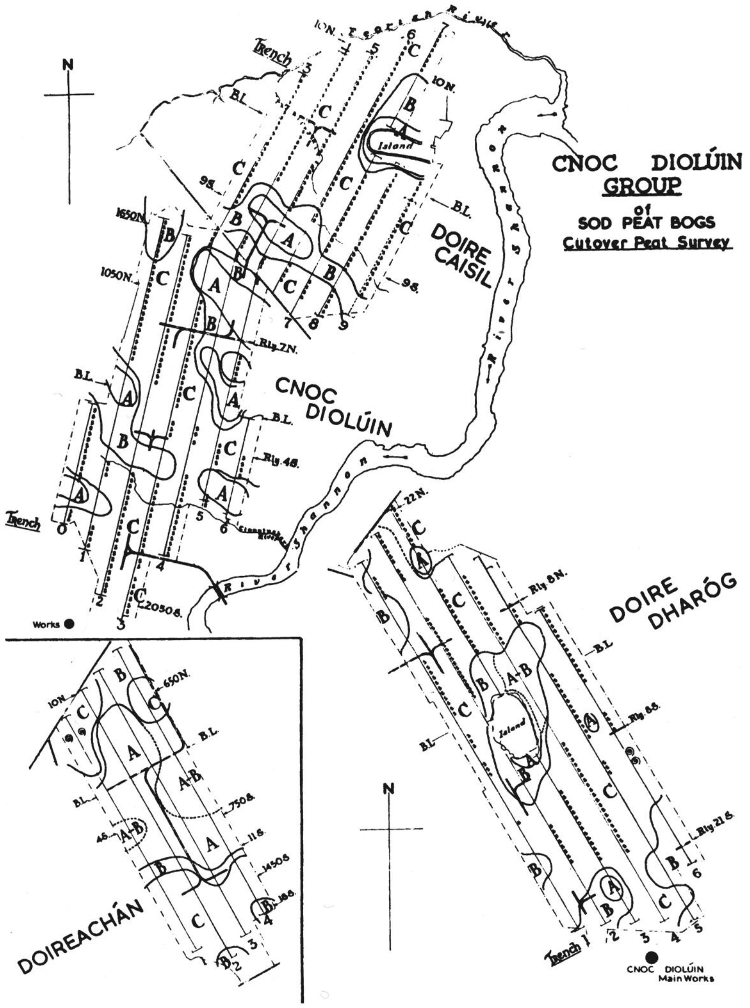
Since the lake is progressively filling in from the sides, the different vegetation types replace each other towards the centre, so that there is a clear *zonation* of the vegetation, with the open-water plants furthest from the shore. There are some plants that are more independent of water depth than water lilies – duckweeds for example – and others which can afford to get their leaves wet, like the pondweeds, and these are not as narrowly confined to particular zones. The vegetation of rock-cut mountain lakes is very different; these lakes are long-lived, because little sediment is being brought, in. In the open water there are also floating-leaved pondweeds and amphibious bistort, and submerged plants that include spiked water-milfoil, Canadian pondweed, true pondweeds, horned pondweed, stoneworts and the prominent black moss *Fontinalis.* Few of these, however, will venture into really deep water.

Swamp vegetation rarely follows directly upon the late-glacial and early post-glacial snail and chalk muds; there is usually a thin layer of detrital or algal mud (gyttja), and the swamp vegetation overlays this. This may be an indication that in some cases an actual drop in the water table may have been responsible for the transition from marl deposition in open water to fen conditions - the second such sudden transition since the Ice Age. A fall in sea level, or an upward bounce by the land mass, stretching its shoulders so to speak as it recovered from the burden of the glacial ice, may have been factors. The occasional occurrence of thin layers of peat in the marl provides some evidence that conditions fluctuated for a time in some areas. Reedswamp peat (composed largely of the remains of common reed) is sometimes several feet in depth, and shrinks in a characteristic way when exposed on the surface.

From swamp to fen to bog

As time goes by the marsh plants consolidate and build up a more solid footing as decaying vegetation accumulates, and the marsh is gradually replaced by fen. To the soil scientist, *fen* is a peat-forming sub-aquatic soil that can be poor or rich in nutrients; the pedologist would recognise a variety of types, characterised by their differing plant constituents, and the different physical and chemical properties that follow from this compositional difference. The term is rather more loosely applied to calcareous soils high in organic matter and plant nutrients formed under more or less stagnant water. To the plant sociologist, fen refers to the many kinds of living communities that produce this peat. The plant communities of fen are assigned in phytosociological terms to the order Tofieldietalia; most Irish fen communities are dominated by black bog-rush, usually accompanied by grass of Parnassus, common butterwort, and the moss *Cam pylium stellatum.*

There are numerous variations, reflecting the rather wide variety of environmental contexts in which fen can form, but one of the commonest kinds is a low-nutrient type which grades into the wet grassland communities dominated by purple moor-grass, in which plants such as bog thistle, bog pimpernel, cross-leaved heath and bog myrtle are prominent. Other species, which are very typical of these fen communities, although they are also found in a wide variety of other heath and bog communities, include marsh helleborine, early



Legend

A - Mixed forest debris (oak, pine, yew, birch) resting on the mineral floor.

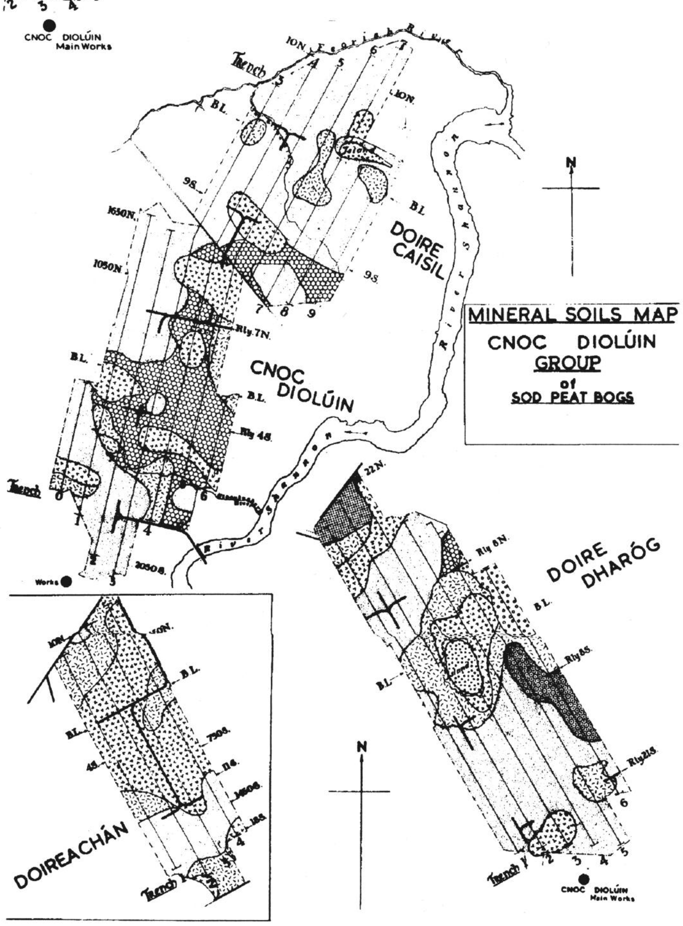
B - Birchwood peat with some moss (usually non-sphagnum), and sometimes common reed in the mixture = WOODY FEN PEAT.

C - Reedswamp *(Phragmites)* See below.

Figure 5.12: When the younger peat is removed from a raised bog, the earlier peats which are exposed near the bottom are the remains of the plant communities which lived in an earlier pre-bog landscape. These communities were determined to a large extent by the nature of the underlying soils and the topography. The 'natural regions' which these earlier peats represent }lave been mapped for many of the larger bogs. Such mapping is essential when considering future land use options for different areas of cutaway bog. The maps show the natural regions and underlying mineral soils for [part of] the Cnoc Dioluin Group of bogs in Longford-Roscommon. The table (b) outlines the characteristics of the different regions (From Barry, Carey and Hammond, 1973).

Legend

SOIL	MAP SYMBOL	% AREA	SOIL DESCRIPTION
1.		Derryaroge Island	Grey brown podzolic. Sandy loam. Never covered by peat apparently.
2. (S1)*		19	Well developed relict soil. Sand-loam to loam.
3. (S_3b)		18	Undeveloped relict soil. Loam to clay-loam.
4. (S_3at's)		10	6/9 inches coarse and fine sands overlying loam to sand-loam drift.
5. (S_3at'd)		48	Deep silts, silty clays.
6. (S_3at'd)		1.5	Deep sands with pockets of silty clay.
7. (S_3at's) (S_3at'd)		1.5	Complex of shallow sands and deep silty clays.
8. (S_5)		2	Shell marl and calcareous muds.



(b) Characteristics of sub-peat regions

Natural region	Bog-floor topography	Undisturbed peat		Immediate substratum (usual)
		Type (most prevalent)	Amount (range of averages per bog)	
A	Convex	Forest peat	30 to 61 cm	Mineral soil non-calcareous (Most often Soil No.2)
B	Sloping	Woody-fen	91 to 122 cm	Mineral soils of various kinds
C	Concave or flat	Reedswamp	152 to 274 cm	Mineral soil (Most often Soil No.5)
D	Concave or flat	Reedswamp	152 to 274 cm	Shell marl (calcareous)
E	Concave or flat	Reedswamp	122 to 183 cm	Sapropel (non-Calcareous, (sulphurous)

marsh-orchid, tormentil, flea sedge, tawny sedge and lesser clubmoss. The characteristic bryophyte species of modern fen assemblages - and of those fossilised in the peat - include *Drapanocladus adunctus, Aulacomnium palustre, Dicranum bonjeani, Ctenidium molluscum, Calliergon stramineum* (mainly in fens with lower nutrient status), *Calliergon giganteum* and *Scorpidium scorpioides* (mainly in rich fens), *Drepanocladus revolvens, Cam pylium stellatum, Sphagnum palustre* and *Sphagnum contortum.* Several species that grew in the ancient fens that preceded the bogs are extinct in Ireland today, including *Paludella squarrosa, Meesia triquetra,* and *Meesia longiseta.* (See also Chapter 8).

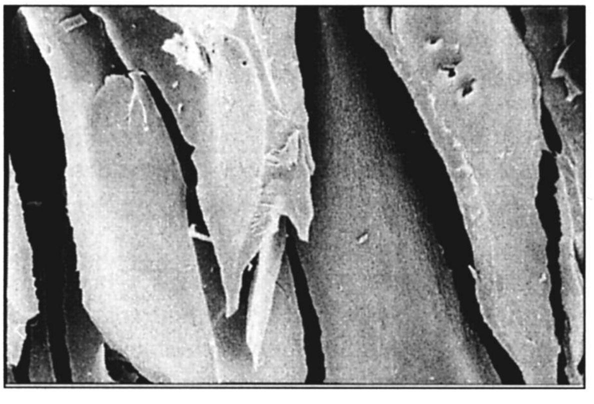
In fens circulating groundwater still filters all the time through the peat and over the surface, and this replenishes the supply of nutrients. In those situations where the postglacial fens began to overdraw on the nutrient reserves in the mineral soil below, conditions became acid. This brought about a slow change in the vegetation, allowing plants that are less nutrient-hungry to find a place for themselves in the community –plants which are able to thrive in conditions where the supply of nutrients from the soil is low. In time, a new sort of community takes over from the fen. This new transitional community – transitional because it is itself replaced by a different community in time – is called *carr* (which in soil terms is a semi-terrestrial peat soil). Carr is characterised by heathery shrubs: heather itself, cross-leaved heath and cranberry, and herbs such as bog-bean and round-leaved sundew, slender sedge and mud sedge. Birch, alder, willow and pine often spread out across the fen, to give wood carr. A new suite of mosses also appears on the scene, of which *Hylocomium splendens* and *Aulacomnium palustre* are very characteristic members, along with several species of sphagnum, the highly specialised bog-mosses, including *Sphagnum subnitens (plumulosum). Sphagnum subnitens* in particular seems to be a vital catalyst in the transition from fen to raised bog. Once these plants get hold, and organic debris begins to accumulate rapidly, the level of the fen begins to grow upwards out of reach of moving groundwater. Conditions turn increasingly acid, and the fen gives way to bog communities largely dominated by sphagnum mosses. The main outside sources of nutrient supply for true bog plants are rainwater and windborne dust.

In many bog profiles the older sphagnum-cottongrass peat is preceded by *woody fen peat* (which contains abundant birch debris, along with the remains of wetland and woodland non-sphagnum mosses) and/or forest or *mixed forest peat,* which contains the stems, twigs, roots, leaves etc. of a mixture of trees – scots pine, oak, yew and birch – depending on the local topography/ecology at the time. When the bog is cut away, exposing some of these early peats, a mosaic of 'natural regions' can be identified which to an extent reflect the vanished ecology of the early bog. This may have considerable practical implications for what can be done with the cutaway.

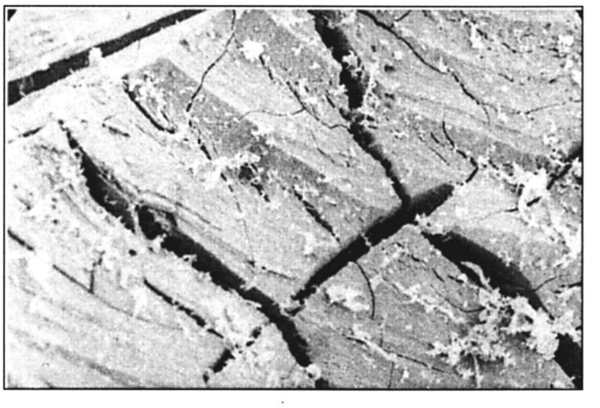
At the base of the minerotrophic peat in many bogs there is often a distinctive impermeable horizon 5-20cm thick, reddish-brown or dark brown in colour when fresh, changing to yellowish-brown or olive on exposure. Although thin, the layers are often of wide extent, sometimes continuous over many hectares. When the material in them is examined with the microscope it is found to be packed with microbial arid plant residues, especially fungal sclerotia and pollen grains [**Figure 5.13**]. These deposits are called *coprogenous earths,* and they are believed to derive from the excreta of animals living in the pre-bog lake in its later stages, together with pollen and other material washed in from the surroundings.

One of the most puzzling materials encountered in bogs is a cheesy-textured substance that occurs mainly as a filling in cracks, channels, crevices and other voids (including hollow stems), occasionally forming dendritic masses up to a metre across. It is metallic black or bluish-black in colour, waxy in consistency when fresh but hardening as it dries. When hard it breaks with a conchoidal fracture (like glass) if struck [**Figure 5.13**]. This is *dopplerite,* a substance of humiluvic origin, i.e. it originates through the precipitation of a gel from circulating solutions of humic substances. These solutions originate in active zones of humification, migrate through the peat, and precipitate in suitable environments such as pre-formed cracks and channels.

Figure 5.13: Photomicrographs of humiluvic materials (dopplerite)(a,b) and coprogenous materials (c,d) from peat (Jim Collins). (The term 'coprogenous earth' includes the materials called 'gyttja', 'sapropel' and'dy'by Kubiena).



a



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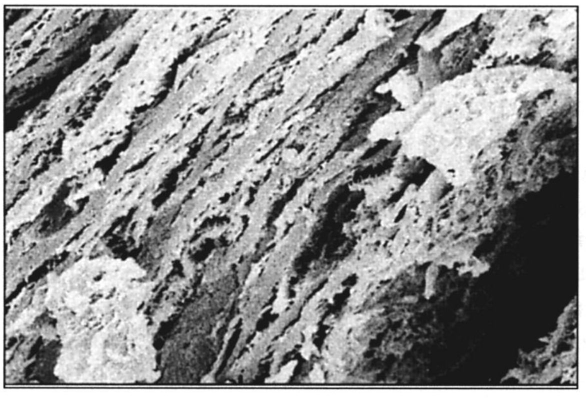

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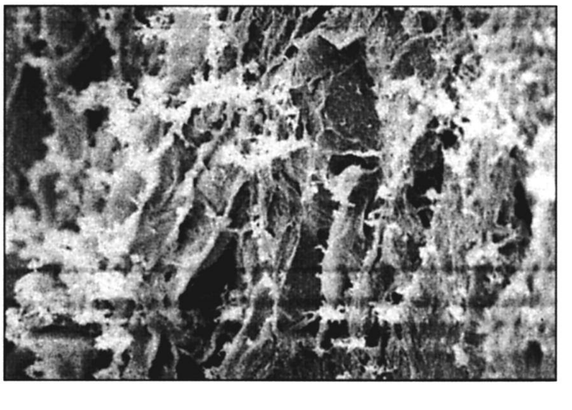


d

Soils under the bog

As the bogs continued their development, they grew not only upwards, but *outwards* beyond the margins of the original lake basins. This is why, in some parts of the midland bogs, peat now rests directly on the mineral soils which had begun to develop on the higher parts of the undulating post-glacial landscape, while the fens were developing and evolving in lower areas. These *relict soils*, developed on the calcareous glacial drifts, generally have an upper *eluvial* (E) horizon which is nearly always pale in colour (usually grey), and a lower *illuvial* (B) horizon which is brownish or yellowish in colour due to accumulation of sesquioxides and/or silicate clay. The underlying parent material (C horizon) often contains the roots of trees still in their original positions of growth, especially Scots pine, though oak, alder, hazel and yew also occur (See Chapter 7).

The extent of the undulation in the floor varies from bog to bog. Higher contours and bigger fluctuations occur in areas where end moraine dominates the topography, like Clonsast and Derrinlough in Offaly, and consequently there is an extensive area of well-developed relict soils here, whereas at Ballydermot-Lullymore the relief of the bog floor is more gently undulating, and the relict soils are poorly developed - many of them are relict gleys and regosols. The convexities can range in area from a hundred metres across to hundreds of hectares, and the lake-filled (and hence marl-floored) hollows show the same range; at times these are several kilometres long, but often they are broken up by undulations of the underlying moraine.

Had these relict soils not been smothered by the enveloping bog, they would in many cases have developed into the grey-brown podzolic soils that are so widely distributed in the Midlands today. The level of development or maturity of these relict soils depends mainly on their altitude. The processes of soil development were active for longest on the hill-tops furthest away from the lakes. At the other extreme, they never had time to get to work at all on the glacial till in the lake-filled hollows in the landscape. But eventually the bog swallowed up hummocks and hollows alike, though occasional hillocks of drift did escape as wooded islands surrounded by bog. These bog 'islands' come in all sizes; some of them are large – Walshe's Island, Lullymore, Lullybeg for example. At the other end of the scale are the 'derries', some of them occupying no more than a few tens of square metres [**Figure 5.14**].

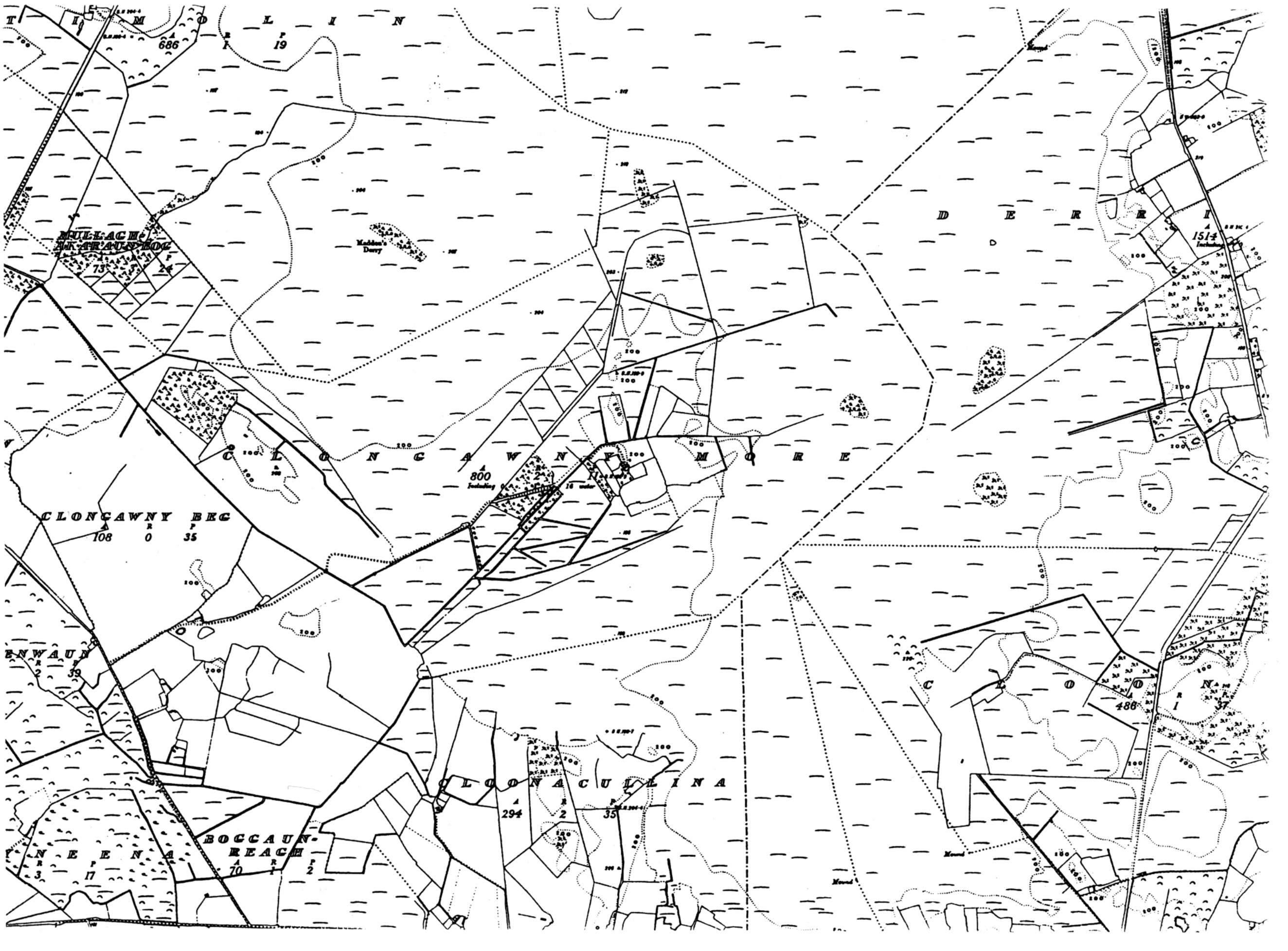
Perhaps half of the area under the midland bogs has these relict soils, the other half being floored by lake clays which never experienced pedogenic processes. When peat extraction comes to an end, it is the sub-peat mineral soils that will generally have the shallowest depth of peat, because they occur on convexities of the mineral floor. But in their natural state these immature soils offer poor prospects for farming or forestry even when the overlying peat is removed: they have low levels of plant nutrients, low biological activity and a compact structure.

When did bog development start?

The timetable for bogland development was not the same everywhere, but we will probably not be far wrong if we picture the open lakes and reedswamps of the Postglacial giving way to fen vegetation around 9,000 years ago, and raised bog beginning to take over from the fens about 7,000 years ago. In the beginning, the countryside surrounding the lakes had few trees. The vegetation was dominated by sedges and grasses, and hardy shrubs like juniper. Marl accumulated in the lakes during what is sometimes called the post-glacial Birch Period - when birch was beginning to become the dominant tree in the open post-glacial landscape. Reedswamp and fen peat were building up during the *Boreal* Period which followed, and the transition from fen to ombrogenous peat began around the boundary between the Boreal and the *Atlantic* periods, as the climate became wetter [**Table 5.7**]. The 30cm woody fen layer at Littleton Bog has been dated to between 6,300 and 7,800 B.P.. The Boreal/Atlantic transition occurs around 7,800 years ago, so the woody fen could have developed either in response to the increased wetness and the lower temperature - or it may simply have been the next stage in the normal, natural succession from marsh to bog.

Away from the bogs, the transition is marked by a decrease in pine pollen and the appearance in the landscape of a new species of tree - alder. At this time the older sphagnum peat was forming and the bogs were probably fringed by birchwood, which in turn was perhaps fringed by a ring of alder woodland. In terms of calendar years the changeover probably took place somewhere around 7,500 years ago. But in higher topographic situations, where mineral soils were forming at this time, peat formation did not begin until later. On these higher areas, wood fen was directly succeeded by ombrogenous sphagnum peat. This change in the peat profile from the base-loving plant communities of the fen to

Figure 5.14: Clongawny bog west of Derrinlough briquette factory, in the undulating end moraine country north-east of Birr, County Offaly. Notice the group of *derries* – wooded islands surrounded by bog, the tops of moraine hillocks which the expanding bog never managed to surmount. These derries remained as naturally-wooded, isolated wildernesses even in recent times.
In earlier times townlands which bordered on bog on one side had no defined boundary on this side. 'The bog' was the boundary for all of them; the line between farm and bog in each townland moved back and forth over the centuries across what William Richardson described (in 1809) as 'the cincture enveloping the morass ... sprinkled over with small green tummocks, rising from the black mire which has been wrought into mortar by the frequent treading of the cattle'. The advent of, the Land Valuation, and the demand by the authorities for fixed bounds between townlands necessitated the establishment of new boundaries in the bogs; these new boundaries march in straight lines into the middle of the bog, defined by no topographical features, to meet at some mereing point agreed by the landlords. Notice how Clongawny More had already established itself by reclamation of a peat-covered ridge around a former bog island. Most of the bogs in this area have now been stripped of their peat for the manufacture of briquettes at Derrinlough.



(a)

Climatic Period	Character	Forests
Sub-atlantic	Cool and wet 500 B.C.	Spreading beech, spruce
Sub-boreal	Dry, warm and continental 3000 B.C.	Mixed oak forests
Atlantic	Warm, moist and oceanic 5600 B.C.	Mixed oak forests
Boreal	Dry, warm and continental 7500 B.C.	Hazel scrub, pine
Pre-boreal	Cool summers, severe winters 8000 B.C.	Birch

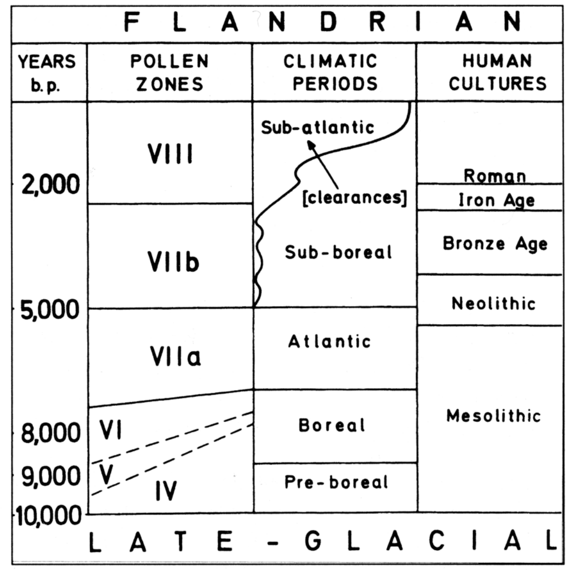


Table 5.7: Simplified calendar of post-glacial (Flandrian) time.
(a) The original Blytt and Sernander climatic calendar, worked out in southern Scandinavia in 1931. (b) Table showing the general relationship of the climatic periods to pollen zones and human cultures (After Godwin, 1978).

(b)

the acid-tolerant communities of bog is nearly always sharply marked.

Most sections through bogs show older and well-humified sphagnum peat succeeded by younger, less-humified peat. The change from older to younger sphagnum peats may have been triggered by climatic change around 500 B.C., the start of the Sub-atlantic period, but it occurred at different times in different bogs, and is probably due to local edaphic and hydrologic factors which were operative at different times on different bogs. Sometimes the boundary marking this change is very sharp, but often it is more gradual.

It is easy to identify these different growth stages in the bog profile, which contains a record of the vegetational history of the local area throughout the period the bog was forming. And it is not only the entombed remains of the plants which grew on the bog itself which constitute this record: pollen from plants growing in the surrounding area, which was blown onto the bog surface, is also preserved in the growing peat (See Chapter 13).

Why did the bogs start to form?

Around 5,000 B.C. the climate became much wetter, triggering the development of ombrotrophic bog right across north-west Europe. This change defines the boundary between the Boreal and Atlantic episodes in the calendar of post-glacial time. One of the factors responsible for this climatic shift seems to have been the flooding of the land connection between mainland Europe and the islands; the restored water circulation in the North Sea made for warmer and moister conditions. However, several other factors also played a part. The change came about at a time when the natural *succession* of vegetation in the post-glacial lakes was moving inexorably towards bog anyway – bog is the natural climax vegetation in this kind of development. Without an intermediate fen stage the change from reedswamp to bog might have taken 1,000 years; with fen developing after reedswamp it could take between 2,500 and 4,000 years. Other factors are also involved in triggering the invasion by sphagnum, and the transition to bog vegetation. Recent work in the Netherlands suggests that *Sphagnum cuspidatum* only grows luxuriantly when high concentrations of CO_2 are present, and that ombrotrophic quaking bog only forms in bodies of water with high levels of CO_2. This has implications for bog regeneration: one of the reasons why a layer of fen peat must be left to encourage regrowth is that the production of CO_2 in minerotrophic fen peat is high.

But another factor acted as a catalyst in the apparently simultaneous transition from fen to bog across the Midlands. There was a sudden and dramatic drop in the level of the midland lakes. This fall drained the wide floodplains of most of their standing water, facilitating a rapid transition to fen over the extensive flats that were under the control of water levels in the Shannon. Evidence for this is provided by groups of wave-marked boulders which are found in several places around the midland rivers, lakes and bogs, and which provide bench marks for the water level and former extent of the greater lakes of the Postglacial [**Figure 15.3, Plate 1**]. The largest groups occur on the shores of Lough Ree and close to the Shannon between Clonmacnois and Shannonbridge. Wave-worn erratics at Crancreagh, on the west side of Drinagh and at Lumcloon record the maximum level of Greater Lough Boora. A large wave-eroded boulder near Derryharney records the position of the undulating shore of the post-glacial lake 5.5km south-east of Clonmacnois. There can be little doubt that more of these rare and special sentinals of post-glacial Ireland await recognition elsewhere, though the majority have probably been removed during the five or more thousand years since they were stranded.

But why did this widespread drop in lake level take place? One of the most interesting and intriguing new insights into what happened to the landscape after the Ice Age has been the recognition that many of the deep boulder clays (tills) exposed around the Irish coast were laid down in the sea, not on land. Today, they stand high above sea level. This is due partly to isostatic recovery by the land once the burden of glacial ice had finally been removed. There is now evidence that this bouncing back did not take place all at once, but by means of a series of movements along faults that had been active in the Tertiary. It is possible that the change in water level recorded by the wave-washed boulders of the Midlands was due not to a lowering of lake levels as such, but rather to a final rebound by the land along a still active fault zone that is known to extend across the Midlands beneath the bogs. Studies in recent years suggest the existence of a fault-controlled Tertiary basin beneath the bogs. There is, indeed, the possibility that lignite deposits, now hidden by peat, may occur in parts of this basin. This is the third time such a rapid ecological transition has taken place since the Ice Age (See pages 174-75); the earlier transitions may have been related to similar rebounds.

The Atlantic episode gave way to the Sub-atlantic in the postglacial calendar around 500 B.C., when conditions became much wetter, and mean summer temperature was some 2 lower than it had been during the Atlantic. This caused a drop in the tree line of some 200m, and provided conditions that were optimal for the expansion of blanket bog and an acceleration in the growth of raised bog. Average growth rates of between 80 and 25 years per cm of peat have been suggested for the period before the great acceleration in growth which took place after 500 B.C., and between 20 and 2 years per cm for the period after.

How raised bogs grow

Living, actively-growing sphagnum occupies only the thinnest of skins at the surface of the bog – less than 0.1m. Below this it dies back, and eventually begins to decompose. But there is no sudden change from living to dead sphagnum. The big change takes place further down, at a depth of around 0.2-0.5m, where there is a sudden transition from barely decomposed and loose sphagnum to decomposing compacted sphagnum. Why the change should be so sudden is not at all clear, but may relate to a time lag in the weakening of the plant’s biochemical defences against the onset of decay. It should be remembered that the sphagnum at this depth is still physically connected with that in the dying-but-intact and living zones above: they are the same plants. (This transition needs to be distinguished from the acrotelm - catotelm transition: see Chapter 12).

The surface of an undisturbed raised bog is not at all uniform; typically, it consists of a network of shallow pools separated by drier and often hummocky areas which have very different vegetation. On many bogs however, the vegetation consists of lawns and hollows of spongy sphagnum broken by few pools, and with scattered low hummocks dominated by heather. For a long time it was thought that, as time went by, the build-up of the mosses

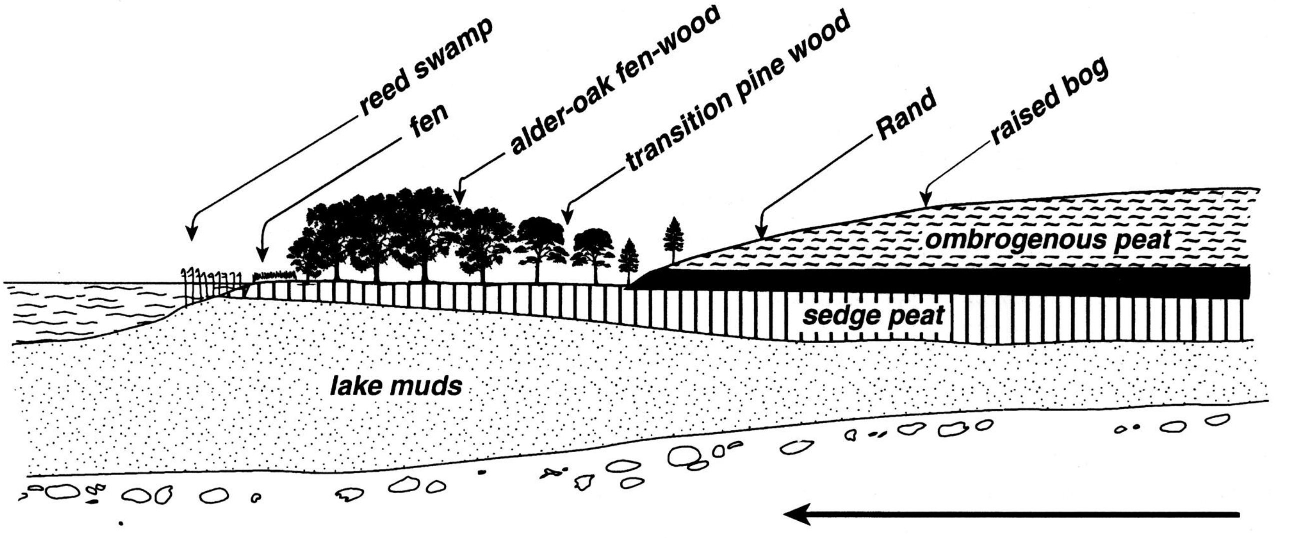


Figure 5.15: The development and growth of raised bog by invasion of open water. A fringing mat of reedswamp advances into the lake, followed by fen, which in time is colonised by trees. As the surface of the growing peat becomes acidic the fen woods are replaced by pinewoods, on the floor of which sphagnum mosses develop. As the floor becomes waterlogged, treeless raised bog begins to take over.
[After Godwin (1981), from an original drawing of Steffen].

and other plants growing in the pools would make these areas shallower, so that eventually they would cease to be pools altogether. On the other hand, as the hummocks got bigger and higher, the drier conditions would retard their growth. Eventually, upward growth of pool areas would overtake the hummocks, and their roles would be reversed - former pool areas would now begin to develop into hummocks, and new pools would start to form on top of the old hummocks.

There appears to be a series of recognisable stages in this hollow-hummock succession, each dominated by a particular plant. Aquatic sphagnum species dominate the first stage; the second stage seems to be dominated by white beak-sedge, often with sundews; then bog asphodel and finally heather take over as the hummock begins to form. The sphagnum mosses change too, and there are lots of other plants associated with each stage; *Sphagnum cuspidatum* is the moss that dominates the flooded hollows, and as it grows up it is replaced frequently by *Sphagnum magellanicum,* often accompanied by *Sphagnum papillosum. Sphagnum tenellum* is frequently associated with *Sphagnum cuspidatum;* it favours wet hollows, but not the shallow pools inhabited by *Sphagnum cuspidatum. Sphagnum rubellum* is the main bog moss in the hummock-building stage, assisted by *Sphagnum papillosum* and *Sphagnum plumulosum* (See Chapter 8). As the hummocks begin to dry up and their growth slows, the bog mosses lose their grip, the cladonia lichens seize their opportunity, and on the higher cushions the moss *Leucobryum glaucum* is often very conspicuous.

The first scientist to seriously explore the relationship between the upward growth of the bog and the behaviour of the different communities on the surface was Rutger Sernander, who taught and wrote of it in terms of a *rejuvenation cycle.* In the 1920s Sernander's brilliant pupil, Hugo Osvald, refined and elaborated the ideas and observations behind this hypothesis into the theory of the *regeneration complex.* And it was not only on the surface that there seemed to be evidence for such a cyclic succession of bog vegetation; the same sequence could be seen in the peat profile, which is made up of a sequence of superimposed peat lenses which apparently record the repetition of this cycle over and over and over [**Figure 5.16**]. In the peat profile 'hollow' peat has a characteristic soapy or greasy feel and is highly humified, whereas 'hummock' peat is much more loose-textured and is not highly humified.

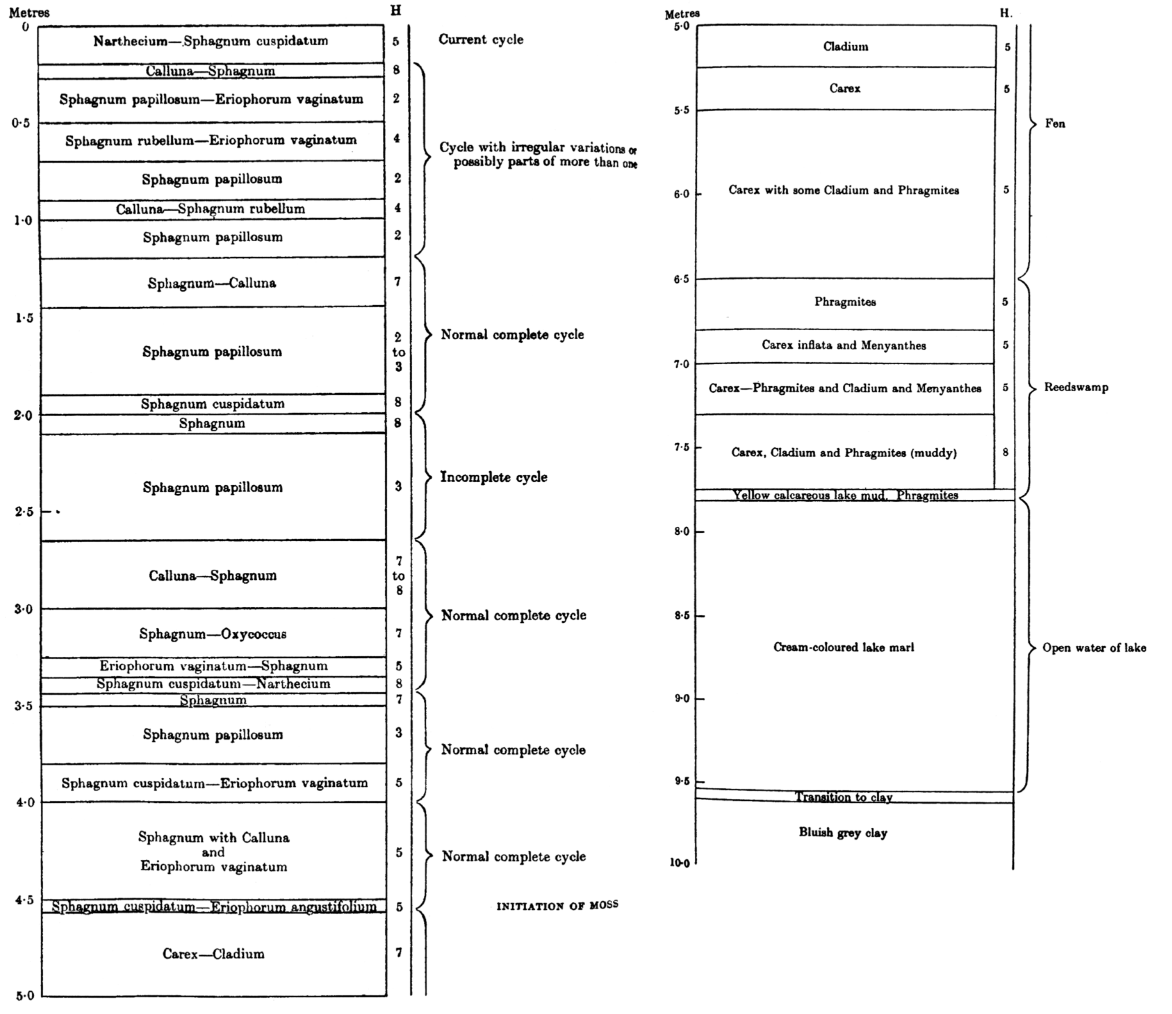


Figure 5.16: Arthur Tansley's classic profile of raised bog south-west of Athlone bog.
The profile shows seven cycles above the fen peat. The incomplete cycle is due to the fact that the augur taking the peat core does not always pass through the centre of the hummocks in the profile, but may hit the sides. Open water lake marl is typically followed by reedswamp and fen peat. Not always however; sometimes (in Edenderry bog for instance) it follows fen carr or woodland dominated by alder and birch which were growing on wet clay in depressions of the moraine.

However, over the last 30 years or so, particularly since the work of D. and P.M. Walker in the late 1950s, much doubt has been cast on the general validity of the idea that the upward growth of raised bogs is brought about by a self-perpetuating growth mechanism, and it is generally accepted nowadays that pools and hummocks seldom alternate in this simple cyclical way. The regeneration complex is probably important in more mature phases of bog growth, and it seems to be especially significant in the formation of moss-peat bogs. At Littleton Bog there is evidence for the regeneration complex only at the top of the peat profile.

The stratigraphical evidence seems to indicate that hummocks originate primarily on mature surfaces that are dominated by heather and hare's-tail cottongrass: the type of vegetation that is most nearly in equilibrium when the hydrological regime is stable. Once a hummock is well established, it seems able to persist, growing upwards for very long periods and surviving the kinds of hiccups which could produce flooding in adjacent areas, and sometimes extending laterally to initiate secondary hummocks. Some hummocks are known to persist for as long as 2,500 years. Most pools seem to originate through flooding of hollows on mature surfaces rather than by the swamping of senescent hummocks. These pools are eventually overgrown, it would appear, not so much by an inevitable succession in bog vegetation as by a change in conditions *outside* the bog. On the other hand, the pools in some bogs are very long-lived. At Cill Béara bog in Kildare, for instance, one particular *Sphagnum cuspidatum-dominated* pool seems to have existed throughout most of the life of the bog. Cyclic climatic variation as reflected in humification changes in peat is therefore best studied in the peat from hollows (See Chapter 14).

One of the most important insights to emerge from the careful stratigraphical studies of the Walkers and others has been the realisation that a given bog surface reacts all over and in the same direction at the same time. If a *Sphagnum-Calluna* lawn is overtaken by flooding, hummock growth accelerates also – there isn't an alteration between the time of maximum pool growth and maximum hummock growth. Moreover, these same phenomena can be seen in many bogs, which suggests that an external factor such as periodic climatic fluctuation is the regulating factor, initiating a cycle in which the bog progresses from a wetter, very rapidly growing sphagnum-controlled stage to a more mature, more uniform, slower-growing stage dominated by slower-growing species of sphagnum along with vascular plants. The *rejuvenation surfaces,* which these observations suggest, are reminiscent of the recurrence surfaces that are discussed in Chapter 14.

Blanket bogs

Blanket bogs are *climatic* peatlands. They develop wherever the summers are cool, humidity is high, and there is more than 1,250mm of rain throughout the year, spread over at least 250 or so rain days. (A rain day is the meteorologist's name for a day when at least 0.2mm of rain falls). In Ireland such very rainy conditions occur mainly in the west of the country, and on the mountains. The name blanket bog is very descriptive, because these bogs are like carpets of brown peat covering huge areas like a blanket, following the surface topography except where the slope is very steep (generally greater than 25º, undulating as the underlying mineral rock and soil undulate, and ranging from 2-8m in depth. They rarely start off as depressions in the landscape, so they don't have a layer of fen peat at the bottom. There is also a geological dimension to blanket bog, because it generally develops where the underlying rock is nutrient-poor, and its distribution is often strongly influenced by the structural trends in the underlying rocks – strikingly so in the Ox Mountains and the Derryveagh Mountains.

We have already noted that there are two principal kinds of blanket bogs:

Lowland blanket bog is found spread across extensive areas of flat ground below 150m in the west of the country where precipitation exceeds 1,250mm/year. The main expanses of this Atlantic low-level peat are in Galway and Mayo, with extensive areas also in Kerry, Cork and Donegal. Peat development in these areas is favoured not only by the high rainfall, but also by the acidic rocks and human influence.

Upland blanket bog occurs between 150-300m in the west of the country; this is sometimes distinguished from *mountain blanket bog,* which is found above 300m all over Ireland.

There are also important differences between mountain blanket bog and lowland blanket bog. For instance, bilberry thrives on mountain bogs, but not on lowland bogs because it needs higher humidity than they can provide, and crowberry grows mainly on mountain bogs because it is essentially an alpine species. On the other hand, black bog rush does not occur on mountain blanket bog because the nutrient status here is too low for it, but it is often very abundant on low-level blanket bog. There is a *floristic gradient* between mountain and lowland bogs, and there is also a floristic gradient from east to west across the country [**Table 5.3**]. As one travels westward across Ireland, annual rainfall gets higher, and along the western seaboard the proximity of the ocean increases the nutrient content of the bog. A whole range of species thrive under these ecological conditions, species which

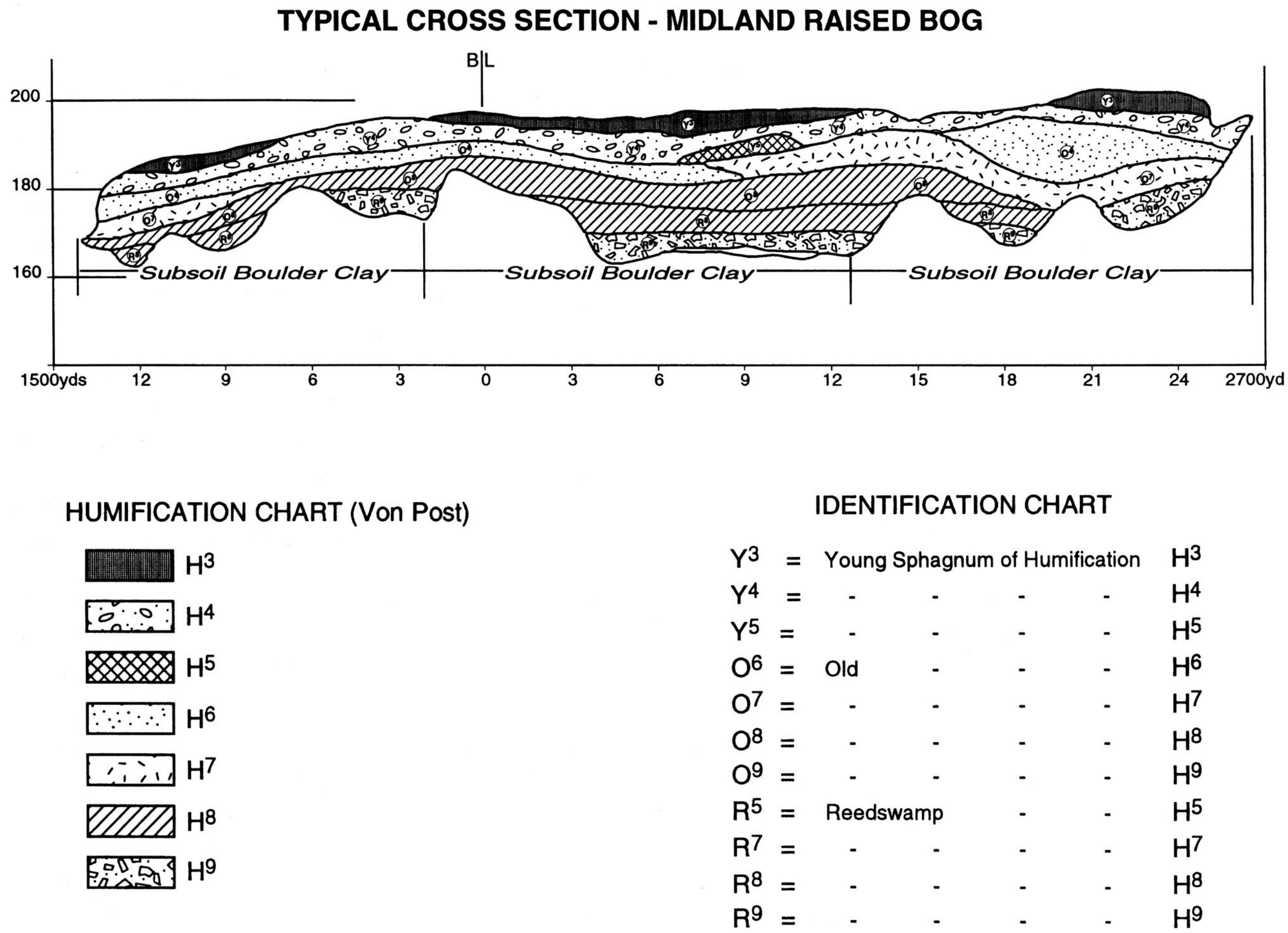


Figure 5.17: Cross section through a typical raised bog, showing peat types and Von Post humification values [Redrawn from Lee (1976)].

cannot as a rule live in raised bog: purple moor-grass, heath milkwort, lousewort and tormentil. These species however do occur in fens, and they are very characteristic of cutover areas around raised bogs, where ecological factors approximate those of the western bogs.

Large areas of blanket bog in Wicklow in the east of the country are dominated by deergrass, which forms almost lawn-like vegetation (Scirpetum) on the flatter waterlogged areas lying between 1,250 and 1,500 feet (380-610m), but which rarely plays an important role in the western bogs. On the plateau blanket bogs of the Dublin-Wicklow mountains turf is cut only from this Scirpetum. The improved drainage which results from turf-cutting is often followed by an invasion of heather-dominated vegetation (Callunetum). Purple moor-grass is often abundant in these marginal situations, whereas in the west it is characteristic of drier places in blanket bog, such as older sphagnum hummocks. It is also quite widespread in Cork and Kerry, where it is known as 'fionán' (from its winter colour; *fionn* means white or fair in Irish). Bog cotton (cottongrass) often covers extensive areas of the Wicklow Mountains; so extensive is this Eriophoretum that part of this bog near the Wicklow-Dublin county border is known as the Featherbed.

In Connemara and Mayo, lowland blanket bog covers the wide expanses of ground between the mountains, which are composed for the most part of metamorphic rocks. Everywhere the pine forests beneath the peat tell of a very different landscape in earlier times, nowhere more vividly than around Lough Mask. The dominant vegetation is a mixture of hare's-tail cotton-grass, purple moor-grass, white beak-sedge, black bog-rush and deergrass. Heather is nearly always present, but it only dominates in drier areas where the buried rock is close to the surface, and in these rocky places western furze often occurs. Stunted woods of oak and birch, and scrub with weather-beaten hazel, hawthorn and holly, eared willow, the occasional mountain ash, grow here and there in drier and more sheltered parts. Erosion is prevalent in many plateau bogs, exposing the pine and birch stumps which tell of the drier sub-Boreal conditions that prevailed before the wetter sub-Atlantic climate accelerated peat formation.

There are pools and lakes of all sizes, and in many places depressions and basins in which reeds and great fen-sedge - faint relics of vanished reedswamps – mark the location of former swamps which have now filled in. Although there are sphagnum hummocks, their role is not as important as in raised bogs. Blanket and raised bogs have the same dominant species of bog mosses: *Sphagnum subnitens, Sphagnum papillosum* and *Sphagnum magellanicum,* with *Sphagnum subsecundum* holding the wetter ground between hummocks. When the hummocks have become sufficiently dry, heather, purple moor-grass and bell heather invade, and they are later joined by cladonia lichens, especially *Cladonia arbuscula* and *Cladonia uncialis,* and the dry hummock mosses: patches of *Rhacomitrium lanuginosum,* black patches of *Cam pylopus atrovirens,* and cushions of *Dicranum, Leucobryum* and *Aulacomnium palustre* (See also Chapter 8).

Because the mineral content of the rain raises the nutrient status of western oceanic blanket bogs, they have a mixture of hard-core ombrotrophic plants together with others that are more minerotrophic in character. Both species of cottongrass, deergrass and bog asphodel are generally more prominent in blanket bog. In raised bogs these tend to occur towards the edge of the bog, or where the surface has been modified by drainage or burning. Plants such as black bog-rush and purple moor-grass play a much more important role in the blanket bogs of the west than in mountain blanket bogs. In the Midlands these are plants that are associated with calcareous fens and old cutover. At its margins, blanket bog grades into *heath,* in which heather and heath species are prominent. This in turn grades *into-grass heath,* where the dominant plants are coarse grasses.

Because the topography is often so rugged in the west and on the mountains, areas of blanket bog are often enriched by water moving from higher to lower ground; these sloping bogs often have thick deposits of reedswamp peat at the base. In areas of blanket bog, fen peat only develops in enclosed basins. Sloping blanket bogs tend to have a very irregular hydrology; they are very wet in rainy periods, but the surface may become very dry during periods of drought. This, together with the effects of surface flow following rain, causes a reduction in the diversity of liverworts and species of sphagnum, whereas blue-green algae become more prominent.

The profile of a blanket bog is quite different to that of a raised bog. It usually consists of two distinct layers, a lower well-humified layer (H8-9 on Von Post's scale), below a younger and less well-humified peat of similar composition. The plant composition of the peat is correspondingly different. Because sphagnum is not usually dominant in blanket bog, it is much less important in the make-up of blanket peat; the main constituents are heathers, sedges and grasses. The relict soils under blanket bogs are almost always relatively mature, because they were exposed to soil-forming agencies for a long time before the bog began to develop.

How blanket bogs grow

Blanket bog does not grow in the same way as raised bog, although the upward growth of the peat is the result of a somewhat similar succession [**Figure 5.18**]. Sphagnum does not have the same luxuriant dominance in blanket bogs; the wetter parts are often dominated by white beak-sedge, but as it builds up it is succeeded by quite different dominants - purple moor-grass and black bog-rush - and it often appears to follow an earlier wetter stage where

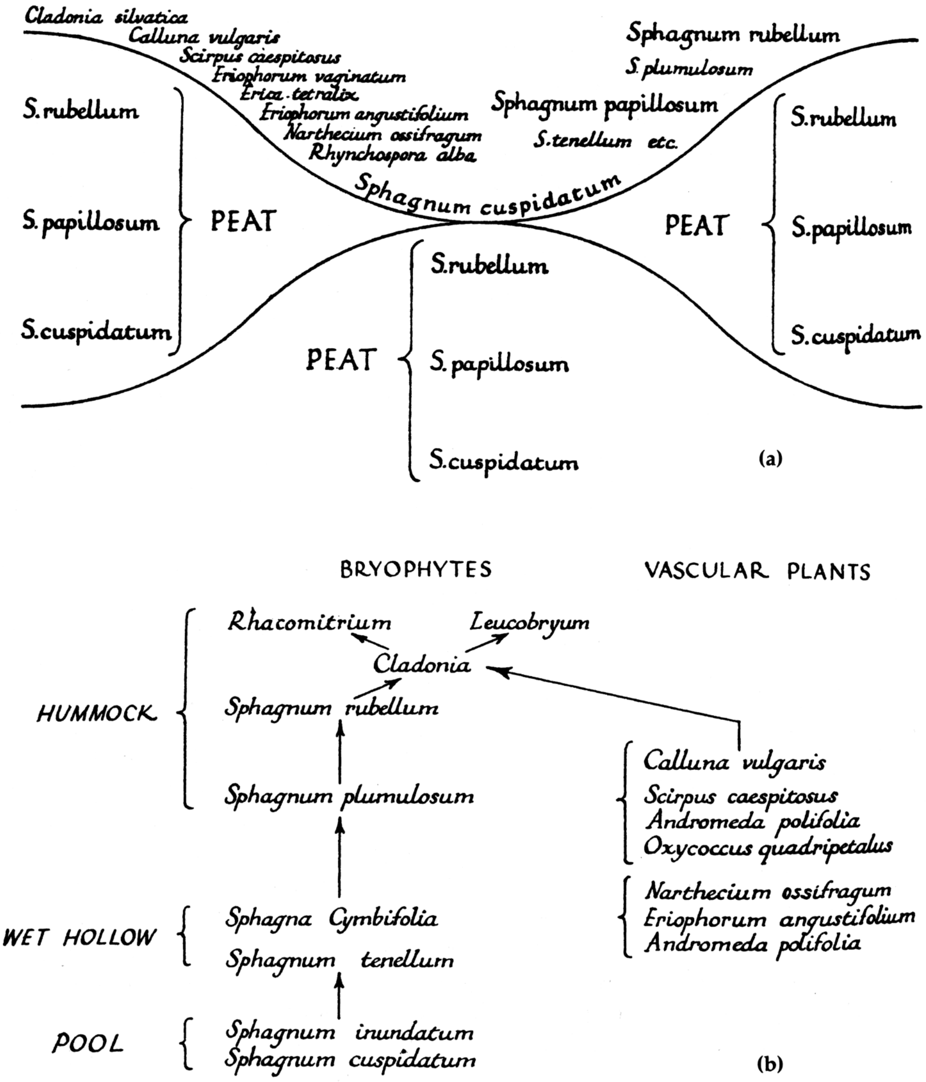


Figure 5.18: Tansley's figures illustrating (a) the succession of species ('seral structure') forming the peat in a typical hummock-hollow cycle (regeneration complex); (b) the succession of species in a hummock in the blanket bog of the Wicklow mountains, where 'the bryophytes are the actual builders of the hummocks, the vascular plants colonising at the levels indicated' . H = humification scale (1-10).

bare peat has been colonised by a thin web of the filamentous green alga *Zygogonium ericetorum.*

Why did these great expanses of bog form in the first place? Was it simply because of the wet climate, and because the unfavourable geology eventually led to podzolisation and the growth of bog? These were indeed the key factors: but there was another influence at work as well: human interference.

In the aftermath of the Ice Age, peat did begin to accumulate locally in waterlogged situations in the west of Ireland, as it did everywhere these conditions occurred, but most conspicuously in the watery Midlands. Over most of western Ireland and on the mountains, the post-glacial vegetation consisted of grassland, wood and heath, and these areas were particularly favoured by early farming communities on this account. It was only at the beginning of the Atlantic period that bog really began to spread, and peat began to accumulate much more extensively in western Ireland and on the mountains throughout the country. The growth of raised bogs in the Midlands was beginning to accelerate at about the same time. Until the end of the Atlantic period, somewhere around 5,500 B.C., there was undisturbed woodland in most places, but a thousand years later, towards the end of the fourth millenium B.P., woodland was no longer the predominant vegetation type in these areas. Broadly speaking, the general opening up of the woodlands began in the early Bronze Age, largely because of the new and more efficient tools for the clearance of trees which then became available.

Bog did not develop everywhere at the same time: it grew at different times in different places, which is not something we would expect if it were simply due to pedogenic evolution or climate alone. In the northern part of Ireland the breakup of the woodlands and the widespread expansion of bog occurred in the fourth millennium B.P., but in Connemara and south-west Ireland it was half a millennium later. In some places bogs were only starting to develop in the early part of the third millennium. Physiography had an important role to play in this expansion. The nuclei from which the expansion took place were low-lying, waterlogged basin areas: by late Atlantic times peat had developed extensively in such situations, but it was much later - well into the sub-Boreal or even the sub-Atlantic - before widespread expansion took place.

Bogs were absent from most of the west when the first farmers moved in. But it was not simply the clearing of the woods at a time of deteriorating climate that triggered the expansion of the bogs. What was perhaps more important was the prevention of its regeneration: burning the vegetation so that trees and shrubs could not re-establish themselves, allowing soil deterioration to set in, encouraging soil waterlogging and leaching, and preparing the ground for the transition to bog. It is becoming increasingly clear that it was not simply climatic change that allowed the spread of blanket bog, but the way the land was managed by the early farming communities. The part which poor land management played in the ancient spread of blanket bog was as important as the part it plays in the disappearance of blanket bog today.

A short history of bogland studies

Ireland's bogs have attracted the attention of naturalists for well over 300 years. Gerald Boate in his early account of Ireland's natural history devoted two fascinating chapters to bogs. The practical and accurate classification in Boate's *Naturall History* however is not original; it was compiled from information supplied to him by his brother and other observers in Ireland, and simply reflects the accepted classification of the time. A clear distinction is made between three main kinds of peatlands. First of all there are the moory, or boggy heaths' which include the dry or red bogs – what we now call raised bogs – and which are characterised by the 'earth in them being reddish, and overgrown with moss of the same colour'. Secondly there are true heathlands – 'dry heaths' – which, as Boate recognises – are not of great extent in Ireland. Finally there are the 'wet bogs', which Boate divides into four categories. It is difficult to equate these with modern categories, partly because this is a common-sense 'users" classification, and partly because the bogs have changed in some respects since Boate's day. The treacherous 'grassy bogs' in his classification seem to correspond to the wet and extensive western blanket bogs. These are sometimes very dangerous, 'for the earth being spungy can bear no weight', although those who know them intimately can usually find a way through. Boate's 'watery bogs' probably correspond to callows, extensive flooded grasslands such as those along the Shannon, though it may include some kinds of blanket bog or fen as well. 'Hassocky bogs' correspond to reedswamp, fen and carr. The final category, 'muddy bogs' is difficult to pinpoint, but it may describe areas of eroding peat.

What is perhaps most interesting about Boate's account is his belief that the bogs did not develop naturally, but resulted from the 'retchlessness' of the native Irish in failing to keep the land properly drained:

> it may easily be comprehended, that whoso could drain the water, and for the future prevent the gathering thereof, might reduce more of the bogs in Ireland to firm land, and preserve them in that condition. But this hath never been known to the Irish, or if it was, they never went about, but to the contrarie let daily more and more of their good land grow boggy through their carelessness, whereby also most of the bogs at first were caused.

He was led to this sweeping conclusion by the incontrovertible evidence of former forests buried by the bogs, and by reports of plough marks and other relics of settlement and agriculture on the mineral soil under some bogs. But whatever about the error of his racist notions on their origins, he did have a clear idea about the practical steps needed to drain bogs.

In 1685 Archbishop William King presented a paper – *Of the Bogs and Loughs of Ireland* – to the Royal Society. This is generally regarded as the earliest work to appreciate the nature of peat and the significance of vegetational succession in the growth of bogs. King is credited with being the first to understand the organic nature of peat: 'young light spungy turf is nothing but a congeries of the threads of ... moss ... [which] is so quick growing a vegetable, that it mightily stops the springs, and contributes to thicken the scurf especially in red bogs'. He also drew attention to the evidence of former farmland overwhelmed by bog – even quoting one case of a bog which had been a ploughed field within the memory of man. He followed Boate in concluding that bogs formed as a result of careless land management. 'No wonder', he wrote, 'if a country, famous for laziness as Ireland is, abound with them'. In King's time the marginal *lagg* which once surrounded every raised bog was still widespread, and very treacherous for cattle: 'Every red bog has about it a deep marshy sloughy ground, which they call the bounds of the bog, and which never fails to be worth the draining' – which explains why so few survived into the present century. He remarked too on the characteristic domed profile of the raised bog, and the presence of springs in the middle of many

The Civil Survey of the late 17th century adopted a practical fourfold division of bogs on the basis of vegetation: pasturable bog, wood bog, shrubby bog and red bog. Some eighteenth century observers made the simple distinction between black bog (fen) and bog proper. In the 19th century a distinction was sometimes drawn between red, dry bogs and wet, green bogs, which probably corresponds to the difference between raised bogs and blanket bogs. The 19th century survey of the Manor of Hillsborough equates green bogs with cutover bogs, which is again not altogether inappropriate. The attempt to classify bogs on the basis of colour can be traced back to the Middle Ages. In medieval documents the distinction between red *(rufa mora)* and white bogs *(alba mora)* is sometimes made. Perhaps this finds a parallel in the native Irish tradition in some of the placenames, which incorporate colour elements such as *roe* (red) and *bawn* (white).

The first comprehensive survey of Ireland's bogs was carried out in 1810-14 by specially appointed Commissioners for Bogs. This survey estimated the total area of bog in Ireland at 2,851,000 acres (1,200,000 hectares). About half, 550,000 hectares, was upland bog; the remainder was raised bog and low level blanket bog, which were classified together as 'red bog'. The total area occupied by the midland raised bogs in 1814 seems to have been 731,000 acres (295,835ha). Blanket bog accounted for 851,000 acres (344,400ha). As the survey was carried out with large-scale reclamation for agriculture in mind, it did not pay much attention to the smaller bogs (those which were less than 200 ha in extent). The survey reports listed all the major flat bog complexes over 500 acres (c.200ha) in extent: there were 23 of these. 400,000ha was surveyed in detail, three-quarters of it in the Midlands. The maps, which accompany these early bog survey reports, are the earliest detailed bogland maps we have for most of the country. (See Chapter 2).

The most remarkable figure in this survey of bogs was the young Richard Griffith (Jnr.), who was one of the engineers [**Figure 2.10**]. In 1,300 days of intensive field work spread over four years, beginning at the age of 25, he surveyed 80,000 hectares of lowland bog and 100,000 hectares of mountain bog in detail, and was the main contributor to this work of enormous value and interest. The reports are all the more important for having been written at a time when the bogs were still largely undisturbed, and based on such a vast amount of personal observation. After nearly two centuries, the *Reports of the Commissioners on Bogs* remain the most valuable single work on Ireland's bogs.

The debate on the nature of bogs continued into the 19th century and beyond. Bernard Mullins summarised the state of speculation in his day (towards the middle of last century):

> The growth of peat has been ascribed to various causes; amongst which the destruction of forests, by interrupting the drainage of the country and producing stagnation of water, and the consequent growth of aquatic vegetable matter, is the most generally received

opinion. Changes on the surface of the earth by volcanic agency, and the deposit of rivers, in raising impediments to the discharge of water, have also been mentioned by authors; and the opinion of a diluvial origin, to which so many things have been ascribed for want of a better reason, has had its advocates, it being supposed that bog was formed by the deposition of promiscuous vegetable matter carried by the flood.

In his diary for 1827, Humphrey O'Sullivan shows that the basic nature of bog growth was well understood by intelligent observers in his time:

Chím cionnas fhásann an mhóin. Tá luibh ar an ngaireann siad súsán. Fásann so sna poill mhóin agus d'éis feo dó, iontaíonn sé ina ghar, agus d'éis iomad blian líontar an poll móna mar so, agus bíonn ma phort arís.

I can see how the bog grows. There is a plant, which is called 'súsán' [sphagnum], which grows in bog holes. After it dies it changes into peat, and after many years the bog pool fills up in this way and becomes dry bog again.

The bogs were mapped more systematically during the course of the primary Geological Survey of the country between 1845 and 1887, and the one-inch maps published by the Geological Survey (and the six-inch field sheets upon which they are based) are the most detailed systematic maps of Ireland's bogs ever produced [**Figure 5.19**]; the accompanying memoirs also contain valuable notes on the bogs in each district. In 1920, the Geological Survey published a coloured peat map of Ireland, based on its survey work, on a scale of 1": 16 miles.

Little significant work on the nature and ecology of Irish bogs appeared during the rest of the 19th century. The first ecological account of an Irish bog is a short introductory article by Robert Lloyd Praeger that was published in the popular journal *Knowledge* in 1902. Praeger and Pethybridge were the pioneers of plant ecology in Ireland, and their study of the Dublin Mountains, carried out in the early years of this century, is the first real ecological account of Irish bogland.

A comprehensive survey of Ireland's peatlands was carried out for an Foras Talúntais in the 1970s by Bob Hammond. This resulted in the publication in 1979 of an important monograph on the peatlands, and the first map (at a scale of 1:575,000) to show the distribution of the different classes of bogs (See page 163). Hammond's survey provides little ecological information, and was not detailed enough to guide conservation policy. To remedy this, the Wildlife Service (then the Forest and Wildlife Service) spent several years between 1983 and 1987 mapping the raised bogs of the Republic, under the direction of John Cross. Lowland blanket bogs in Donegal, Kerry, Mayo, Galway and Sligo and upland deep bogs were surveyed by the Wildlife Service between 1987 and 1991. The data from the raised bog survey were summarised in a map on a scale of 1:575,000 with an accompanying book, based on a comprehensive six-inch map (1:10,250) database and descriptions of individual bogs. The two most striking things about the map are (1) the surviving *extent* of raised bog in Ireland, and (2) how little of it is undisturbed. Any estimate as to how many of the bogs retain their original natural character depends on the precise criteria used to define virgin bog. In fact, *all* Irish bogs have been modified to a greater or lesser extent, at least around the edges. Matthias Schouten felt in 1981 that less than 2% of the raised bogs could be classified as natural. The Irish Peatland Conservation Council (IPCC) estimated in 1982 that only 6% of the surviving raised bogs were relatively intact; Bord na Móna's own estimate at around the same time was 5%, and that of the Wildlife Service in 1989 was 7% (22,OOOha). As part of the recent selection process to identify raised bogs for designation as Special Areas of Conservation (as required by the EU Habitats Directive) the Wildlife Service has recently carried out a re-assessment of 104 of the less damaged raised bogs; this study included very detailed ecological and hydrological surveys of 47 sites: data which are vital for rehabilitation and future management.

A detailed peatland map for Northern Ireland was compiled for the Environmental Service of the Department of the Environment in the late 1980s by Margaret Cruickshank and Roy Tomlinson. This was based on aerial photographs and was hand-drawn on 285 maps at a scale of 1:20,000; the classification devised for the map was essentially a land-cover classification of the vegetation. The information was later transferred to 1km^2 grid squares and two maps showing total and intact peatland in Northern Ireland were prepared. The data were subsequently entered in a Scientific Information and Retrieval (SIR) database management system to enable data storage and manipulation. This greatly facilitates subsequent statistical analysis, graphical presentation and GIS analysis of the information with ease and flexibility [**Figure 5.20**]. The approach is particularly valuable because the digitised information can be used with PC ARC/INFO to relate the peatland data by overlay to relevant topographical and attribute information stored in other databases in order to show patterns and trends. An example of such comparison is the overlay of maps illustrating different socio-economic factors on maps that show the distribution of peat extraction on blanket bog, or the comparison of ecological survey data with peat extraction maps. The system is an invaluable tool in planning and management, and could with great benefit be extended to the whole of Ireland. However, it is essential to clearly understand the interpretation and classification of peatland used in these surveys.

Satellite imagery provides a potentially invaluable tool for the mapping and monitoring of peatland. At present, spatial resolution is a limiting factor in the application of SPOT and Landsat TM to peatland interpretation, but ongoing work makes it clear that this is the way of the future **[Plate 1].** The limitations in the information provided by current satellite imagery necessitates the use of a simpler system of peatland classificiation, such as that devised for the Corine Land Cover map. Radar is also a useful remote sensing tool in peatland study, especially in the evaluation of peat density/moisture content and the measurement of peat depth.

How much bog?

Bogland covers 1.34 million hectares of Ireland's surface today – 16.2%, a higher percentage than any other European country except Finland (17.2% of the land surface of the Republic, 12.4% of that of Northern Ireland). Most of this is concentrated in the Midlands and along the western side of the country. The amount varies greatly from one county to another. Wexford has only 3%, whereas west Donegal has 62.3%. Estimates as too how much bogland has been cut away by hand down the centuries range from around 300,000ha to twice that figure. Estimates made in the 1930s calculated that Ireland's bogs contained 5,000 million tons of air-dried peat (at 25% moisture), of which some six to seven million tons were burned annually as fuel.

Sir Robert Kane estimated in 1844 that the area of bog was 2,833,000 acres (l,147,000ha), almost all of which he believed capable of reclamation. Johnson (1861) calculated that there were 1,861 square miles (4,820 square kilometres) of bog in Ireland. Kilroe (1907) estimated that about 2 million acres (809,400 hectares) of bog remained at the beginning of this century. This varied greatly in depth, from two to forty feet. Less than half (0.429) was shallow mountain peat between one and three spit in depth – a spit being the depth of a turf spade or slane. The remainder – what was then generally called red bog – averaged 25′ (8m) in depth, and was much more suited for cutting. It was estimated that 'red bog' covered 1,648,000 acres, and 'peat soil' covered 1,380,000 acres. Most of the deeper bogs were in the Midlands, but there were extensive red bogs in the west and other areas as well – notably in Erris and Tyrawley, Connemara and Wicklow.

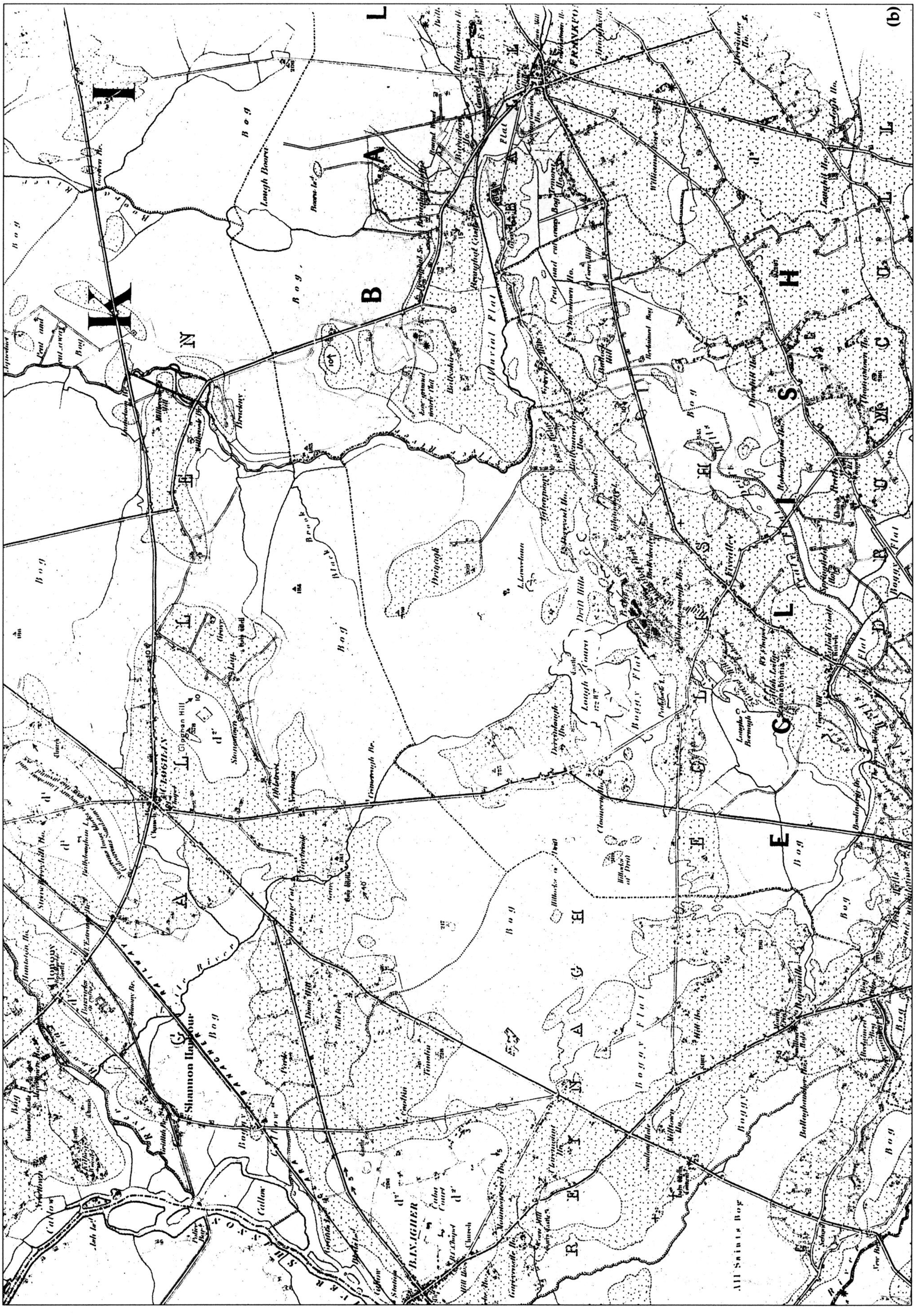
By the time Bord na Móna was established in 1946 nearly half of the total area of large midland raised bogs recorded in 1814 had been cut away by hand: some 2,000 acres a year (809ha), at 1,000 tons of fuel to the acre a total of around two million tons of turf.

Careful calculations carried out in 1969 showed that there were then 250,000 acres (just over 100,000ha) of raised bog remaining in the Midlands, of which Bord na Móna owned around 110,000 acres (45,000ha), and around 600,000 acres (243,000ha) of blanket bog, mostly along the western seaboard. Bob Hammond's survey published in 1981 shows 1,170,000ha of peatland, of which 773,500ha is blanket bog.

(a)

Figure 5.19:

The most important map of Ireland's bogs from a historical point of view is the one-inch map of the Geological Survey. This shows the distribution and limits of the bogs as they were around the middle of the 19th century, before the advent of mechanical exploitation, and before the large-scale hand-cutting of the present century. Its value is greatly enhanced by the accompanying geological, topographical and other detail, and by virtue of the fact that it covers the whole of Ireland. The one-inch map is based on the unpublished six-inch field sheets of the Geological Survey, themselves a mine of information, and is supplemented by written memoirs for each sheet, which often contain nuggets of information on 19th century bogs. The map - which comprises 20S sheets altogether - was published between 1856 and 1890.
(a) The area west of Eyrecourt, County Galway (Sheet 116), with numerous small bogs in the hollows between the hills and ridges of eskers and moraine, and on the west bank of the Shannon.
(b) The extensive bogs north of Birr, County OHaly, which is just of the south edge of the map (Sheet 117). Note the location of Drinagh, Derrinlough and Crancreagh, where there are wave-edge marker stones. Boora is at the north-east corner, and Lough Coura is near the centre. The area west of Derrinlough is shown at the six-inch scale in Figure 5.14.


(b)

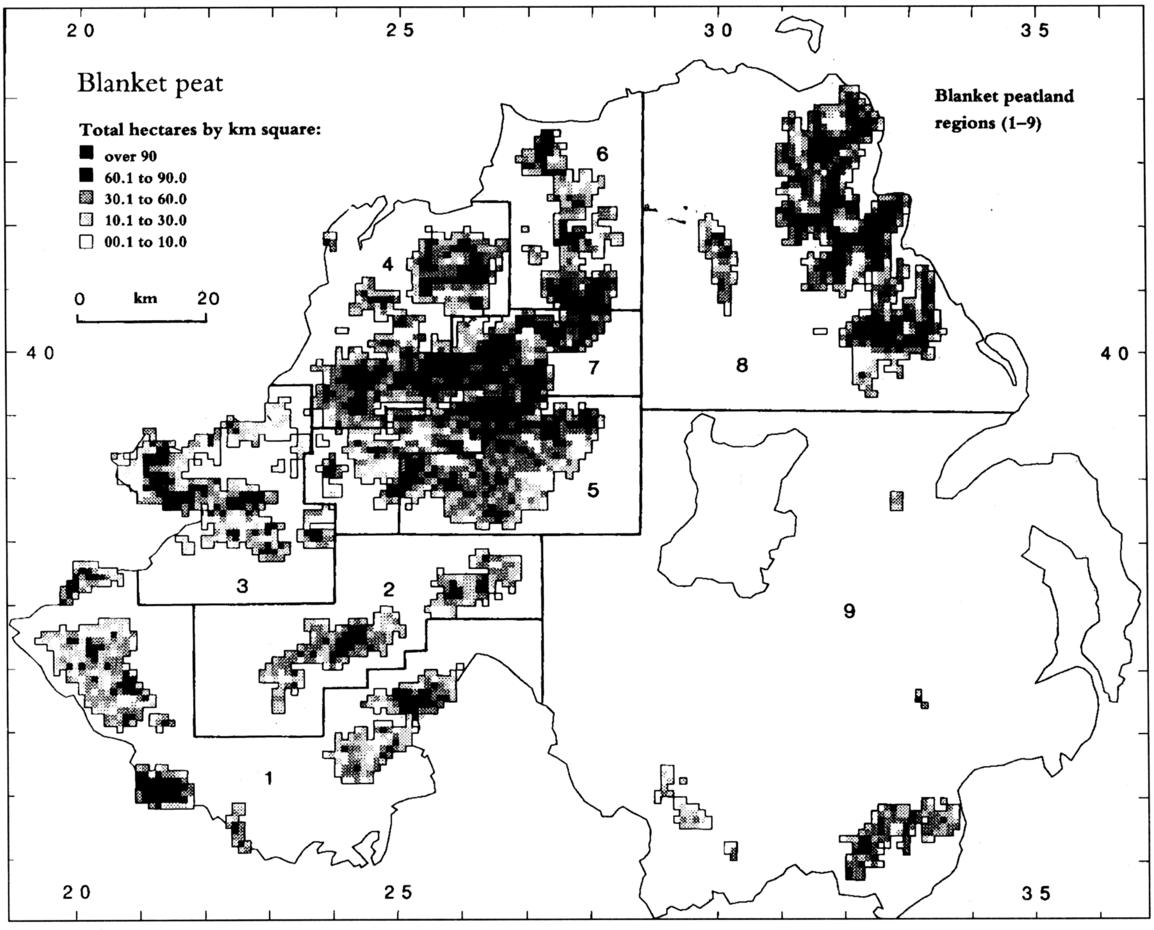


Figure 5.20: Computer-generated map from the Northern Ireland SIR database, showing eroded blanket peat as ha/km^2. (From Cruickshank *et al.*, 1993).

The growth of new bogs

Fuel peat bogs grow at a very slow rate, on average perhaps somewhere between 10 and 100cm every 1000 years. Estimates using C^{14} dating techniques suggest rates of formation of between 0.2 and 1.6mm a year. But when conditions are optimal the upward growth of raised bog can be very rapid. Johnson claimed that bog growth could be anything up to six inches a year, and Kilroe reported a case where a canoe was dug out of a bog near Omagh at exactly the point where an 80 year-old local man remembered fishing in open water as a boy:

> In a small bog in the townland of Farrest, north of Omagh, a well formed canoe, hollowed out of an oak log, at least three feet in diameter, was found buried under 3 ft. 6 inches of peat. As indicating the age and mode of formation of the bog in question, and that doubtless of others in similar positions, it may be mentioned that the peat now occupies the site of a former loughlet, which yielded fish to a peasant who was in his eightieth year about the time of the discovery of the canoe.

Although 1mm in one or two years is often given as a typical rate of peat accumulation, Ryan quoted an average growth rate of about two feet per century, but he also mentioned places in Hanover where rates of as much as four to six feet in a period of 30 years had been recorded. The 1921 *Report on Peat* made some interesting deductions from the accepted average:

> The average growth of a peat bog is, however, about 2 feet in a century, corresponding to 256 tons of air-dry peat for every acre. As the total area of our bogs in 1814 was about 3,000,000 acres, it may be assumed that the amount of peat formed during the period 1814-1914 was upwards of 750,000,000 tons, an amount which is probably in excess of that utilised during the same period, even when allowance is made for the relatively

small area of bog cut away during the century. If these conditions were to continue in the future our bogs would last almost indefinitely

Richard Griffith referred to a bog where peat had accumulated steadily at the rate of two inches every year for twenty years. These very high figures are entirely due to the growth of sphagnum. Hummock-forming sphagnum can grow by 3.5cm a year, and species growing in wet hollows by as much as 40cm. This extraordinary growth rate makes it very difficult for other plants to keep up, especially in an environment to which the bog mosses are so remarkably well-adapted. The net production of dry matter by sphagnum is comparable with that of other plant communities: it may be as much as 50% more than grassland under optimal conditions.

The accumulation rate is of course much less than the growth rate, because the volume will be much reduced by compression, but these growth rates will still result in an accumulation of between 1cm and 4cm a year, and as we have just seen, moss peat in Ireland has been known to accumulate at a rate of a metre in twenty years. This will not surprise anybody who is familiar with raised bogs, where old turf cuttings provide striking evidence of the rapid growth of sphagnum. Deep peat workings and drainage channels, excavated little more than a generation ago, are already choked by the accumulation of bog mosses. All of this has important implications for the regeneration of damaged bogs, a theme to which we will return in Chapter 16.

What these growth rates suggest is that there is at least the *possibility* that under the right conditions moss peat could be grown and harvested as a crop, and that its exploitation need not be the depletion and exhaustion of a highly valuable but limited and essentially non-renewable resource.

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Chapter Six

Plant Life on the Bog 1: Vascular Plants

An' there's plenty to mind, sure, if on'y
ye look to the grass at your feet,
For 'tis thick wid the tussocks of heather,
an' blossoms and herbs that smell sweet
If ye tread thim; an' maybe the white
o' the bog-cotton waved in the win',
Like the wool ye might shear off a night-moth, an'
set an auld fairy to spin;
Or wee frauns, each wan stuck 'twixt two leaves on
a grand little stem of its own,
Lettin' on 'twas a plum on a tree;
an' the briers thrailed o'er many a stone
Dhroppin' dewberries, black-ripe and soft,
fit to melt into juice in your hould ...

Jane Barlow: *By the Bog-hole (1893).*

Introduction: the problems for life on the bog

A considerable number of chemical elements are essential for the healthy growth of plants. Some are needed in relatively large amounts (the *macroelements),* while only small amounts of others (the *microelements)* are required. The 16 elements which are essential for plant growth are:

Macroelements	***Microelements***
Carbon	Manganese
Hydrogen	Copper
Oxygen	Zinc
Nitrogen	Molybdenum
Phosphorus	Boron
Potassium	Chlorine
Calcium	Iron
Magnesium	
Sulphur	

Plants get all the carbon, hydrogen and oxygen they need from carbon dioxide (CO_2) in the atmosphere and water (H_2O) in the soil. Most of the other nutrients come from the weathering of minerals in the soil and underlying rock, and they are taken up in solution by the plant's roots. This includes nitrogen, in spite of the fact that four-fifths of the air is composed of nitrogen. Green plants can only use nitrogen in the form of nitrogen *compounds* in the soil. These essential plant nutrients are *recycled* when dead plants and animals decay, and are then available for use by other living plants.

This explains why bogs are such difficult places for plants. The soil in which they must grow is the peat itself, consisting of the only slightly decomposed remains of earlier inhabitants of the bog. The nutrient reservoir in the underlying mineral substrate is out of their reach. The peaty soil is generally waterlogged and devoid of oxygen – which is why dead plants accumulate in the first place: because the fungi and bacteria responsible for the decay of dead plant matter need oxygen. Consequently the nutrients in all this dead plant material are locked away, unavailable to the plants living on the surface. Many nutrient elements are in very short supply in bogs, but potassium and nitrogen are particularly so; however, the most important limiting element seems to be phosphorus. A scarcity of potassium, phosphorus and nitrogen limits protein metabolism, but the plant can manufacture all the carbohydrate it needs from water and carbon dioxide.

Nitrification – the breakdown process by which nitrogen becomes available in the form of nitrates which plants can take into their roots from the soil – is extremely slow or altogether absent in bogs. Many bog plants seem to acquire their nitrogen mainly in the form of ammonium ions (NH_4^+); plants with mycorrhizal partners get their nitrogen in organic form from their symbiotic fungi. Hare's-tail cottongrass seems to take up its nitrogen largely in the form of free amino acids. The problem with ammonium as a nitrogen source is that it upsets the ionic balance in the plant cell; it suppresses the uptake of potassium ions (K^+), which has to be compensated for by the release of hydrogen ions (H^+) from the cell – which increases the acidity of the surroundings. Sphagnum is something of an exception in its reliance on nitrogen in nitrate form in rainwater.

The surface of the undisturbed bog is made up of an almost unbroken carpet of bryophytes – liverworts and mosses, mostly species of sphagnum – among which a relatively small number of vascular plants grow. All of these plants of the bog need to be specially adapted, in one way or another, to cope with these harsh conditions of nutrient 'rationing'. Each has its own strategy for coping with the problems of living on the bog, and this is one of the reasons why the natural history of bogs is of such interest. In this chapter we will make the acquaintance of some of these prominent plant denizens of the bog and the communities in which they live.

There is considerable variation in conditions between one bog and another as well as between different parts of the same bog – local variations in climate, in slope, drainage, depth of peat, the level and nature of interference by man and animals and so on. The plants of bogland vary in the degree to which they can take advantage of these variations, and so different parts of the bog have quite different communities of plants that can be recognised and defined as such. An understanding of these communities can be translated into some understanding of the underlying local bog environment. In the early part of this chapter we will look at these communities in general terms, and then later in the much more formal language of the phytosociologists – the scientists who specialise in the study of plant communities and their structure.

Bogs are a relatively recent arrival on the European (and Irish) scene. The plants which colonised them as they developed and spread during the millennia following the Ice Age came from a variety of other different sorts of habitats: marshes, mountains, fens, acid woods, heaths. Although some individual plant species are more or less confined to bog, it is the communities as a whole that are unique. Now that so little survives of many of the other communities from which their constituents came, bogs are now among the richest areas of natural vegetation remaining in Ireland. Some 50 species of flowering plants may be regarded as more or less characteristic of bogs, along with 50 or so species of bryophytes and rather fewer lichens.

Inevitably, the plants growing in the bog are all competing for the same limited pool of resources, but like shops in a town, all seeking to extract money from the customers' pockets, they go about it in different ways, so that although there is this basic element of competition, there is little direct conflict. Each species has its own 'profession' as it were, occupying a different niche in the ecosystem. Although all plants need a supply of both the major and micro-nutrients, each has evolved its own unique strategies and balance.

Four specialist strategies are available to bog plants to solve the problems of their nutrient budget:

1. Enlist the help of fungi to regain some of the nutrients lost to the peat.
2. Collaborate with nitrogen-fixing bacteria that can help with the provision of essential nitrogen.

3. Make use of the abundant nutrient reserve in the bodies of bogland animals.
4. Make better use of what little nutrient material the rain brings in. (Rainwater however is very low in phosphorus).

Even with these special strategies, nothing is wasted. All bog plants – including sphagnum – carefully husband the precious nutrient resources they obtain, remobilising and recycling their reserves from older to younger plants. For example, when old leaves or other parts of heathers are dying off, their chemical components are partly disassembled and taken away to younger, more active parts of the plants: a bit like taking the workforce and machinery out of a factory which is outmoded, and shifting them to more strategically-located premises. The actual framework of the building of leaves and stems is not so important because the structural materials of which they are composed – cellulose and lignin – are made almost completely of the nutrient elements which are most easily obtained: carbon, hydrogen and oxygen.

Taking root

Life in the bog is demanding enough for plants at the best of times, but it is particularly difficult in winter, when cold winds and rain sweep across a heathy desert that offers little in the way of shelter, and when the ground is often frozen or nearly so. Flowering plants which opt to spend the winter above ground need to be able to cope with these problems, and further on we will look at some of their strategies – the woody heaths and wiry sedges in particular. Others take, as it were, the easy way out. They shed their vulnerable stems and leaves with the approach of winter, withdrawing what reserves the year has left them with into storage below ground. These plants have special underground stems or roots in which these valuables are stored, and which spread through the peat, increasing the area of bog territory occupied by the plant. Because of their rapid growth underground, plants such as bog asphodel and many of the sedges often occur in extensive patches.

Roots are the most critical organs in most plants for obtaining essential nutrients, and bog plants have developed the root systems that best enable them to exploit the limited resources of the peat soil. These are often quite different from those of plants growing in mineral soils. It is difficult to establish a secure hold on the bog in the first place, and once a plant does manage to find a place, it holds onto it; most true bog plants, therefore, are perennials. Root systems exploit the peat to different depths. Heathers and heaths are shallow-rooting plants, seldom sending roots deeper than 15cm. Bog asphodel seldom penetrates deeper than 20cm into the peat. The roots of deergrass exploit the peat zone between around 15 and 30cm, but it is bog cotton that has the deepest rooting system, exploiting the underlying peat between 15 and 60cm.

Two main kinds of rooting systems are found in bog plants. First of all there are plants with fairly shallow systems with little lateral spread. Heathers and heaths have short, shallow rootstocks that product a mat of fine adventitious roots that fully explore the upper 10 centimetres of the peat; aerial shoots, produced from adventitious buds on the rootstock, form small compact tussocks. Bilberry has a very extensive branching rhizome that forms a closely-interwoven network from which adventitious roots ramify in all directions.

There are other plants with deep rooting systems that have little lateral spread. In this case the upper few centimetres of the peat are occupied by closely-branching rhizomes that are often extensively branched to give compact tussocks. The active root area extends down to about 15cm, though it can sometimes be twice as deep as this. Some bog plants, such as bog asphodel, heath rush, deergrass and purple moor-grass also have long cord roots that explore more widely [**Figure 6.1**]. Purple moor-grass has a very deep root system but little lateral spread. The very strong contractile cord roots look like yellow strings, and at intervals they produce fibrous roots that branch out and ramify in all

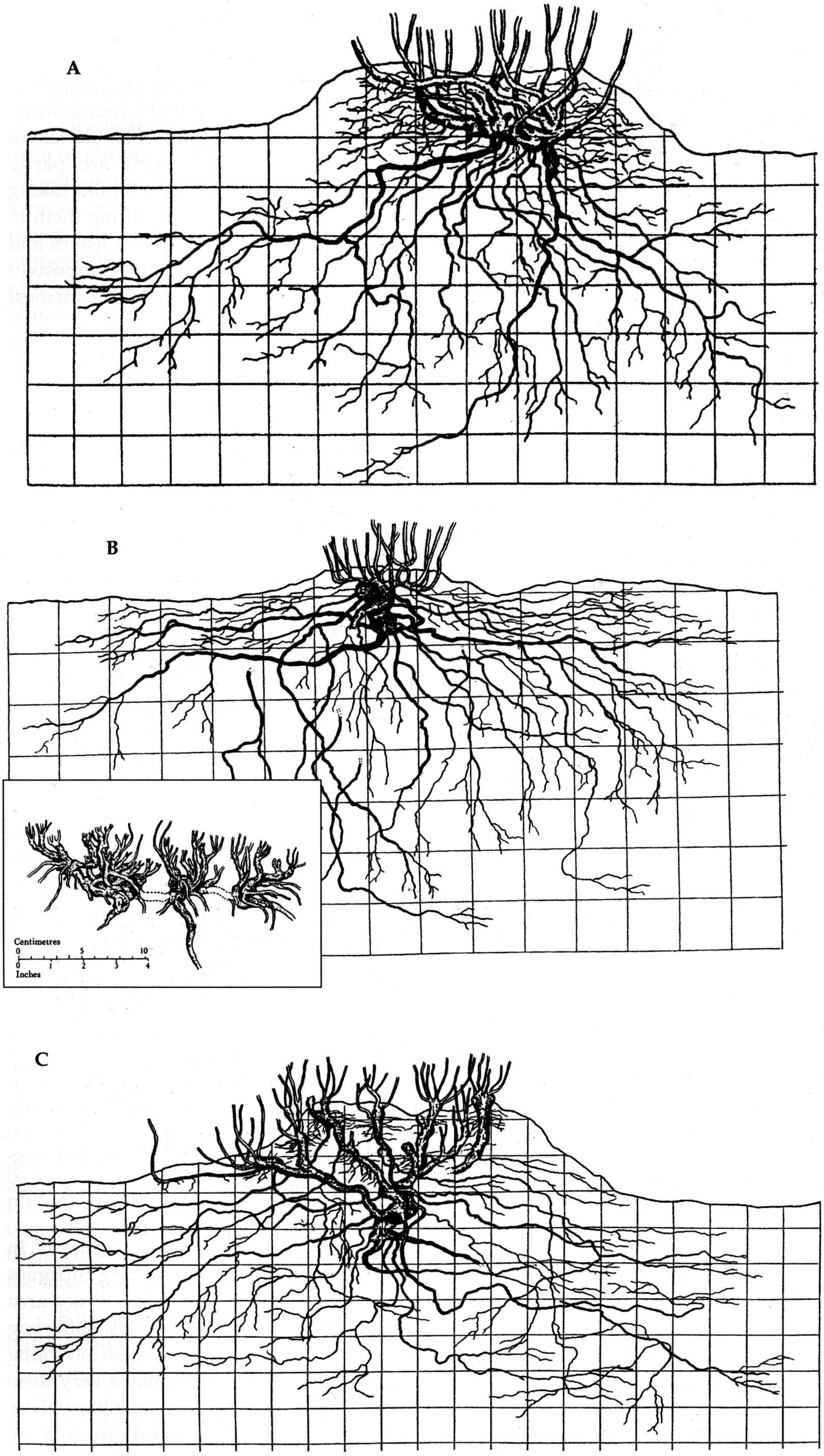
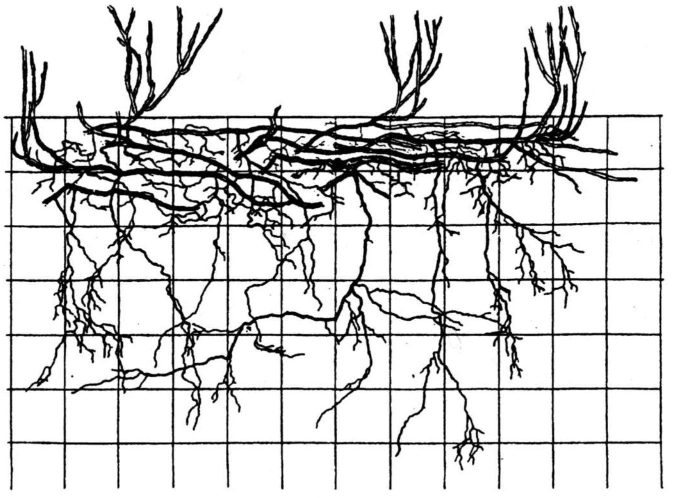


Figure 6.1: The rooting systems of some bog land plants. **A**. Heather (about 12 years old). Note the well-developed mat of adventitious roots near the surface. **B**. Cross-leaved heath (14-15 years old): primary root horizontal at about 3cm. The inset shows the creeping habit of the species; this is a 12-year old rootstock from which the finer roots have been removed. **C**. Bell heather (age 19 years); note elongated rootstock with fine adventitious rootlets. **D**. The horizontal rhizomes of bilberry. **E**. Western furze has a deep tap root, with long upper lateral roots that run horizontally through the peat. (The peat-mineral soil junction is indicated by the dotted line). (The squares here are 30x30cm). **F**. Heath rush. This is the rooting system of a small portion of a tussock formed by the branching rhizome. All the roots tend to grow downwards, with little lateral spread. Although a few cord roots go deeply, most are within 10cm of the surface. The form of the rooting system is influenced in part by variations in the peat soil and by the neighbours. **G** shows two variations in the rooting systems of bog asphodel; (i) with horizontal rhizomes and (ii) with vertical rhizome. Note the long cord roots and shorter fibrous roots in (ii). (From Heath *et al*., 1938).

D



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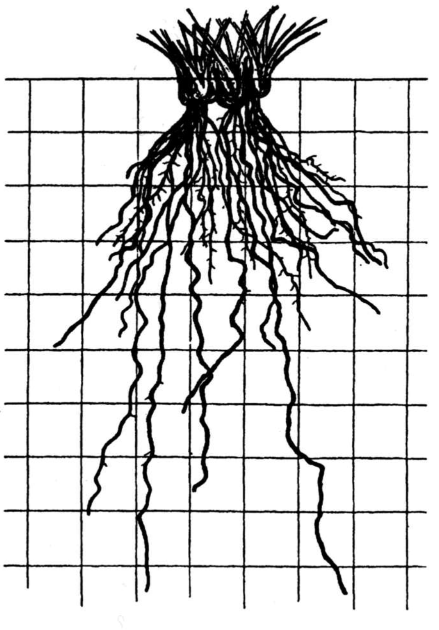

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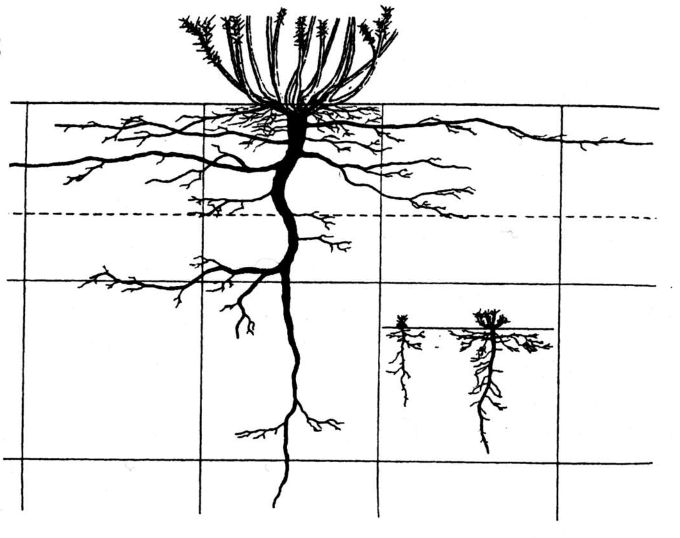
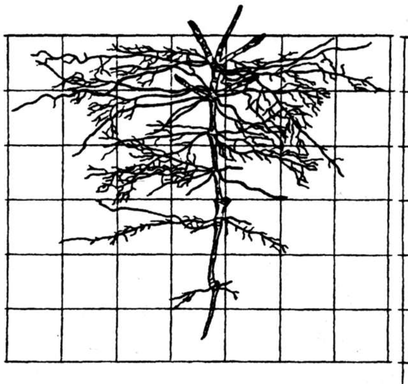
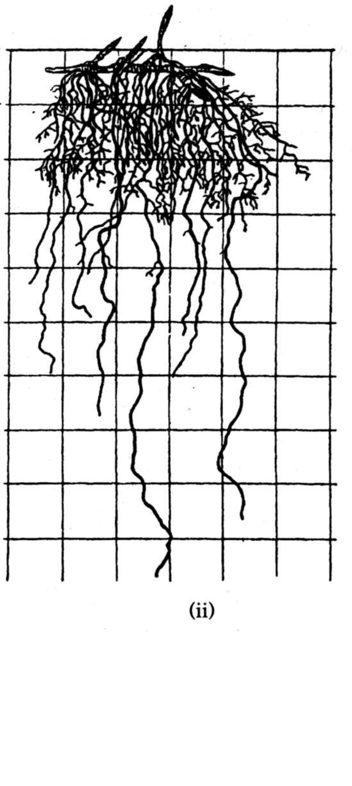




(i)

G



(ii)

directions, giving the grass a very thorough exploratory network. The rhizome of deergrass has a vertical growth habit, continual branching of which produces its distinctive close-tufted habit.

Non-woody herbs of cutover bog such as heath bedstraw, tormentil, lousewort and heath milkwort have restricted root systems that may spread out as little as 5cm or so from the stem, penetrating no more than 15cm down into the peat. Milkwort and bedstraw have fairly normal root systems – tap roots with branching laterals – but the peculiar character of peat soil favours the replacement of the normal tap-and-lateral root system with an adventitious system developed on an elongated rhizome. The root system of furze is somewhat intermediate between root systems typical of bog and mineral soils. It still has a very deep tap root, but there are also long lateral roots branching off from it and running out a metre and more from the plant just a few centimetres below the surface: but as well as this there is a dense mat of adventitious roots that arise from the swollen base of the main stem. Heather also has a well-developed tap root when it is young, but lateral roots take over later.

On cutover bog and in the marginal fens, rooting systems can explore more deeply. But even though purple moor-grass and rushes such as heath rush penetrate far down into the peat, their most active absorbing regions are still usually less than 10cm below the surface. The black rhizomes of bracken run vertically about 10-20cm below the surface, advancing rapidly and branching in all directions to establish total control of its living space. Older parts of the rhizome die back, giving independent existence to the individual branches. Most of the roots are near the apex of the rhizome.

The strategies of bogland plants 1: mycorrhizae

Few bog plants rely on their own unaided efforts to make a living from the peat. Most form mutually beneficial alliances with fungi. Such plant-fungi associations are called *mycorrhizae* (which comes from two Greek words meaning 'fungus-roots'). It is now known that over 90% of higher plants form mycorrhizal associations, but they seem to be particularly important to those which grow in situations (such as bogs) where essential nutrients are in short supply. In return for a share in the carbohydrate produced by their hosts – which they cannot manufacture for themselves – the fungi help the plants to obtain essential nutrients: the principal benefit seems to be with phosphorus. Recent research is beginning to suggest that the mycorrhizal relationship also protects the host against harmful nematodes and pathogenic fungi – indeed, this may even be its primary function.

There are two basic kinds of mycorrhizae. In *ectotrophic* mycorrhizal associations (ectomycorrhizae) the fungal mycelium forms a kind of sheath around the roots (which are short and stumpy), replacing the root hairs, and between the cells of the root cortex. The fungus helps the plant to regain some of the nitrogen, phosphate and various metal ions it has lost through leaf fall, and in return is paid in the currency of energy-rich carbohydrate manufactured by the plant. Ectomycorrhizae are especially characteristic of trees in the temperate forests of the northern hemisphere. The fruiting bodies of the mycorrhizal fungi associated with birch are one of the special features of autumn – toadstools such as common yellow russula, fly agaric, brown roll-rim, brown birch bolete and many others. These toadstools are especially conspicuous in the birch woodlands of cutover bogs and in coniferous plantations on peat. The fungi involved are nearly all basidiomycetes. They appear again in Chapter 9.

In *endotrophic* mycorrhizae specialised fungal hyphae enter the cells of the root cortex and form special structures inside the cells, producing spores on the surface mycelium. The fungal partners in this case are mainly members of the order Endogonales. These associations occur widely throughout the plant kingdom, but because they do not alter the appearance of the host root their importance has been recognised only recently.

Much of the early pioneering work on mycorrhizae was carried out on heather. In the special type of mycorrhizal associations found in all members of the heather family (which are called *ericoid* mycorrhizae) the fungus forms coiled hyphal structures in the cortex of the host root [**Figure 6.2, Plate 6**]. In heather, the mycorrhiza is formed only by the layer of large cells that bounds the root cortex; root hairs are not developed. Up to 80% of the total volume of these cells may be occupied by the fungus, and 60% of the fine roots as a whole, a level of infection much higher than that found in other mycorrhizal types. Interaction and transfer of resources take place between the fungal coils and the cytoplasm of the cortical cells, and both eventually slough off and are replaced by new ones. Transfer of material from fungus to host is partly effected through digestion of the fungal mycelium. The fungus is also widespread in cells of the above-ground parts of heather, even the seed coats, ensuring re-infection of the next generation of seedlings – which is essential, because the seedling cannot develop without its fungal partner. The fungus partner transfers nitrogen and phosphorus, which it has extracted from the soil, to the root. This fungus was originally assigned to the genus *Phoma,* but is now known to be an ascomycete called *Hymenoscyphus ericae*. The spore-producing fruiting bodies of the fungus are seldom observed; they are tiny cup-shaped bodies produced on soil near roots or on the roots themselves. Other fungi may also be involved, including *Clavaria argillacea* (See pages 315-316). Bearberry has a mycorrhizal association that is rather different from but related to that found in the Ericaceae.

Orchids also have a special mycorrhizal association, mainly involving species of *Rhizoctonia* that form intracellular coils in the host tissue. Orchids are involved with their fungal partners from a very early age: their tiny seeds carry no food reserves for germination, and they depend on the fungus to foster them through germination and seedling establishment and sometimes through their entire lives.

A number of other bog plants rely on mycorrhizae to help them along, including bog asphodel and crowberry, as well as the willows and birches. Sedges and rushes seldom have them. Plants like cottongrass and black bog-rush compensate for this lack by having much deeper and more extensive rhizome and root systems, which explore a much wider area of peat in their search for nutrients; the roots of cottongrasses often go down into the peat for more than a metre. There are a few exceptions: both deergrass (a sedge) and purple moor-grass are mycorrhizal.

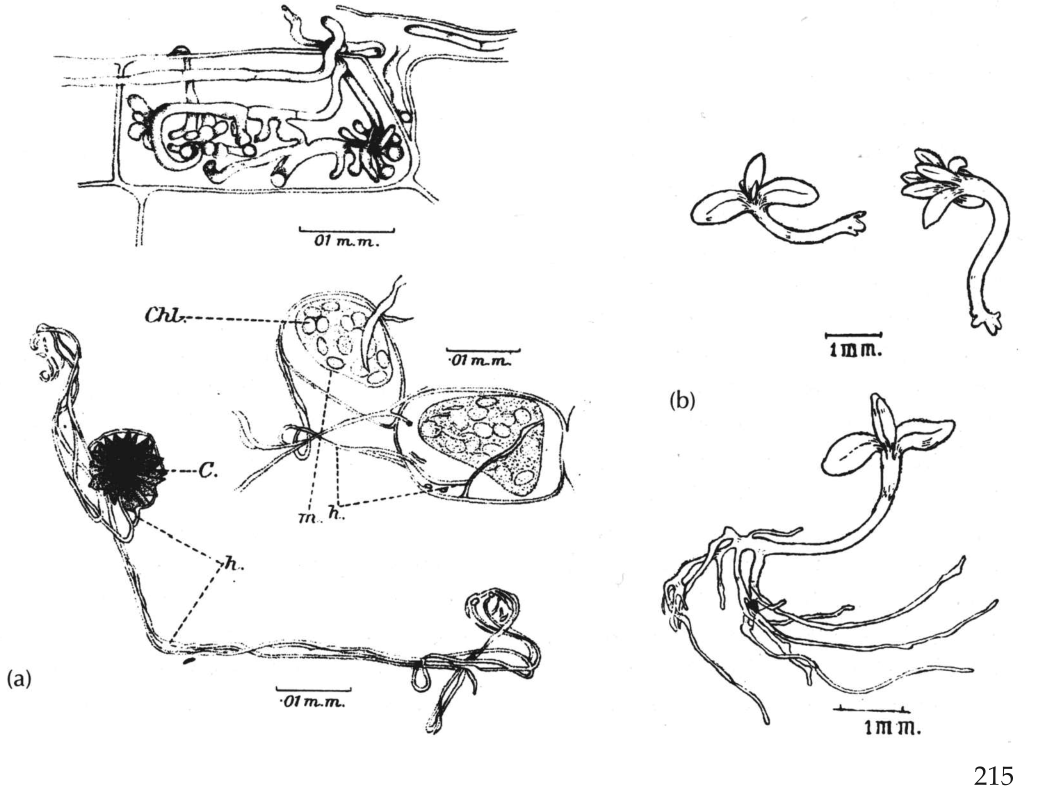


Figure 6.2:
(a) Coiled fungal hyphae in heather cortex.
(b) Heather seedlings four months after germination. The ones above were grown under sterile conditions; the one below was infected normally with its fungal partner (Rayner, 1915).

Heather and its relatives (Ericaceae)

Heathers belong to a family of low-growing woody shrubs most of which are specialised for living in peaty soils and heaths in many parts of the world. Heather or ling is a species that is more or less confined to Europe, but most of the 740 or so species of heaths, belonging to the genus *Erica,* are native to Southern Africa – no fewer than 657 are confined to Africa south of the Limpopo. Our handful of European species – there are only 20, most of them around the Mediterranean – all with pink or purple flowers, give little idea of the wonderful explosion of colour and floral variety found in their South African kin, many of which have showy flowers in brilliant reds and yellows, oranges and greens, and where the basic family design of the flower is modified in all sorts of wonderful ways. But all are built to the same basic floral blueprint, and nearly all possess the characteristic ericoid leaf: small, narrow and folded downwards so that the edges almost meet in the centre. And virtually all of them are plants of acid, nutrient-poor soils with lots of moisture.

Although heather and its relatives are generally thought of in Ireland as bog plants, they are more widely associated elsewhere with heathland. True heaths are dry areas with a shallow peaty layer overlying impoverished, generally sandy and often poorly aerated soils. They are *secondary* ecosystems that developed following deforestation – often in prehistoric times – with subsequent leaching and soil degradation. They are characterised ecologically by conditions of water stress and extremes of temperature. The peat often absorbs a large proportion of the water that falls as rainfall, preventing it from percolating down to the underlying mineral soil. It also heats up quickly in the sun, and just as quickly cools down, so that there may be considerable variation in temperature in a 24-hour period. Heathy soils generally have an iron pan caused by the leaching of iron in the form of ferrous compounds from the upper layers and its precipitation as an impermeable pan of hydrated oxides further down. Most blanket bogs had a heathy phase at an early stage in their development, but true heaths are uncommon in Ireland today. Wet heaths are a transitional phase to bog, but bog seems very different from heath in ecological terms. However, waterlogged peat is also a low-nutrient growth medium, and water is often unavailable to plants because of low temperatures in the peat. Moreover, bogs – like heaths – are very open, windswept areas which are prone to extremes of temperature at the surface.

Heather

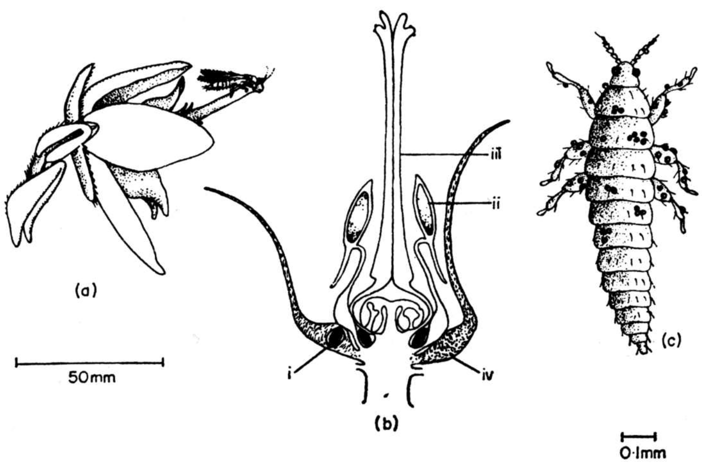
Heather may seem to be everywhere on many bogs, but in fact it is quite particular about its habitat. It becomes luxuriant and dominant wherever drier and better-drained conditions occur: on hummocks, on the sloping fringes of undisturbed bog, especially behind the facebanks in old turbary areas, or along drainage channels. It takes over on bogs that stop growing or reach what Hugo Osvald referred to as the 'stillstand' stage, whether this happens naturally or because of drainage. Dry periods in the bog profile are marked by an abundance of heather, together with hare's-tail cottongrass. Under certain circumstances – when it is surrounded by *Sphagnum capillifolium* on blanket bog for instance – heather behaves somewhat like sphagnum itself, growing at the tips of the shoots and dying back at the base where the sphagnum smothers it.

The flowers of heather consist of a deeply-split four-lobed corolla tube surrounded by a calyx of four sepals that are longer than the corolla; this in turn is enclosed in four petal-like bracts, and all three sets of floral organs are pink or rose in colour. The sight of carpets of these pink flowers from July to September dominates the mental image many people have of bogland. Each flower produces a capsule that contains between 20 and 30 wind-dispersed seeds. The Latin name for the plant is from the Greek *kallinein,* to beautify – not, as you might expect, because of the beauty of a heather-covered bog in August, but because of its widespread use in earlier centuries in the making of brooms.

Figure 6.3: A glimpse of a thrips.
(a) Single heather flower with thrips on stigma.
(b) Section of heather flower, magnified; (i) eggs of thrips; (ii) anther; (iii) style; (iv) base of petals.
(c) General thrips body form.
(d) Intimate details of *Ceratothrips* (Taeniothrips) *ericae*: pronotum and antenna.

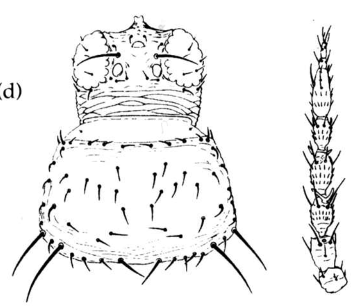
Because of its liberal production both of nectar and pollen, heather is a popular flower with bees, flies and moths. The nectary is a continuous, prominent ring under the ovary, but to get at the nectar an insect has to be able to force the filaments of the stamens apart, and in so doing is inevitably dusted with pollen.

Some 30 or more insects are closely associated with heather, not counting the insects that pollinate the flowers. These include many different kinds of bees: small bees like *Mellinus, Colletes, Halictus, Sphecodes, Andrena, Epeolus, Nomada,* as well as bumble bees (*Bombus*) and honey bees (*Apis*), which are particularly fond of heather. Several species of flies and thrips are also associated with heather flowers. Thrips are very tiny insects which feed on sap. The most extraordinary thing about their appearance is their wings, which are very narrow and fringed with long hairs. There are some thrips that spend their entire lives in heather flowers: the commonest species is *Taeniothrips ericae* [**Figure 6.3**]. The females can fly from one flower to another in search of male partners, but the males are wingless and spend their whole life in the same flower. The female lays four eggs in each flower, depositing them in the succulent bases of the petals. The fauna of flowering heather also includes several animals that lie in wait for the nectar-sipping pollinators. Apart from the many insects associated with heather flowers, a considerable number of species feed on the leaves; most of these will be met with in Chapter 11.



Larger animals also play a part in the ecology of heather. Hares and grouse feed on the young shoots, as well as mountain sheep and cattle. To maximise the growth of young, green shoots for grouse and grazing farm animals, heather moors and blanket bog are periodically burnt, and this is a major factor in their ecology. Young heather recovers well from the effects of fire by vegetative regeneration, but it loses this ability after about 15 years. Unburnt heather has a life span of about thirty years; after this it becomes long and 'leggy', dying back in the centre and making an opening for other species to invade. Although they have a low phosphorus content, heather shoots are high in calcium, magnesium, iron, manganese, copper and cobalt, especially in early summer, so they make good grazing. Heather has tiny triangular leaves that occur in four rows which overlap like roof tiles along the stem. The significance of these will be discussed later.

(d)

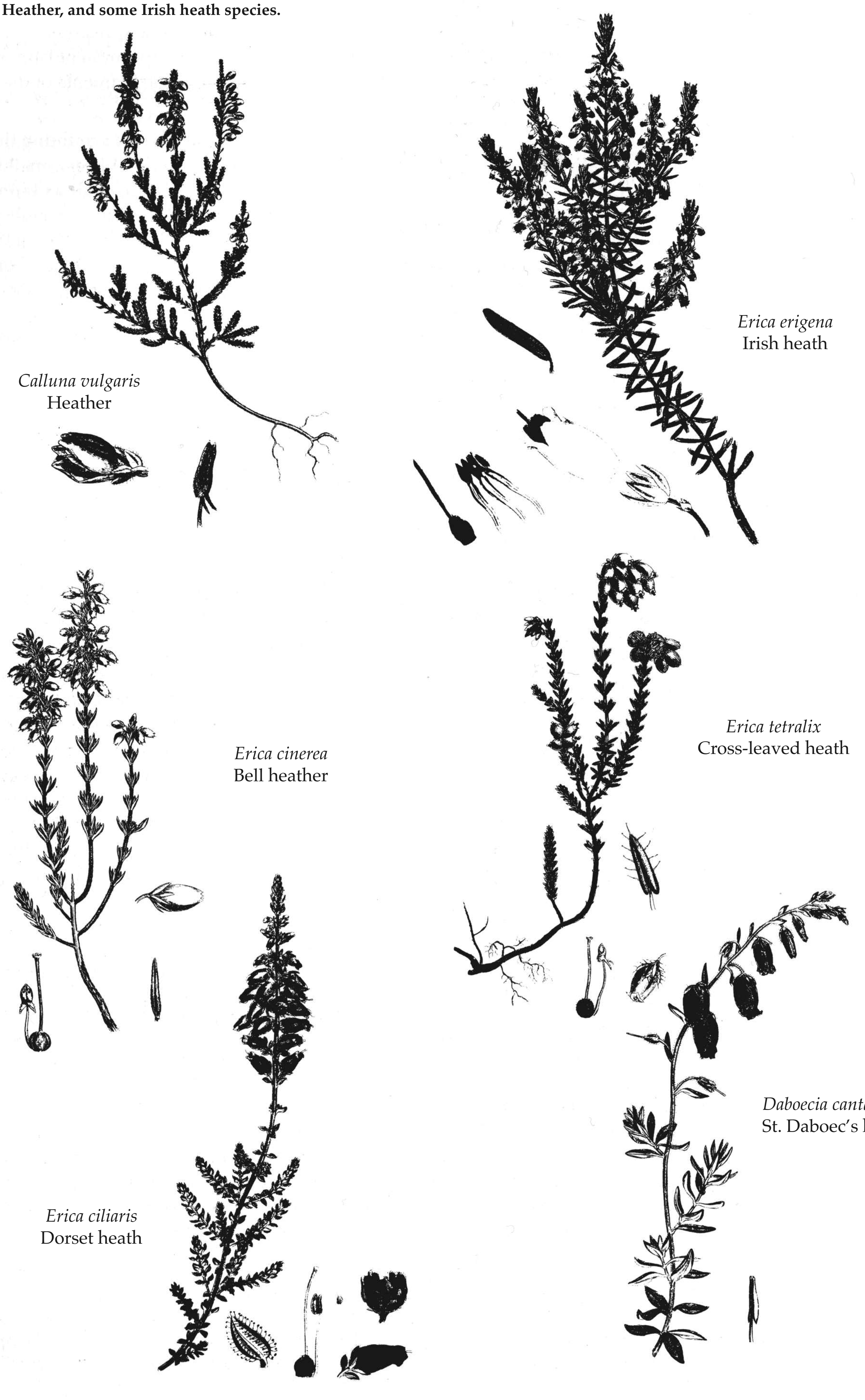


The heaths *(Erica* and *Daboecia)*

Several species of heaths occur in Irish bogs, but only two are common: cross-leaved and bell heather. Cross-leaved heath is so called because its leaves are arranged in fours along the stems. It is found in bogs of all kinds, where it tends to occur in small colonies; it prefers somewhat wetter conditions than heather. The species is especially characteristic of raised bogs, and is often prominent in recently burnt areas, because its powers of recovery after fire are better than either heather or bell heather. In the blanket bogs of the west it grows abundantly in association with black bog-rush.

In bell heather the leaves are needle-like and arranged in whorls of three, with little bunches of smaller leaves in their axils. It is characteristic of the better-drained parts of blanket bog, though more typically associated with well-drained acid mineral soils. In

Figure 6.4: **Heather, and some Irish heath species.**



these habitats it often extends over large areas, but it is absent from raised bogs. In both species the narrow linear leaves have downward-rolled margins. In cross-leaved heath these inrolled margins are fringed with fine hairs, which are absent in bell heather. The rootstocks of heaths were at one time used in the making of 'briar' pipes – a name that derives from the French word for heath, *bruyere.*

Heaths have drooping urn-shaped flowers in different shades of red and purple. The flowers of cross-leaved heath are pale pink or rose in colour; those of bell heather are generally reddish-purple, and smaller. One of the most fascinating things about the heaths is their floral structure. The style occupies the centre of the narrow opening of the urn-shaped flower, and it is surrounded by eight stamens whose anthers are pressed close together and against the style. In most flowers the anthers split lengthwise to release the pollen; in the heaths they open by small openings at the ends, but the pollen is not released from the anthers because of the way they are pressed closely together, end to end. At the broader outer end of each anther there are two little lever-like latches. Abundant nectar is produced near the bottom of the urn, and it takes a strong tongue to get at it. It is inevitable that the probing tongue will push or pull one of these latches, pulling the anther out of the tightly-pressed ring so that pollen spills out all over the bee's head, on which it will be carried to another flower.

The flowers of heaths are largely pollinated by bees and flies, but they do not rely entirely on larger insects for pollination. Bees, which are so attracted to heather, find it difficult to reach the nectar at the base of the corolla in the heath species. Pollination in cross-leaved heath is probably largely effected by the thrips *Taeniothrips ericae,* which is hardly ever absent from the flowers: indeed, it spends its entire life here. Although it also inhabits heather flowers, it is not always present in them. On the other hand, it is never found in bell heather (which is self-pollinated) or any other native member of the family.

There are several other Irish heaths, and although they play a very minor role in the ecology of the bogs, they are a fascinating part of the bog story because of their distribution. These rare heaths belong to a small but diverse group of plants – and indeed animals – of Pyrenean-Mediterranean origin that occur in Ireland. Among bog plants, the group also includes two butterworts, pale butterwort and large-flowered butterwort. The extraordinary distribution of this group of plants, whose true home is in warmer climes, has provoked and continues to provoke much debate. Were they here before the Ice Age? Did they arrive during a warm interglacial period and somehow survive in a refuge area somewhere offshore (remembering that at the height of the last Cold Stage of the Ice Age sea level was 100m lower than it is today) or have they arrived since the Ice Age?

Mackay's heath looks like a bushy version of cross-leaved heath at first glance, and it is abundant at only two places in these islands: in and about Roundstone Bog and Carna in County Galway and at Dunlewy in County Donegal. The species occurs elsewhere only in north-west Spain. Dorset heath is a somewhat hairy heath with larger flowers than most of the others. It too occurs widely in western France, Spain and Portugal. It is found locally in parts of south-west England, but in Ireland the species is known from one location only, in a bog near Roundstone. Cornish heath is one of the most beautiful and unmistakeable of all the heaths, with dense leafy inflorescences of pale pink flowers up to 10cm long. It occurs in west and central France and in northern Spain; in Britain it is common only round the Lizard in Cornwall. In Ireland it occurs only on a mountain north-west of Belcoo in County Fermanagh. In the last century (1866) it was recorded from near Tramore in County Waterford, but has not been seen here for many years.

St Daboec's heath belongs in a different genus from the others. It has urn-shaped flowers similar to bell heather, but they are about three times as large. It is common in Connemara, where it forms an attractive patchwork carpet with western furze. It is also found locally in south-west Mayo, but occurs nowhere else in these islands. Its true home is south-west Europe, in north-west Portugal, western France and over much of Spain.

Perhaps the most interesting of the rare heaths is the Mediterranean or Irish heath, so called because outside of its home in Spain and Portugal and in the Gironde in western France it is confined to bogs in West Mayo and Galway. It derives its Latin name *(erigena)* from Duns Scotus Eriugena, the 9th century Irish philosopher (depicted on the old Irish five pound note). It is taller than its relatives, growing up to 2m high, and unlike the other heaths it flowers in spring. Careful search in the pollen archives of the bogs shows that this heath appears to be a recent arrival in Ireland. Irish heath makes its first appearance in the peat profile at Claggan Mountain in County Mayo some time towards the middle of the fifteenth century, at a time when the bog surface was drying out following the burning of the mountain, which allowed the spread of dry heathland vegetation, and when agricultural activity in the surrounding area was on the increase. It is a plant of man-influenced heathland rather than natural bog. It has been suggested that it may not be native to Ireland at all, but could have been introduced in medieval times, when there was considerable traffic between Ireland and Spain. The idea that the Mediterranean heaths may not be truly native to Ireland is not a new one, but it is not one that is often seriously considered. And yet, it is not entirely impossible that all the Mediterranean heaths came originally with the megalith builders of the Neolithic, whose homeland was in these areas. They could have been accidentally introduced with seeds or roots – or perhaps even deliberately, for their usefulness in the making of brooms and matting, or simply as relics of home carried to the strange new land of Connemara and Mayo! They would originally have established themselves at a time of warmer climate, when this part of Ireland was probably much closer ecologically to their present home in continental Europe, but were able to maintain a niche for themselves when climatic conditions changed and bog took over.

Other genera in the Ericaceae

Bog rosemary is confined, almost, to raised bogs, and is therefore a fitting symbol for the Offaly county crest [**Figure 6.5**]. Some years ago, when pitcherplant was deliberately introduced to north-west Mayo, bog rosemary was accidentally introduced with it. This carried the species deep into an area where it does not occur naturally, thereby ‘forging nature’s signature’ (as has perhaps happened with many of the heaths). However, it does occur naturally in upland blanket bog in Slieve Bloom, which, significantly, is surrounded by lowland raised bogs. Bog rosemary has leaves that are dark green above and pale blue-green underneath, and with strongly inrolled margins. Each plant has only a few flowers, beautiful pendulous bells that are rose-pink or pale pink in colour; the scientific name for bog-rosemary is *Andromeda polifolia,* named for the beauty of Andromeda, who in Greek mythology was chained to a rock to be devoured by a sea monster in order to appease the anger of Neptune, but was rescued by Perseus. *Andromeda* was named by Linnaeus, the great 18th century Swedish botanist who devised our system of Latin nomenclature for plants and animals, and gave most of the common plants and animals their scientific names. It was also a particular favourite of his. It is worth quoting in full his account of why he named the plant *Andromeda:* because it indicates how much there may be behind an obscure Latin name, and shows the personal and passionate way many of the early botanists of the Romantic era related to the plants they studied [**Figure 6.5**]:

> I noticed that she was blood-red before flowering, but that as soon as she blooms her petals become flesh-coloured. I doubt whether any artist could rival these charms in a portrait of a young girl, or adorn her cheeks with such beauties as are here and to which no cosmetics have lent their aid. As I looked at her I was reminded of Andromeda as described by the poets, and the more I thought about her the more affinity she seemed to have with the plant; indeed, had Ovid set out to describe the plant mystically he could not have caught a better likeness ... Her beauty is preserved only so long as she remains a virgin (as often happens with women also) – i.e. until she is fertilised, which will not now be long as she is a bride. She is anchored far out

in the water, set always on a little tuft in the marsh and fast tied as if on a rock in the midst of the sea. The water comes up to her knees, above her roots; and she is always surrounded by poisonous dragaons and beasts – i.e. evil toads and frogs – which drench her with water when they mate in the spring. She stands and bows her head in grief. Then her little clusters of flowers with their rosy cheeks droop and grow ever paler and paler ...

Figure 6.5:
(a) Bog-rosemary and the Offaly county crest.
(b) Linnaeus' drawing of *Andromeda*.

As Linnaeus' account shows, bog rosemary occurs especially at the edges of pools and growing among aquatic and emergent sphagnum, but it is often equally at home at the dry margins of drained bogs.

Bilberry [**Figure 6.6**] is one of the most widespread plants of mountain bogs in particular. Like its relatives it is a rhizomatous perennial, but it differs from them in having 'normal' leaves that are seasonally deciduous, and it has photosynthetic stems. The drooping urn-like flowers are pink with green tips, and are mainly bee-pollinated. They are produced singly, each giving rise to a sweet, black berry covered with a blue bloom. These ripen around August, and the gathering of them was the occasion for the celebration of Fraughan Sunday or Bilberry Sunday on the last Sunday in July – the modern version of the ancient Celtic Festival of Lughnasa – in many parts of the country in former times.

Cowberry, although a close relative of bilberry, has a very different vegetative structure. Its dark green, glossy leaves are evergreen, oval in shape, and leathery in texture, about 2cm long. The pale pink bell-shaped flowers are produced in drooping racemes. It grows in blanket bogs mainly in the north and east of the country, but is not common.

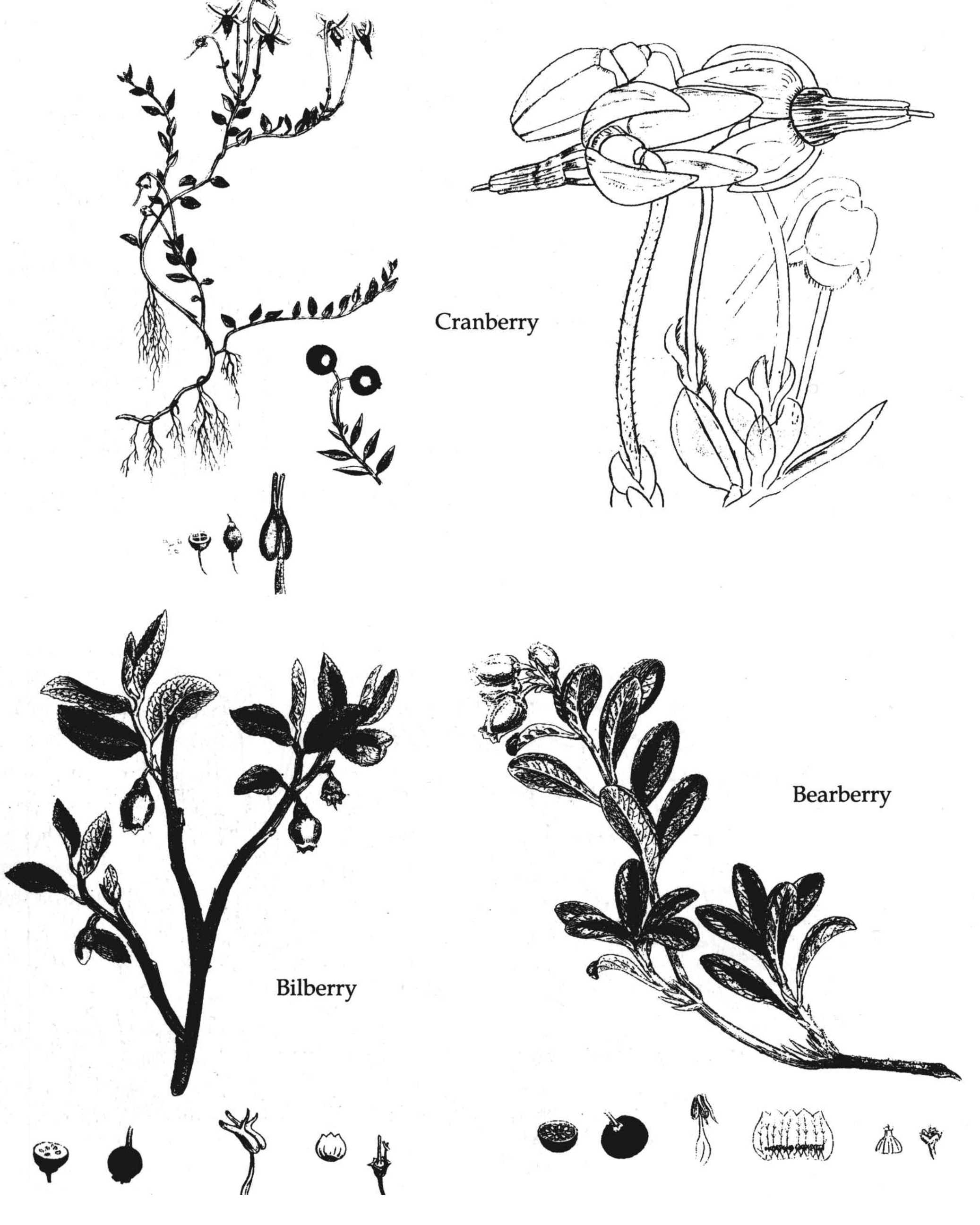


Figure 6.6: Cranberry, bilberry and bearberry.

Cranberry is one of the characteristic plants of raised bogs, in which it occurs only in the wettest parts, its unobtrusive stems trailing across the sphagnum. The flowers are small but exceptionally beautiful [**Figure 6.6**], borne in racemes of up to four flowers, each like a minute cyclamen, with four fully reflexed pink petals, and nodding at the end of a slender red pedicel. The oblong leaves are dark green and shiny above, but white or glaucous underneath, and rolled under at the edges (partially revolute). The large berries are sometimes red and sometimes brownish and mottled, and they ripen in September and October, in time for picking to make cranberry sauce for Christmas. The cranberry sauce in the supermarket is made from the closely-related North American cranberry, which can be found growing in a few Irish bogs, such as Woodfield bog near Clara in County Offaly, to which it has been introduced. American blueberry is also a member of the genus to which bilberry and cranberry belong (*Vaccinium*); it is not native to Ireland, but it is being grown commercially in a few places in the Midlands, and the fruit can occasionally be bought in shops.

Bearberry occurs locally in blanket bogs near the west and north coasts, the most striking representative of a small group of plants of Arctic-Alpine affinity still clinging on in the west. It is a low-growing evergreen shrub with glossy dark green leaves that are oval and not at all heath-like. The flowers are clusters of pendulous pale pink urns that produce bright red berries.

This brief review of members of the Ericaceae found on Irish bogs would not be complete without a mention of the most striking member of the family. Rhododendron is a native of the Mediterranean region and Asia Minor, and is now naturalised and very much at home on bogs in many parts of the country, on which it sometimes spreads widely by seed. It did occur here naturally in the distant past, during the Gortian Warm Stage of the Ice Age (250,000-200,000 years ago).

Crowberry (family Empetraceae)

Crowberry belongs to a different family from the heathers, but it has a superficial resemblance to them [**Figure 6.7**]. Its flowers (which appear in May) are wind-pollinated, and its fruits are bird-dispersed – all very different from the heaths. Grouse are especially fond of the juicy black fruits; they also feed on the young shoots. It has wiry stems that trail through the heather to establish straggling, prostrate colonies that form a persistent and loose mat by binding the plants over which they clamber by means of a network of adventitious roots.

It is a plant of various habitats in the cool, moist climate of north and west Britain and Ireland, but it is especially characteristic of blanket bogs, and is also abundant on some wet raised bogs. Although it favours undisturbed wet areas, it is often luxuriant along the edges of peat hags on eroding bogs and on the peaty edges of tracks cutting through deep upland bog, a preference it shares with bilberry. Like the heaths, it is assisted in its nutrition by an ericoid mycorrhizal association.

Life in a watery desert: bog xeromorphs

One of the most striking and at first sight puzzling features of most of the dominant plants of bogland is that they have a whole range of features that are characteristic of plants that live in an environment subject to drought; to use the technical term of the botanists, they are *xerophiles (xeros* means dry or parched in Greek). Xerophilous plants have evolved various ways of reducing water loss by evapo-transpiration. Loss of water from the leaf surface (transpiration) is prevented as a rule by an armour of impervious cuticle, but there are special structures called stomata on the undersides of the leaves that let in the carbon dioxide the plants need in order to manufacture sugar during photosynthesis, and also because they need to have some way of getting rid of most of the water they take in from the soil.

The best way to reduce water loss is to reduce the leaf area, or at least to shield the lower surface that has the stomata, as much as possible. This can be done by reducing the size of the leaves, or indeed by getting rid of the ordinary type of leaf altogether, and transferring their function to green stems. Or it can be done by having leaves which are rolled up backwards *(revolute),* or have a tile-like overlapping arrangement *(imbricate).*

An early stage in the leaf-rolling strategy is found in bog rosemary and cranberry, where the edges of the leaves are curled downwards. The downwards curling of the leaves is taken further in crowberry and the heaths, in which the edges of the backward-curved leaves almost meet [**Figure 6.7**]. The glossy, smooth leaves of crowberry look round and succulent, but if one examines them closely it will be found that they are completely rolled into a hollow cylinder with the edges meeting along what looks like a white line down the middle of the leaf, and that the inrolled surface is the lower surface, the one that has the stomata. Strictly speaking, the leaves are not actually rolled; the hollowing of the under side does not result from a simple rolling back of the upper side of the leaf, but develops as a secondary groove or furrow on the lower side. In bell heather the leaf is completely rolled downwards, a thin seam marking the line where the two edges join; in cross-leaved heath however, the edges are not so close, but the gap is screened by a curtain of hairs.

In heather, the leaf-rolling strategy is taken a step further. Each leaf is completely revolute, leaving only a very narrow suture where the edges join. But in this case the leaves are arranged in four overlapping rows along the stem; each leaf is V-shaped in cross-section, so that the four rows can dovetail neatly together. The tile-like arrangement

(a)

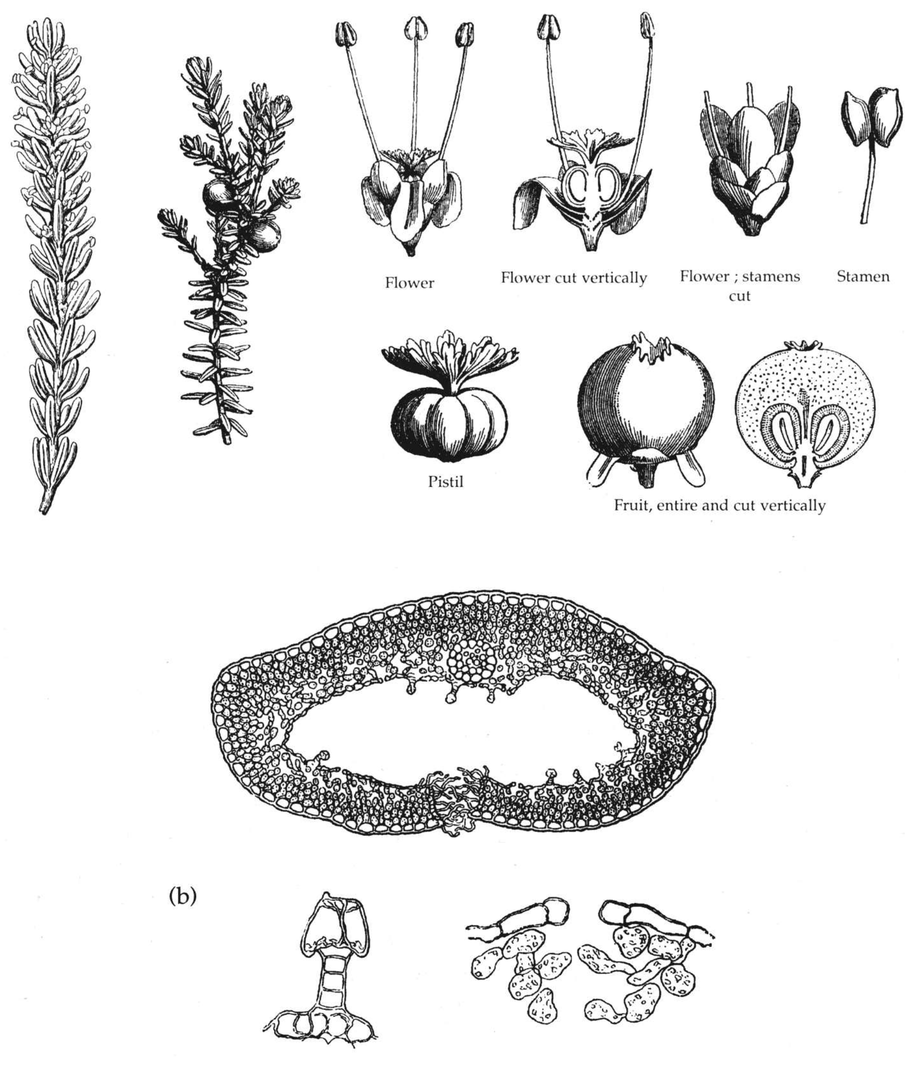


Figure 6.7: (a) Part of crowberry shoot (one in flower and one in fruit), with details of flower and fruit magnified. (b) Cross-section of crowberry leaf, showing the rolled-up form. The lower figures show one of the peculiar hairs on the enclosed under side of the leaf, and one of the stomata. The stomata are also confined to the enclosed under surface. [From Miall (1896); fruiting plant and detailed drawings from Le Maout and Decaisne (1876)].

allows the keel of each leaf to nestle snugly into the hollow of the leaf below, covering and further protecting the narrow slit along the keel. The leaves tighten up in very dry conditions, so that the leaf seam is protected within the sheltering valley of the leaf below. This superb adaptive strategy means that of all bog plants (with the possible exception of bracken, whose deep-seated rhizomes extend as much as half a metre down into the peat), heather is probably the least susceptible to the effects of physiological drought.

But surely the last thing plants growing on the bog are likely to run short of is that one resource that is in endless supply on the bog: water? This of course is true, but drought and excessive transpiration can occur under conditions other than the heat of summer. Low temperatures with wind produce the same effect, because the cold slows down water absorption by roots in the soil – and eventually stops it altogether, and of course wind accelerates evaporation. And to make things worse, little water can be held in the tissues of the plant because if it freezes it can kill the cells: which is why heather and other bog plants are so dry, transmitting very little water through their conducting systems. So efficiently do these contrivances work for our bog plants that their distribution extends far to the north: heather, bog rosemary, cranberry, bilberry and cowberry to beyond the Arctic Circle, while cross-leaved heath and bell heather reach close up to it.

Many of these plants are also evergreen. The reason for this is perhaps that even in summer the temperature around the roots is low, and water may not be all that abundantly available for photosynthesis. So in order to compensate for their low carbohydrate output at the time of year ordinary plants are engaged in rapid photosynthesis, they keep the factory open for longer hours, as it were, to compensate for their low output.

Bilberry seems to be something of an exception. Its close relations, cranberry and cowberry, are both in the front row of obvious xerophytic bog plants, but bilberry looks very different. On the other hand, bilberry is not a true bog plant: it only occurs where the peat is better drained. It has relatively large, thin-textured leaves, which are usually shed in winter (except in sheltered places), but it also has green stems, and continues to photosynthesise during the winter. Then when spring comes again, it produces a luxuriant cover of green leaves that enable it to overshadow the competition.

Over the last 50 years or so a different sort of explanation for the xeromorphic character of heather and its relatives on bogs has come to be preferred. This suggests that xeromorphism in bog plants is not due to physiological drought, but is a result of nutrient deficiency: an adaptation to the limited supply of nitrogen and phosphorus. But if nutrient deficiency is a factor, it is likely to be so in relation to physiological drought.

Partnership strategies 2: nitrogen-fixing bacteria

Although plants are washed by a veritable ocean of nitrogen in the air of the atmosphere and soil, nearly all of it is in molecular form (N_2), which plants simply cannot use. It has to be part of an organic or inorganic compound first. 'Fixing' nitrogen means binding it chemically in compound form. Among living organisms, the only creatures that have the capacity to fix atmospheric nitrogen are certain groups of bacteria: those possessing the critical nitrogenase enzyme that brings it about. These bacteria live in close symbiosis with various plants, dwelling in special nodules in the roots. Fixing nitrogen is a very costly process in energy terms, and this energy is provided by the host plant in the form of carbohydrate; in return the plant is supplied with organic nitrogen.

The best-known nitrogen-fixing bacteria are the *Rhizobium* species that live in the root nodules of members of the legume family (Fabaceae); these belong to the phylum Gracilicutes. Not many leguminous plants live in bogs however; furze is the outstanding example.

Bacterial microsymbionts of a different kind are found in the roots of bog myrtle and alder. Bog myrtle is a deciduous bushy shrub that grows a metre or so high in the mesotrophic conditions of bog margins, areas of old cutaway and acid fens. The plant is at its most striking around May, when the bush is covered in golden catkins. The leaves have a wonderfully fragrant scent that is produced in the glistening, golden bead-like glands that cover them; the flowers and fruit are also resinous. Much of the nitrogen present in the leaves during the growing season is salvaged before the leaves are shed in late autumn, and stored over the winter in the rhizomes. Alder is not a bog plant as such; its preferred habitats are the shores of lakes and the banks of rivers, and in swampy woods. It does occur in fens and acid marshes however, where it frequently forms small woods and groves. These woods and groves are known as alder carr.

The microsymbionts in bog myrtle and alder are filamentous bacteria assigned to the genus *Frankia* in the phylum Actinobacteria. Nitrogen fixation requires plenty of oxygen as well as carbohydrate. This is not a problem for the *Rhizobium* bacteria, whose partners generally live in well-aerated soils, but bog myrtle and alder live in waterlogged situations, so they need to assist the bacteria in getting access to oxygen. The Actinobacteria resident in bog myrtle are more tolerant of the acid conditions of bogs than the aerobic *Rhizobium* bacteria of furze and its relatives. Associations between actinobacteria and their hosts are described as actinorhiza (to parallel the term mycorrhiza that refers to comparable fungal associations). Actinobacteria are not known to be associated with birch (which is closely related to alder – they belong to the same plant family), but it is an intriguing fact that infective particles of *Frankia* are more abundant in soils under birch than under alder. Birch, of course, forms many mycorrhizal associations: but then, so too does alder.

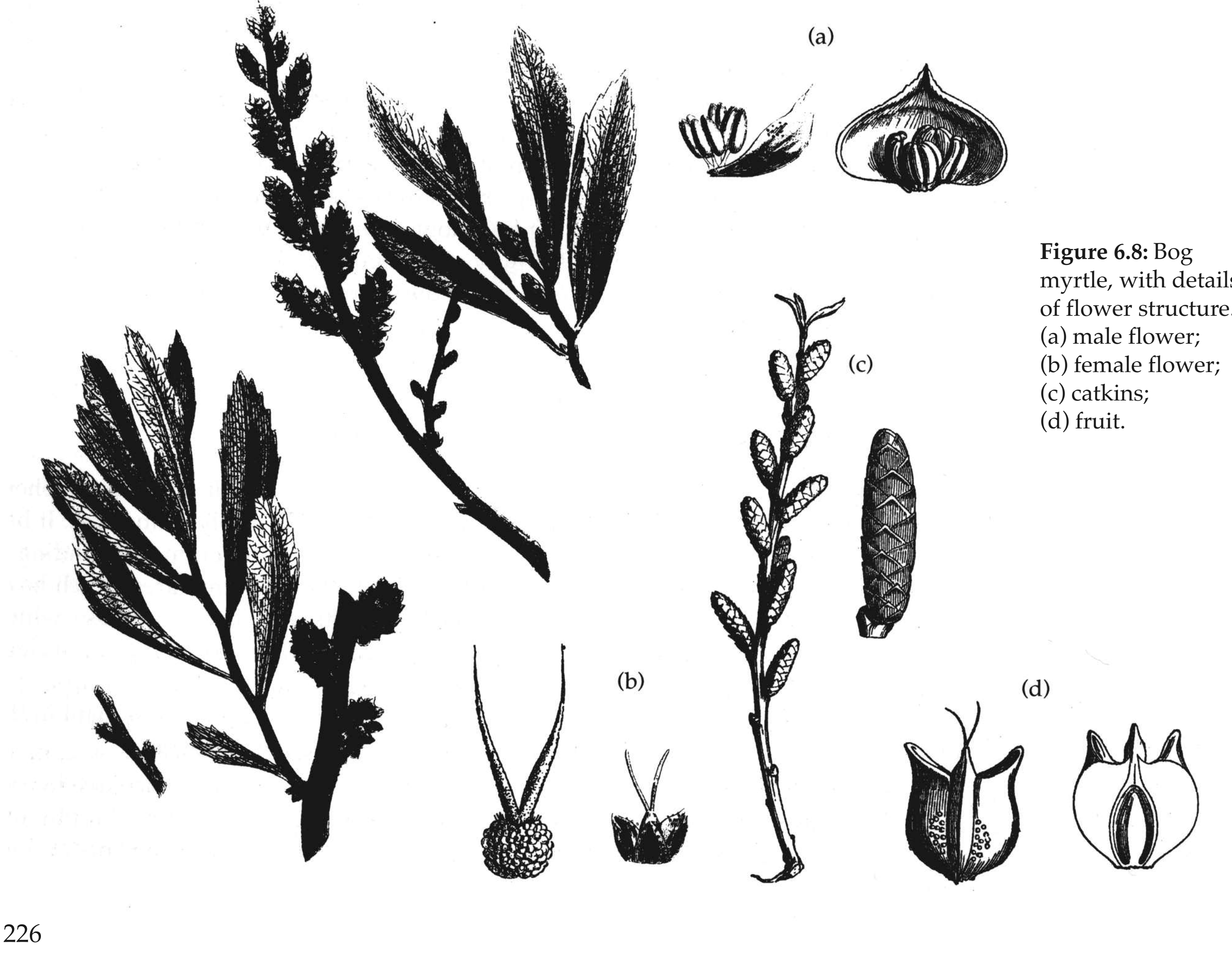


Figure 6.8: Bog myrtle, with details of flower structure. (a) male flower; (b) female flower; (c) catkins; (d) fruit.

More xeromorphic strategies: the abandonment of leaves

The purpose of the revolute and imbricate structures of the Ericaceae and Empetraceae is to reduce the total leaf surface exposed to the air. Another solution would be to dispose of leaves altogether, and transfer their function to the stems; in dry deserts the most familiar plants to have adopted this approach are the cacti. Many of the plants associated with the wet, cold margins of the bog have adopted the same solution. Furze is the most obvious example, but the same strategy has been developed by two other groups, the rushes and some of the sedges, in many of which specialised green stems have taken over the photosynthetic activity of the plant from the leaves, which are often narrow and reduced or altogether absent.

Furze

Ireland has two species of furze: common furze that occurs almost everywhere: and western furze, which is largely confined to the southern half of the country and parts of the west and north-east. Western furze is smaller, hardier, and more strongly calcifuge than its more common relative. It seldom grows more than half a metre above ground, extends further up the slopes of mountains, and is especially characteristic of thin peaty soils. In the northern-most third of the country the name furze is replaced by *whin;* the English name *gorse* is not often used in rural Ireland.

Furze is more typically associated with heathland, but in spring flowering furze bushes form a golden aureole around every bog. The spines with which furze has replaced its leaves have a dual purpose; they are essentially a xeromorphic strategy, but they also provide an effective defence against large browsing animals. However, the thorns are soft at first, and under certain conditions rabbits can keep the plant grazed to a few inches above the ground. But the thorns are no defence against the many insects that feed on their nourishing tissues – beetles, bugs, caterpillars and other small creatures, which can manoeuvre freely between the thorns. Some insects are welcomed and indeed specially catered for. Apart from the bees that pollinate the glorious flowers, furze must be registered among the select group of plants that merit the impressive adjective *myrmecochorous,* which means that their seeds are especially adapted for dispersal by ants. To begin with, the seeds are dispersed mechanically, by the explosive opening of the pods in the sun: common furze in summer, dwarf furze in the spring. Most of these seeds will end up on the bare ground under the plant, where they have no chance of success in life. But attached to each seed is a bright orange appendage called an *elaiosome,* which is rich in oil. These structures are especially characteristic of seeds adapted for dispersal by ants, which haul them back to their nests to harvest this oil supply. Many a seed will be lost on these hazardous journeys, some in habitats favourable for germination. It has been suggested that the lines of furze bushes that can sometimes be seen running across mountain or heath mark the route of a major ant thoroughfare. However, it has to be said that the ants of bogland are all *diffuse* foragers: which means they do not have permanent pathways to and from their nests, and none of them has a reputation for collecting special seeds. Perhaps the elaiosomes are an adaptation for dispersal by ants in the southern part of the plant's range, in Spain and Portugal, where some of the harvesting ants live.

Figure 6.9: Furze seedling, showing the hairy trifoliate leaves.

Furze does not possess its spiny defensive armour when it is young. To begin with, it has ordinary leaves reminiscent of less belligerent members of its important family (Fabaceae) [**Figure 6.9**]; it soon adopts the spiny armour of maturity however, and its success is due in no small measure to these spines. But what is equally important is that, like all the members of its family, its roots bear nodules which contain nitrogen-fixing bacteria, so that it has no difficulty obtaining all the nitrogen it needs in spite of the low-low nutrient status of the peat.

Apart from its great botanical interest, furze once played a very considerable part in the self-sufficient economy of rural Ireland. Today it is seen by everybody as a troublesome nuisance, difficult to eradicate, but it was regarded very differently in the past; there are few plants in the Irish flora that were put to such a variety of uses. One indication of this is the fact that in one of the few parts of the country where the common furze does not occur naturally (in Bangor Erris in Mayo and west Galway for instance) it was introduced for fencing and fodder by improving landlords in the early part of the 19th century. Although we know that furze was valued by farmers in Celtic times, we know little about how it was used in those early days. We know much more about its importance in the new farm economy that replaced the Gaelic order throughout Ireland after the 16th century. An early indication of its value appears in a note in the mid-17th century Down Survey referring to Newcastle and Uppercross baronies in County Dublin:

> The Quality of the Soil is generally very good Arable Meadow and Pasture with underwood and Furz which Furz yield as much profitt as the Arable Land.

Note that furze is used here as a plural word, as it often was – and indeed still is. Furze was widely planted for fencing, either as seed or cuttings. In many areas it was the principal or only hedge plant, especially perhaps in boggy areas where whitethorn and other hedge thorn plants would not grow well. It was even planted as a crop sometimes, especially in the southern half of the country, where furze *brakes* or meadows were cut by scythe and provided excellent winter feeding for animals. The brakes were cut when the furze was about half a metre high, and it was used mainly for feeding horses. Whether it was planted specially or not, furze was cut and chopped or pounded as horse feed all over Ireland; special furze-bruising machines were developed in the 18th and 19th centuries. Between the 16th and 18th centuries, tithes were levied on furze in certain parts of the country just as they were on other agricultural produce.

Furze was commonly used as fuel in most parts of rural Ireland between the 15th and 19th centuries, especially for kindling and in ovens for baking bread, and more particularly where turf was in short supply. It was occasionally used in other ways as well: as animal bedding, later to be used as manure, in the making of animal and even human shelters, for drains and the foundations of roads and corn stacks, for cleaning chimneys and making dye, for walking sticks – and even hurleys. It played a part in rural custom and belief as well, occasionally featuring alongside whitethorn in the celebrations of May Day, for making the fires of mid-summer and other festivals, and as a wren bush on St Stephen's Day.

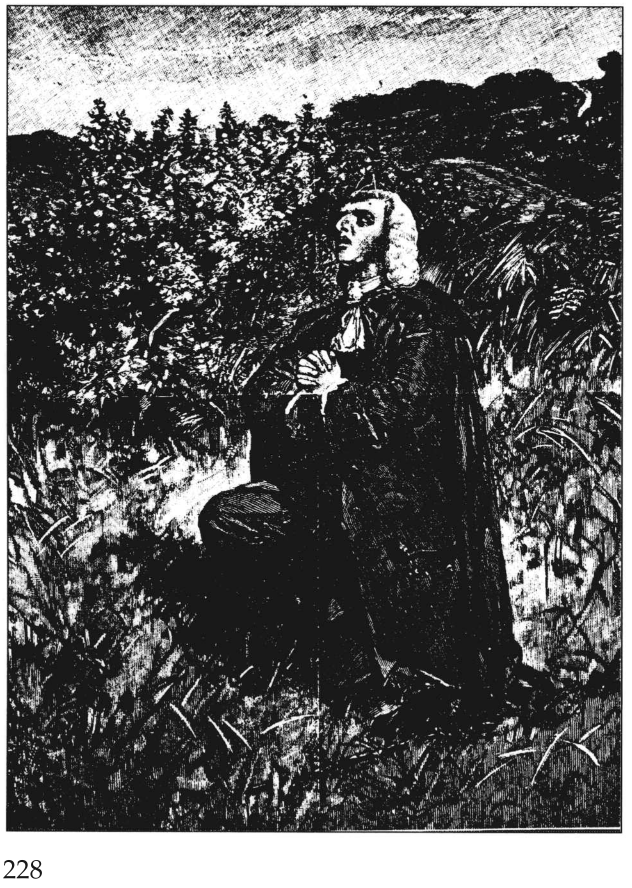


Figure 6.10: *Old print of Linnaeus all his knees among flowering furze.*

The story of Linnaeus falling to his knees when he saw furze in blossom for the first time during his brief visit to England in 1736 may be apocryphal, but it deeply impressed the imprisoned Oscar Wilde: 'I tremble with pleasure when I think that on the very day of my leaving prison both the laburnum and the lilac will be blooming in the gardens, and that I shall see the wind stir into restless beauty the swaying gold of the one, and make the other toss the pale purple of its plumes so that all the air shall be Arabia for me. Linnaeus fell on his knees and wept for joy when he saw for the first time the long heath of some English upland made yellow with the tawny aromatic blossoms of the common furze; and I know that for me, to whom flowers are part of desire, there are tears waiting in the petals of some rose'. (*De Profundis*, p.207, Penguin Edition).

Few plants are more interesting or more beautiful, or taken so much for granted. We no longer have the ability to see furze through the eyes of those who are less familiar with it. There is a legend that recounts how, when Linnaeus visited England in 1736 and saw furze in riotous flower for the first time, he fell to his knees in wonder [**Figure 6.10**]. Most of us have moved a long way from such simple amazement at the beauty of the world.

The insectivorous strategy

The sundews

Sundews (family Droseraceae) occur throughout the world, almost invariably growing in poor, acid soils – though some Australian species inhabit much drier situations. About 90 species are known, and they vary greatly in size and form. The leaves of some are nearly half a metre long, and some have flowers that are over 5cm in diameter.

The leaves of sundews are covered with tentacles – around 200 per leaf in the common sundew – each with a little knob-like gland at the end, making them look ‘all whiskery like a bee’s leg’ as a Connemara man once described them to Praeger. These tentacles secrete an extremely viscid glue that glistens like dew in the sun, and turns the leaf into a very efficient fly trap. There seems to be some evidence that insects are attracted not just by the colour and glistening appearance of the leaves, but possibly also by scent. When an insect alights on the leaf, the closest tentacles bend towards the centre, gradually followed by those further away. Entrapment by the tentacles is assisted by a folding movement of the leaf blade itself. Small insects are the usual prey, but creatures as large as dragonflies are sometimes captured. The smaller creatures may be killed in as little as a quarter of an hour, because the sticky secretion blocks their tracheae. The tentacle glands also secrete a range of enzymes that dissolve all but the chitinous skeleton of the victim. They are also largely responsible for absorbing the resulting fluid, a task at which they are probably assisted by microscopic hairs scattered over the surface of the leaf.

The process of digestion usually takes several hours, depending partly on how much protein the digestive enzymes have to break down. When the job is done the leaves open out again and secretion slows down so that the leaves can dry out. This means that hard parts like the chitinous skeleton can be blown away before the leaf starts to secrete its deceptive dew again. The sundews depend almost completely on their leaves to supply them with nutrients, so their roots are reduced

(a)

(b)

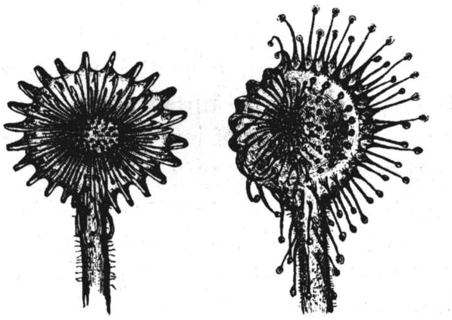


Figure 6.11: Sundews. (a) Great sundew; (b) Leaf of round-leaved sundew (magnified). The leaf on the left has all its tentacles closely inflected; that on the right has the tentacles on one side inflected over a bit of meat placed (by Charles Darwin) on the disc. [(b) from Darwin (1875)].

to two or three short branches not much more than 2-3cm long, which are covered with hairs whose main function is to absorb water. In autumn sundews die back to a tight green winter resting bud or *hibernaculum,* which is anchored in place by the roots (which have died by this time), awaiting the return of spring.

Three species of sundews are found in Ireland's bogs: the round-leaved or common sundew, the great or long-leaved sundew, and the oblong-leaved or intermediate sundew. All three can be found together in some bogs, sometimes in great profusion: but they occupy quite distinct habitats, in spite of their overall similarity. The commonest species is the round-leaved sundew that commonly grows among sphagnum. It is very versatile however, and can occur in great abundance on bare peat, even in very disturbed situations, its little leaf-rosettes held more or less flat against the ground. Great sundew is less common, but more conspicuous because of its long, upright leaves. It usually grows in situations where the water table is at or almost at the surface, so it favours old bog drains and bogholes, where the massed ranks of long bright red leaves often make a splendid sight. The intermediate sundew is smaller but has somewhat similar lanceolate leaves, about 3-10cm long; those of the great sundew are 7-15cm long. Another difference between the two species is that in the intermediate sundew the leaf blade is distinct from its stalk. Unlike the other two species, the flower stems arise from the side rather the centre of the rosette, and the tentacles are dark crimson instead of bright red. It inhabits peaty puddles on the bog surface, or peat over which water continuously seeps, and is especially characteristic of blanket bogs and disturbed situations on raised bogs.

Butterworts

The prey-trapping strategy of the butterworts is akin to the old-fashioned flypaper technique. Butterworts are fibrous-rooted perennials that belong to the family Lentibulariaceae. They have rosettes of yellowish-green leaves that are curled up at the edges and and give off a faint fungus-like scent. The leaves are covered with tiny, stalked glands that secrete a glue so viscid that it can be drawn out into threads nearly half a metre long. These stalked glands are responsible for the greasy sheen of the leaves. The digestive fluid is produced by different, unstalked glands, still more numerous than the stalked glands. These are sunk in shallow pits in the surface, and are so tiny they are difficult to see; they are also responsible for absorption. Between the two kinds, there are some 25,000 glands to the square centimetre. In the butterworts only the margins of the leaves move, curling slowly over small insects and other creatures trapped near the edge. Prey that is trapped near the centre is digested there, but the incurved edges help to prevent it from being washed off the leaf by the rain. It may also prevent the little pools of secretion produced by the glands from spilling over the edge. Like the sundews, butterworts have very small roots covered with absorbent hairs. In earlier times butterwort leaves were sometimes used in place of rennet to curdle milk for cheese making. This practice was widespread in Scandinavia and Lapland, so it may have been the Vikings who introduced it to Ireland.

There are 48 known species of butterworts, three of which are found in Ireland. The most widespread by far is the violet-flowered common butterwort (Irish *mothán*), which grows on a variety of wet soils, both acid and alkaline, across its wide range, which extends right across the Northern Hemisphere. In Ireland it is found mainly in fens and heaths and on bare surfaces in wet cutover areas, mainly in the west, north and centre. It produces rosettes of pale green leaves 3.5-15.5cm across, and each rosette gives rise to two or three flower stalks (scapes). It is a plant that occurs fairly widely in Europe and Siberia, much of Canada and the U.S. The large-flowered butterwort or bog violet is found in similar habitats to the common species, but is confined to the south-west, occurring in extraordinary profusion over wide areas on bog, wet rocks and damp pastures in West Cork and Kerry. Outside Ireland it is found only in France, Spain and Switzerland.

Reginald William Scully wrote enthusiastically of it in his *Flora of County Kerry:*

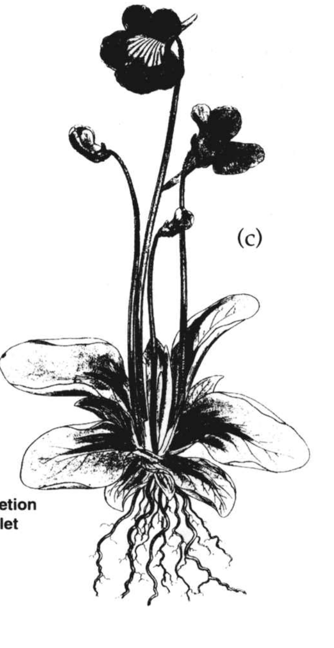
> No one who has seen its groups of deep violet flowers – sometimes over an inch in diameter – on the black dripping rocks of Connor Hill, or on the boggy roadsides between Killarney and Kenmare, will deny its claim to be considered the most beautiful member of the Irish flora.

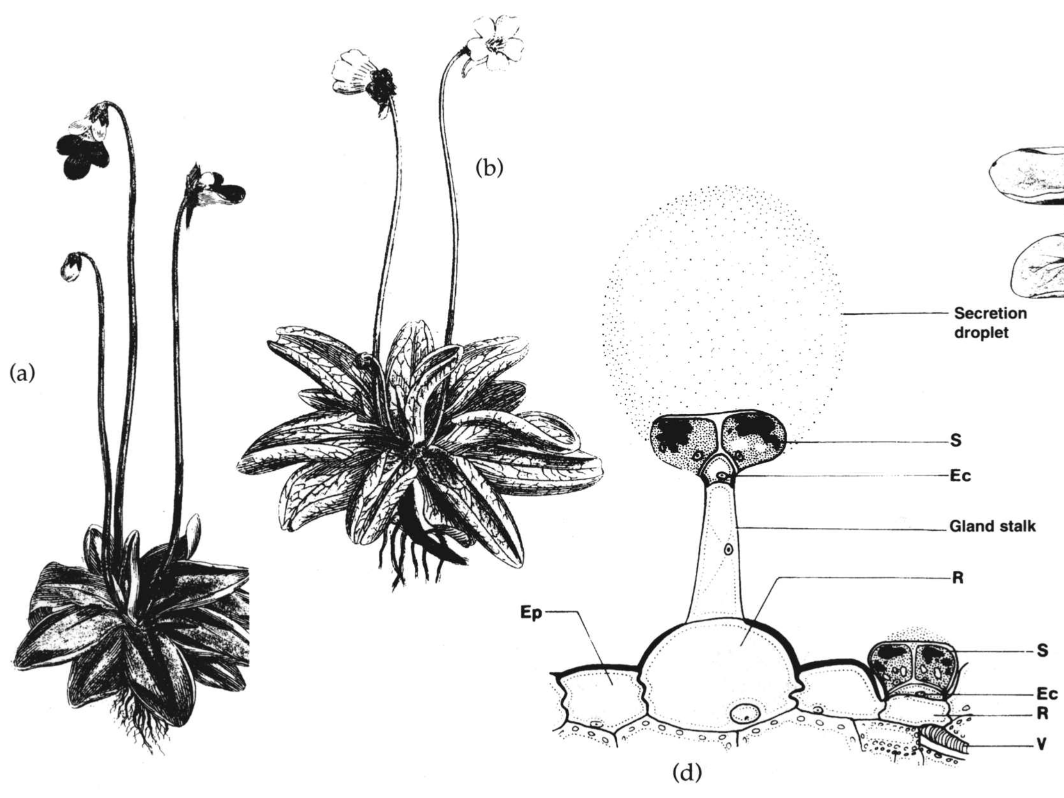
The leaves are somewhat larger than the common species (up to 6.5 x 2.5cm): but the lovely violet flowers are much larger – up to 2.5cm across, on 15-20cm stalks. The lobes of the corolla are broad and overlapping, and have wavy margins, which distinguishes the flowers from the larger-than-usual common butterworts that are sometimes found.

The third species is the pale butterwort, which grows in North Africa, Spain, France, Portugal, SW England, W. Scotland and Ireland; it is much more common in Ireland than in Britain. It is very much smaller than the others, and harder to find: but it is also more truly a bog plant than the other butterworts, because it penetrates more deeply into the bog itself. It rarely occurs in numbers, and is usually found growing deep down between the heather and moss clumps. It is a lovely plant; the leaf rosettes are only about 1-2cm across and are somewhat grey-green in colour, with a pinkish hue when they grow in sunny places; the leaves are almost transparent, with thin red veins, the margins almost completely rolled over. The trumpet-like flowers are a mauve-pink or pale lilac colour, with a yellow throat.

Like the sundews, Irish species of butterworts form tight winter resting buds (hibernacula) before the rest of the plant (including the roots) dies back; the only one of the Irish species that does not do so is the pale butterwort. *Gemmae* – which are tiny reproductive buds formed in the axils of the leaves are also produced. These are like miniature hibernacula, and are an important means of increasing the size of a colony in the immediate vicinity of the parent.

Figure 6.12: Butterworts. (a) Common butterwort; (b) pale butterwort; (c) large-flowered butterwort. (d) The stalked and sessile glands of common butterwort. The adjoining epidermal cells (Ep) have thicker cuticles than those of the secretory cells of the gland heads. S, secretory glands; Ec, endodermoid cell; R, reservoir cell; V, vessel communicating with general vascular system of the leaf. (Diagram and caption from Juniper *et al.*, 1989).





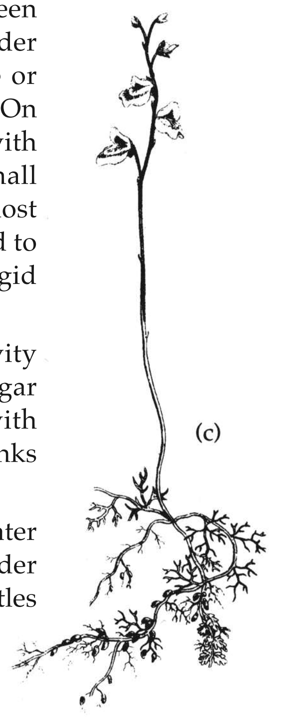
Bladderworts

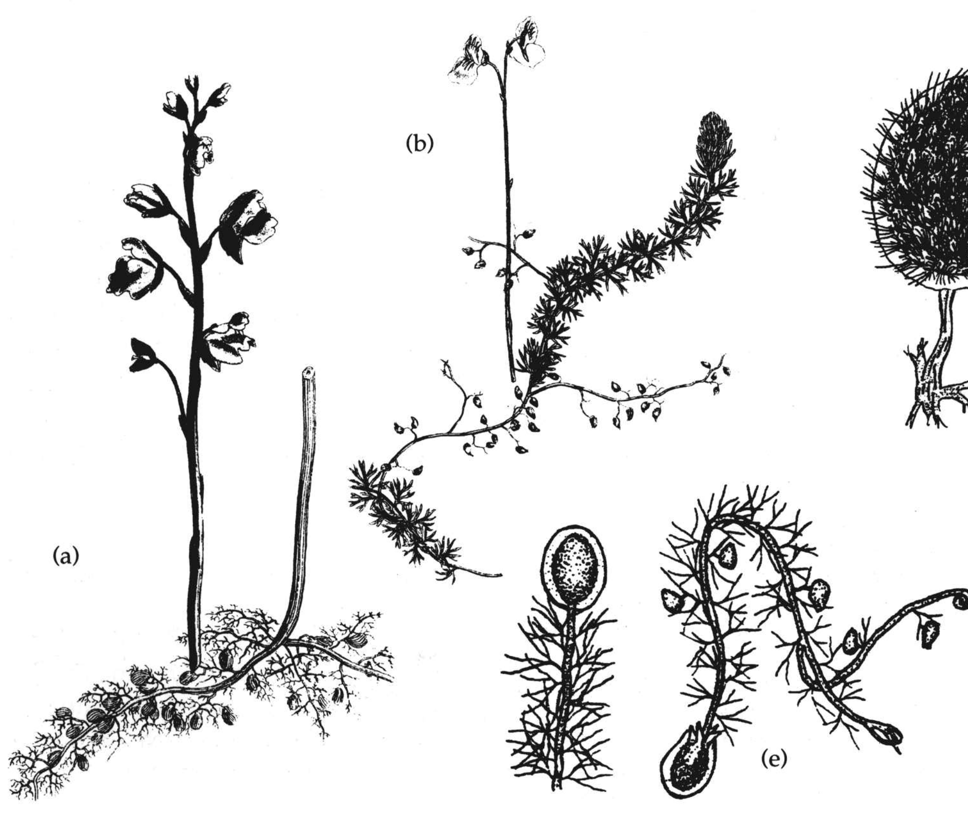
The third group of insectivorous plants that grow on bogs is the bladderworts, of which four species occur in Ireland, growing in bogholes and drains, pools, ditches and on the margins of still lakes. As in the case of the other genera of bog plants, the Irish contingent gives us little idea of the versatility of the group. There are some 250 species worldwide, mostly in the tropics, and although they are all unmistakeably bladderworts, they exhibit an astonishing variety.

The four Irish species are submerged aquatic plants. They are perennials, although they have no roots. The plant consists of a network of branching hair-like leaves on which the tiny bladders – which are actually highly modified leaves – are produced. These bladders are the most fascinating part of the plant: indeed, they are among the most intricate structures found anywhere in the plant kingdom. They are a translucent green colour, with walls only two cells thick. At the end furthest from the stalk each bladder has an opening that is normally closed off by an almost transparent one-way flap or curtain (valve). This is flanked by two long 'antennae', each bearing several bristles. On either side of the entrance a number of long bristles project outwards. These, along with those on the antennae, are arranged in a cone-like fashion, and serve to direct small animals foraging in the vicinity towards the entrance to the bladder. The valve is almost transparent, and is very flexible; it slopes into the cavity of the bladder and is attached to it except along the lower margin, where the free end fits snugly into a thick and rigid collar. This arrangement ensures that it can only open inwards.

The surface of the valve and of the bladder in the vicinity of the conical cavity outside the entrance is abundantly lined with glands that produce mucilage and sugar that serve to attract prey to the trap. The inside of the collar is thickly covered with delicate *bifid* processes, and the rest of the inner surface of the bladder is covered by ranks of four-spined H-shaped structures called *quadrifid* processes.

The prey consists mainly of entomostracan crustacea, small insect larvae, freshwater worms and other minute creatures. They are guided towards the entrance to the bladder by the cone-like arrangement of the bristles outside. When the creature touches the bristles





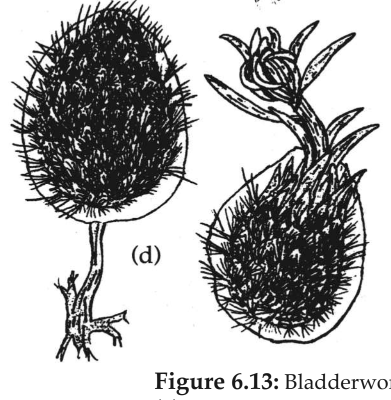
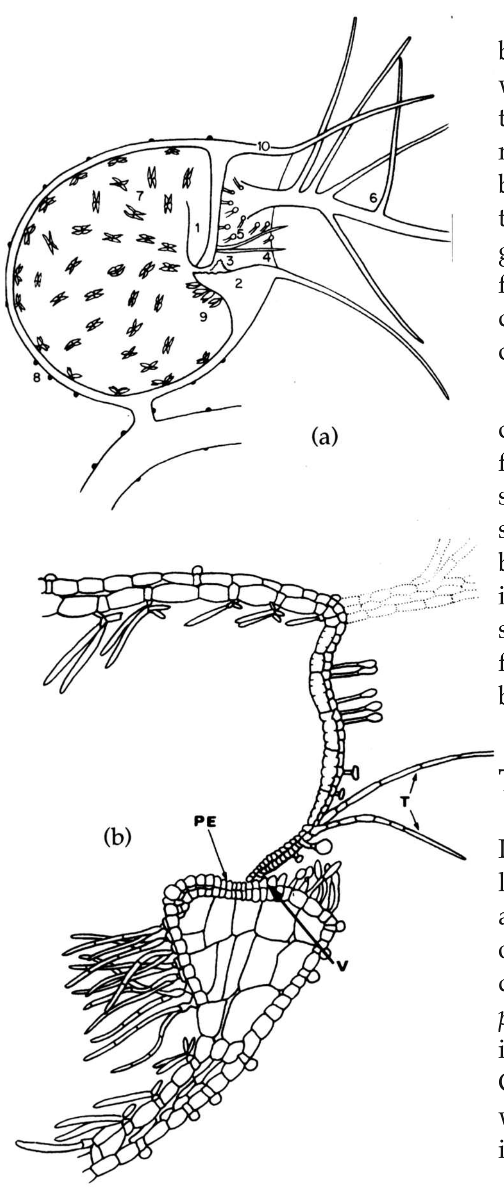


Figure 6.13: Bladderworts.
(a) Great bladderwort.
(b) Intermediate bladderwort.
(c) Lesser bladderwort.
(d) Turion of bladderwort: on the left in winter and on the right after it has germinated in spring; notice the first bladders.
(e) Turion at higher magnification: on the left in autumn, showing its spiny scales; on the right just after it has started growth at the end of winter.

on the surface of the valve, it opens and the walls of the bladder are triggered so as to suddenly distend by as much as 80 per cent of its volume, sucking water into the bladder, along with the hapless creature that triggered the response; all this happens in 10-15 thousandths of a second. Once it is inside there is no way out for the prey. The incarcerated creatures may live for some time, but eventually they run out of oxygen, and are digested by enzymes and acid secreted by the four-armed glands. These glands are involved in pumping water out of the bladder, and in the absorption of the products of decomposition after decay. The two-armed glands probably share this task, but they may also serve to keep prisoners away from the entrance, where they might disturb the trap's delicate balance. The trap is ready for action again between half an hour and two hours after it has been sprung.



Late in summer the leaf network dies back, and the plant begins to form special perennating winter buds called *turions,* into which the plant moves all its reserves before sinking to the mud on the bottom; a turion is a detachable winter bud by means of which many plants – mainly aquatic – perennate. In spring the turions become detached from old decaying plants and float up to give rise to new plants. Each turion is like a tightly clenched fistful of tiny green leaves; it is, in fact, a much abbreviated shoot around which forked, flat leaves quite different from the normal plant cluster densely; the outer shell of leaves is protective, brownish in colour, in contrast to the bright green inside.

There are four Irish species. The two most frequent are common bladderwort and greater bladderwort, both of which favour deeper bog water, whereas lesser bladderwort occurs in very shallow water, and can grow even on bare soaked peat. It is seldom seen in flower. Intermediate bladderwort is the rarest of the four, but is still much more abundant in Ireland than in Britain. It grows in bog pools with a muddy bottom; the bladders are borne on separate branches from the leaves, and they grow down and burrow freely in the peaty mud, anchoring the plant. Like lesser bladderwort, it seldom flowers.

The pitcherplants

In pitcherplants, which belong to the family Sarraceniaceae, the leaves are folded to form funnel-shaped tubes that are magnificently adapted to function as pitfall traps for insects. Of the eight species of *Sarracenia* in its native North America, the most widely distributed is the huntsman's cap or purple pitcherplant *Sarracenia purpurea,* var. *purpurea,* which extends all the way from New Jersey in the south up the eastern coastal plain of the United States into Canada and on as far as the Northwest Territory, where it survives winter temperatures as low as -20°C. It is also the species that inhabits the wettest areas.

Figure 6.14: (a) A schematic transverse section through the trap of bladderwort.
(1) door; (2) pavement epithelium; (3) velum; (4) trigger hairs; (5) stalked mucilage glands; (6) antennae; (7) inner chamber with quadrifid glands; (8) spherical sessile glands; (9) bifid glands; (10) rostrum. (From Juniper *et al.*, 1989).
(b) Detail of the trap entrance. Note the mixture of long and short-stalked trichomes on the outer face of the door-flap. Only two of the trigger bristles (T) are shown in this section. The pavement epithelium (PE) secretes mucilage to achieve, along with the velum (V) a sealing of the lower edge of the trapdoor. Note that the outer layer cells of the two-celled walls of the bladder are smaller than those of the inner layer. Both exposed surfaces are cutinized and both contain chloroplasts. Bifid hairs occur only on the inner face of the threshold. Lloyd (1942) suggested that these may serve to discourage entrapped and creeping prey from reaching the threshold. The two distinct layers of the door are shown, the inner capable of rapid expansion and contraction, the outer more or less rigid. (Diagram and caption from Juniper *et al.*, 1989).

Pitcherplant has curved jug-shaped leaves which look rather like drinking horns [**Plate 4**]. The upper zone of the jug is covered with nectar glands interspersed with short, sharp, downward pointing hairs, and the brightly coloured veins on the jugs guide insect visitors to the nectar. The hood does not cover the jug as it does in many other pitcherplants, with the result that rain collects inside. Insects are attracted to the leaves by abundant nectar secreted around the opening. They lose their footing on the waxy, slippery leaf surface in this region, and once they fall into the water at the bottom they have little chance of escape, particularly since the plant secretes a wetting agent that deprives them of buoyancy.

In the year 1906, Benjamin St George Lefroy introduced specimens of the pitcherplant to a number of raised bogs in Roscommon and Westmeath. In some of these bogs the plants established themselves successfully, and in 1930 three of the Westmeath plants were transplanted by Dr Keith Lamb to the wettest part of Woodfield Bog in County Offaly, where they have established a large colony that is still expanding. Around 1960 some plants and seeds from Ireland were introduced to a bog in Northern England, where they are thriving. Specimens of cobra lily, which is closely related to the pitcherplant, were also introduced into Woodfield Bog by Dr Lamb, but – although still there – it has not enjoyed the success of the latter species.

Pollination in insectivorous plants

The three genera of insectivorous plants native to Ireland are at the limit of their ranges in this corner of Europe. Their flowers are adapted for pollination by insects, but the insects to which they are particularly adapted are not always to hand. In more southerly parts of Europe, common butterwort is pollinated by bees, for which its flowers are specially adapted, but with us it is apparently always self-pollinated, as is pale butterwort.

As is often the case with flowers, those of the bladderwort are too small for their beauty and the elegance of their structure to be appreciated with the unaided eye. The two-lipped corolla is bright yellow; the upper lip acts as a hood or roof, and the anthers and carpels are firmly attached to its underside. The lower lip is larger and somewhat inflated, and projects forward to form a landing place for pollinating bees and such hoverflies as can effect an entrance [**Plate 3**].

The lower lip presses against the upper in such a way that only the weight of heavier insects will depress it. There is a raised platform or palate towards the back, leading up to the narrow entrance between the two lips, which gives access to the broad conical spur at the base of the corolla tube. The palate is streaked with crimson honey guides. When a bee lands on the end of the lower lip, its weight causes it to sag suddenly, and as the visitor clambers up onto the platform, its back comes in contact with the stigma. This touch stimulates the two lobes to fold together and lie against the corolla. The visitor next comes in contact with the anthers behind the stigma. The flowers are produced in few-flowered racemes on stalks that project above the surface of the water. When the flowering shoot is being produced, the stem branches in such a way as to provide the scape with a platform to prevent it capsising. Slight differences in floral structure are among the main distinctions between the Irish species, but little is known of their floral biology or the functional meaning of these differences.

The beautiful star-like flowers of the sundews open only in bright sunshine, but they shine in vain, because they too are usually self-pollinated in this country, and indeed are often *cleistogamous,* i.e. they produce special reduced flowers that never open, but in which self-pollination takes place.

The nodding purple flowers of pitcherplant are much larger, more elaborate and showy than those of the native insectivorous plants. They have five petal-like sepals inside which are the five larger true petals. These overhang the pistil, which looks just like an inverted umbrella and is ingeniously contrived to ensure cross-pollination by the bees which are its main pollinators.

Grasses, sedges and rushes of bogland

Grasses, sedges and rushes are three of the most widespread and successful groups of flowering plants. Few grasses play a prominent role in bogland ecology, but sedges are very important. The sedge family is cosmopolitan, and is especially prominent in the ecology of wet places: indeed, they are sometimes viewed as a wetland ecological counterpart of the grasses. The family contains over 3,000 species in 100 genera worldwide, of which over 70 species occur in Ireland.

Several of these genera contain species which are among the most prominent bogland plants. Among the features to which they owe this success are their tough, xerophytic leaves and their perennial, rhizomatous habit. Many species have a densely tufted habit; the most important of these tussock formers include black bog-rush, hare's-tail cottongrass, deergrass, and to a lesser extent white beak-sedge. Others extend their territory by creeping; creeping rhizomes are found in common cottongrass, brown beak-sedge, and a number of aquatic colonisers, as well as the several species that are important colonisers of cutover bog, such as carnation sedge.

Sedges (family Cyperaceae)

Cottongrasses

Bog cotton or cottongrass is one of the most familiar sedges of bogland. There are four species in Ireland, but only two are common on bogs. Common cottongrass has leaves that are V-shaped in section, and in autumn their russet colour adds to the general display of reds and browns which gave Irish bogs their older name of 'red bogs'. It has black, unbranched aerating roots that enable the plant to carry its exploration further than the anaerobic peat would otherwise allow. It likes areas of shallow water; old

Figure 6.15: The two most common cottongrass species. (a) common cottongrass; (b) hare's-tail cottongrass.

bogholes and silted-up drains are favourite habitats. Here the plant spreads rapidly by means of its extensive creeping rhizome system, producing individual shoots at strategic intervals. In undisturbed bogs it occupies a niche in the early pool stage of the regeneration cycle.

Common cottongrass has many flower heads to each stem, whereas the other widespread species, hare's-tail cottongrass, bears a single flower spike. The latter species occupies a quite different ecological niche. It is densely tufted, and in natural raised bogs it is a hummock builder. In burnt areas where fire has eliminated less tolerant rivals it often forms vast snowy 'meadows' when it is in fruit. The tussocks come about because of its growth habit: new vertical shoots grow through the extremely persistent mat of old leaf-bases and roots. These tufts are very long-lived – perhaps as much as a century sometimes. The living roots may make up only 2% of the total root mass, and where these persistent tufts occur in the peat itself they make the work of the turf-cutter very difficult. We have earlier noted the preference of hare's-tail cottongrass for nitrogen in free amino acid form. It has a pattern of sequential leaf development in which the nutrients present in an earlier leaf are later handed on to its successor. A third species, broad-leaved cottongrass, occurs frequently in fens and old cutover.

The generic name for cottongrasses, *Eriophorum,* comes from Greek, and means wool-bearing. The specific epithet in the Latin name for hare's-tail cottongrass *(vaginatum)* refers to the inflated leaf-sheath that protects the single flowering heads: *vagina* means a sheath in Latin. The epithets of the common and broad-leaved species *(angustifolium* and *latifolium)* mean narrow- and broad-leaved respectively.

Cottongrass can dominate extensive areas of blanket bog, sometimes to the complete exclusion of sphagnum, and the peat formed can be made up almost entirely of its remains. Periods when the bog surface dried out are often readily recognisable in the peat profile by a thick and extensive layer of hare's-tail cottongrass peat, usually underlying a new deposit of sphagnum peat recording the rejuvenation of the bog.

At the end of the last century, bog cotton was sometimes used instead of cotton wool for making surgical dressings. It was also mixed with sheep's wool or cotton in the manufacture of peat wool (75% bog cotton, 25% other material), which was apparently much used in some parts of northern Europe in the late 19th century in the manufacture of cloth, carpets and roofing felt. In some country areas, bog cotton was collected to stuff pillows or to make wicks for candles. However, unlike true cotton, cottongrass hairs lack tensile strength.

Beak-sedges

White beak-sedge is much less conspicuous than the sedges mentioned above, but is at least as important in lowland bog ecology. It has a tufted habit, and is characteristic of pool margins and wet hollows, and in the regeneration cycle is found at the stage where the pools have just disappeared and been replaced by a peaty surface soon to be colonised by hummock-forming sphagnum species. It relies for its propagation mainly on special attenuated shoots called bulbils or turions that are produced both at the base of the vegetative shoots and near the top of the haulm itself; in mid-winter these armies of new spear-like shoots are already poised and ready to lengthen at the earliest opportunity. They are an important component of the food of Greenland white-fronted geese and whooper swans, especially at the end of winter when food is scarce. Brown beak-sedge is also widespread and often abundant in bogs in the west and centre of the country; its rhizomes are far-creeping.

Figure 6.16: Other sedges of bogland: (a) Carnation sedge; (b) glaucous sedge; (c) flea sedge; (d) black bog-rush; (e) great fen-sedge; (f) white beak-sedge; (g) brown beak-sedge.

Deergrass

The dense tussocks of deergrass or deer sedge are a familiar and distinctive feature of bog vegetation. These tufts are composed of the massed, narrow green stems, true leaves being effectively absent. It is widespread on undisturbed raised bogs at the stage where hummock growth reaches above water level, and on the drier fringes of bogs from which turf is cut, where it often spreads rapidly after fire. On mountain bogs it is often very abundant, disputing dominance with cottongrass over wide areas. It is less important in the blanket bogs of the west, where purple moor-grass, black bog-rush and beak-sedges dominate the vegetation.

Black bog-rush

Black bog-rush is one of those plants where the stems have almost taken over the work of the leaves. It forms dense tussocks of packed dark green, cylindrical stems that may be half a metre high, and the leaves are very narrow and bristle like, grouped around the stem base and enclosed in shiny black or reddish-brown sheaths which make it easy to recognise when it occurs in fossil form in the peat itself. It is especially abundant in the blanket bogs of the west, which is surprising for a plant that in other areas of the country is characteristic of eutrophic fen and similar habitats. The anomaly is believed to be explained by the extra dose of minerals it receives in wind-borne salt spray from the sea. Black bog-rush was sometimes used for thatching in south-east Galway (and perhaps elsewhere).

In earlier times black bog-rush was known as 'the black keib' in the west, where it was regarded as an indicator of good grazing.

James Townsend Mackay's account of black bog-rush (published in 1806) is of considerable interest:

> Common on wet sides of mountains, county of Kerry, and very abundant on wet mountains in Cunnamara, county of Galway, where it is known by the name of *Black Keib.* In the months of January, February, and March, when it is yet young and tender, the black cattle feed on it, pulling it up by the roots, which are considered to be the most nourishing part of the plant. It is much esteemed by the graziers of that country, as it supports their cattle at a season when food is very scarce.
>
> It has been supposed by some people in the county of Kerry, with whom I conversed, that cattle are seized with a disorder called the gout, or cripple, from their eating the *Keib* in autumn; others have thought it was owing to their standing in the wet ground, where the *Keib* grows; which last is a more probable cause. I was, however, informed by the Rev. Mr. Russell at Claggen, Cunnamara, a gentleman who has paid particular attention to the above disease in cattle, that he has known them to take the cripple on dry mountains as well as on wet *Keib* mountains. The method of cure for the cripple is, to bring the cattle to the sea side, and make them lie on the dry sand. By this treatment they get rid of it in a few weeks.

Carex sedges

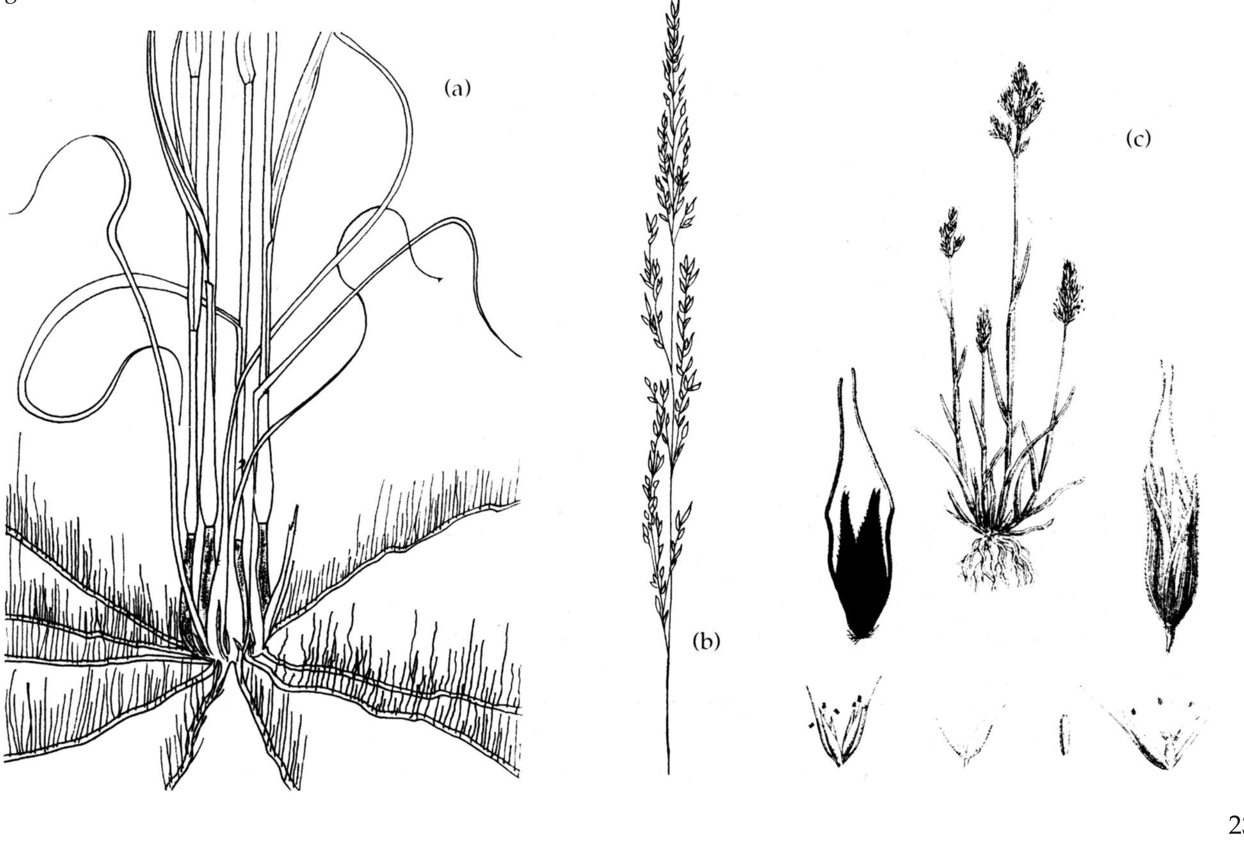
Carex is by far the largest and most successful genus of sedges; there are about 1,000 species worldwide. A number of the aquatic species are important in the colonisation of bogholes and drains, including bladder-sedge and bottle sedge (which is a coloniser of open acid water); these species have inflated utricles to assist in dispersal by water. The utricle is the little 'flask' which encloses the single ovary, from which the seed develops. Carnation sedge is especially prominent on areas of drained peat and cutover bog, where its shortly creeping rhizomes enable it to form extensive patches. Black sedge is another far-creeping species found in all areas of bog where there is some movement of water. Many varieties have been recorded, including one that is characteristic of bogs. Star sedge is a densely-tufted species that is invariably present in cutover areas. Bog sedge on the other hand is a species of very wet areas, especially at the edges of old bogholes and pools. Tall bog-sedge is very similar, but in Ireland is only found on the Garron plateau in Antrim. Flea sedge is a shortly-creeping, densely tufted species characteristic of calcareous mires and cutover; few-flowered sedge is very similar, but in Ireland also occurs only on the Garron plateau. White sedge occurs mainly in fens and cutover mainly in the north and east.

Two other sedges that can be important in bogs are great fen-sedge and many-stalked spike-rush. Great fen-sedge is scattered in occurrence, but it can be locally abundant; where it occurs it forms dense stands in fens and wet cutover. Many-stalked spike-rush often forms extensive stands in old bogholes. It is locally abundant in the west, hut rather rare elsewhere.

Grasses (family Gramineae)

Although many species grow in the grasslands developed on peat, only a few grasses can be considered as especially associated with bogs. The most important of these species, and one that plays a vital role in the ecology of bogs, is purple moor-grass. Although it can also grow on limestone, it is dominant over large areas of blanket bog, as well as in fens, areas of old cutaway, and other situations where there is some circulation of groundwater; it is especially fond of flushes. If conditions become stagnant, it tends to

Figure 6.17: (a) Purple moor-grass in winter, showing the swollen green stem-bases and horizontal roots; (b) flower panicle. Unlike the tufted sedges of bogland, purple moor-grass alllows its tussocks to die back each year, but in a very neat and controlled way. The plant accumulates food reserves in its stem-bases (basal internodes), which become swollen and tuber-like; this is done early in the growing season – before the flowers open – and these reserves are retained through the fruiting season. As winter advances, an abscission layer is produced at the top of the 'tubers' (which are about 2.5cm long), and the stem breaks off across this, in much the same way as the leaves on a deciduous tree in autumn. Unusually for a grass, all the leaves have an abscission layer as well. Early in spring new shoots begin to grow from two or three buds on the rhizome at the base of the basal internodes, drawing on their-food reserves. Their subsequent growth (and the consequent expansion in the number of shoots as the years pass) largely accounts for the density of the tufts. In Canada purple moor-grass is known as 'flying bent' because 'the dead leaves, abscising at the collar, blow across the moors on the wind' (W. Dore, *Grasses of Ontario*). (c) Early hair-grass, with flower details magnified.



give way to cotton-grass. Purple moor-grass is a perennial with greatly condensed rhizomes, and its roots penetrate to an enormous depth in the peat. These are of two kinds: tough cord roots 1.5mm thick and up to half a metre long, which form an almost solid tangle at the top, and much finer, extensively branched roots .3-.8mm thick; root hairs are produced freely on both kinds, in spite of the fact that the grass is mycorrhizal.

Purple moor-grass was known in rural Ireland as *fionnán* or melic grass; in parts of Kerry it was called fedget grass. In the west of Ireland it was considered to make good grazing land. If the side of a mountain had a shiny look from a distance on a windy day – a characteristic of *fionnán* grasslands – it commanded a good grazing rent. On the other hand, if the vegetation had the reddish colour from a distance that indicated a dominance of cottongrass, it would bring in a low rent. It seems to have been especially important in the rural economy of south Kerry, where it was used as bedding for animals, in thatching and the making of creel handles. In parts of south Kerry it was cut for hay at the end of June. Small circular foundation platforms were set aside for making cocks of *fionnán* hay; several hundred of these are known, mainly on the Iveragh peninsula. Experiments to improve melic grass by cultivation were made in the late 19th century (mainly by N.S. Richardson of Tyaquin, County Galway), so that it would make better grazing. Experiments conducted in Ireland around this time also suggested that it might be suitable for making paper; in trials conducted in the 1880s it was shown to rival Spanish and Algerian esparto for both the quality and yield of its paper, kindling a brief optimism among Richardson's Galway neighbours that at last they had a crop that would grow on partially drained bog.

On cutaway and reclaimed bog the most abundant grasses are generally species of bent (*Agrostis*). Three species occur: common bent, velvet bent and creeping bent or fiorin [**Figure 2.1**]. Common bent tends to occur in drier situations than velvet bent. However, it was fiorin that aroused the enthusiasm of 18th century bog improvers. Richard Griffith summarised its virtues in a note in one of his reports to the Bogs Commissioners:

> Which last circumstance [the structure of the stem], accounts for its containing such a quantity of saccharine matter, like the sugar cane, and being so tenacious of life; for when cut, after several months it will look green, and even vegetate, if hung up in the house. It is this circumstance, which renders this grass such excellent winter food, instead of turnips and carrots, and so salubrious to cattle, and which will account for Doctor Richardson's making hay, or rather cutting down this grass in the month of November: It is said by Mr. Curwen to yield 20 tons of green food yearly per acre.

However, this description appears to apply only to a distinct Irish variety selected and bred by Richardson. The sugar from fiorin was used on an experimental scale to produce alcohol: 'six pounds of grass was found to produce one pint of moderately strong spirit, in flavour very much resembling whisky, but of the two rather preferable.' When planted and established under suitable conditions, fiorin

> will soon extend itself, and mat on the surface, to the total exclusion of other grasses or weeds: moist situations appear to be peculiarly adapted to its growth; it is therefore superior to all others for reclaimed bogs, moor, or water meadows; but if highly manured, immense crops of it may be obtained on dry upland; and where distillation is the object, it is probable that grass so obtained, will be found superior to that raised on moist situations.

Mackay in *Flora Hibernica* (1836) describes creeping bent as follows:

> This is the famous Fiorin of Dr. Richardson, of which I saw in Cunnamara, many years ago, excellent crops of hay on reclaimed bog, where it had been introduced three years previously, along with sand from the shore, used there as a manure for potatoes as the first crop, and barley or oats the year following.

This agricultural enthusiasm for fiorin was confined to Ireland, because climatic conditions here favoured its optimal development in a way rarely found elsewhere. Writing in 1829 of 'the *Fiorin-grass* of Dr Richardson and the Irish agriculturalists' in *The Flora of Berwick-on- Tweed*, George Johnston remarked that it had

> ... never been cultivated to any extent in this country. To be in perfection, it requires a

> moist climate or a wet soil, and it grows luxuriantly in cold clays unfitted for other grasses. In light sands, and in dry situations, the produce is much inferior both as to quantity and quality.

Interest in fiorin seems to have waned after Richardson's time, though Baldwin in his *Introduction to Irish Farming* (1874) still counted it among 'the most valuable grasses':

> Fiorin grass has a creeping root, each stolon or joint of which is capable of sending independent roots into the ground and producing an independent plant. It gives a weighty crop on salt marshes and reclaimed bog, where other grasses would not thrive. It is also a useful grass on irrigated lands, especially those of a moory or peaty character. Fiorin grass is propagated either from seed, or by chopping up the plant, and planting the stolons in rows.

Another grass that is found widely on cutover or cutaway bog is early hair-grass [**Figure 6.17**], an inconspicuous little annual of heathy and similar places: dry situations which may experience water shortage in summer, by which time it has flowered and set seed in dense panicles for next year. It seldom grows more than 20cm high, and has bristle-like leaves which help it to conserve its store of water. Heath grass is another species frequently met with on peaty soils, preferring wetter places than early hair-grass. Sheep's fescue and mat grass are among the species most characteristic of peaty pastures, especially in mountain areas.

One of the most important species in the early stages of colonisation of cutover bog is marsh arrowgrass, which is not a true grass but belongs to a small family of rather grass-like plants, the Juncaginaceae. Arrowgrass is often the first plant to invade the bare peat, spreading outwards by means of its rhizomes from the drains. As summer advances, the plant starts to develop tubers at the ends of the underground shoots, and these develop into new plantlets the following spring. The tubers are eaten by Greenland white-fronted geese and whooper swans, especially when other food is scarce.

Rushes (family Juncaceae)

The rush family has about 350 species in eight genera worldwide. The structure of their simple wind-pollinated flowers indicates a common ancestry with the lily family, but they have a distinctive vegetative structure and ecological role. Most have reduced leaves, the photosynthetic role of which is taken over by the wiry, green cylindrical stems. Several species are important in cutover and reclaimed bogs; the most important is common or soft rush, which often dominates extensive areas of reclaimed bogland or cutaway. This is one of several plants growing on and around the bog that provided valuable resources in the self-sufficient economy of rural Ireland in the past. Rushes are not normally eaten by cattle, although Traynor in his account of the English dialect of Donegal refers to the 'common keib' (presumably soft rush) as a 'hard, bad grass for cows'. Rushes were used as bedding for animals – and indeed their masters – for thatching outbuildings, and for making rush lights. Rush candles or rush torches provided the normal lighting inside the Irish cottage in dark winter evenings. The use of rush lights goes back to Gaelic Ireland, and probably beyond that. The Brehon Laws required that only the best rushes should be used:

> ... eight fists in the length of each rush-light, and the root of each rush after being cut equal to the grain by which an inch is measured; the candle to be dipped in tallow and the grease of the flesh meat.

Where more light was needed – in the tower houses of late Gaelic Ireland for instance – more elaborate rush torches were provided:

> These wild Irish never set any candles upon tables ... indeede they have no tables ... But I meane that they doe not set candles upon any high place to give light to the house, but place a great candle made of reedes and butter upon the floure in the middest of a great roome.

Rush lights were held in special holders of a type that was fairly standard throughout Europe. St Bridget's Crosses were – and still are – made from rushes, which were also used for strewing on floors.

Compact rush is very similar to common rush; it is widespread but much less frequent and has a marked preference for more acid soils. Heath rush, bulbous rush and jointed rush are common especially in the wetter areas of cutover bog.

Heath rush is a prominent early coloniser of bare, wet peat. It is a perennial, with a densely tufted habit; its true leaves are more conspicuous than in most of the common rushes. They are up to 15cm long, deeply channelled and sharply reflexed above a sheathing base. The green stems are much taller than this – up to 50cm. Heath rush has a fascinating way of taking over the ground once conditions become wet enough to give it a competitive advantage. Its leaves grow up vertically through the resident vegetation, and then recurve outwards until they come to sprawl across it like the spokes of a wheel. Such is the pressure they exert that if they are lifted they fly back like a spring when released. In this way they smother the vegetation and monopolise the light, while at the same time forming nest-like hollows on the surface.

Bulbous rush is a small, tufted, grass-like perennial, procumbent and rooting at the nodes and with swollen stem-bases. It often grows in bog holes and drains. Toad rush is an annual, an opportunist coloniser of many wet habitats including bare peat. Two other rushes that can be found sometimes on the margins of bogs are sharp-flowered rush and blunt-flowered rush.

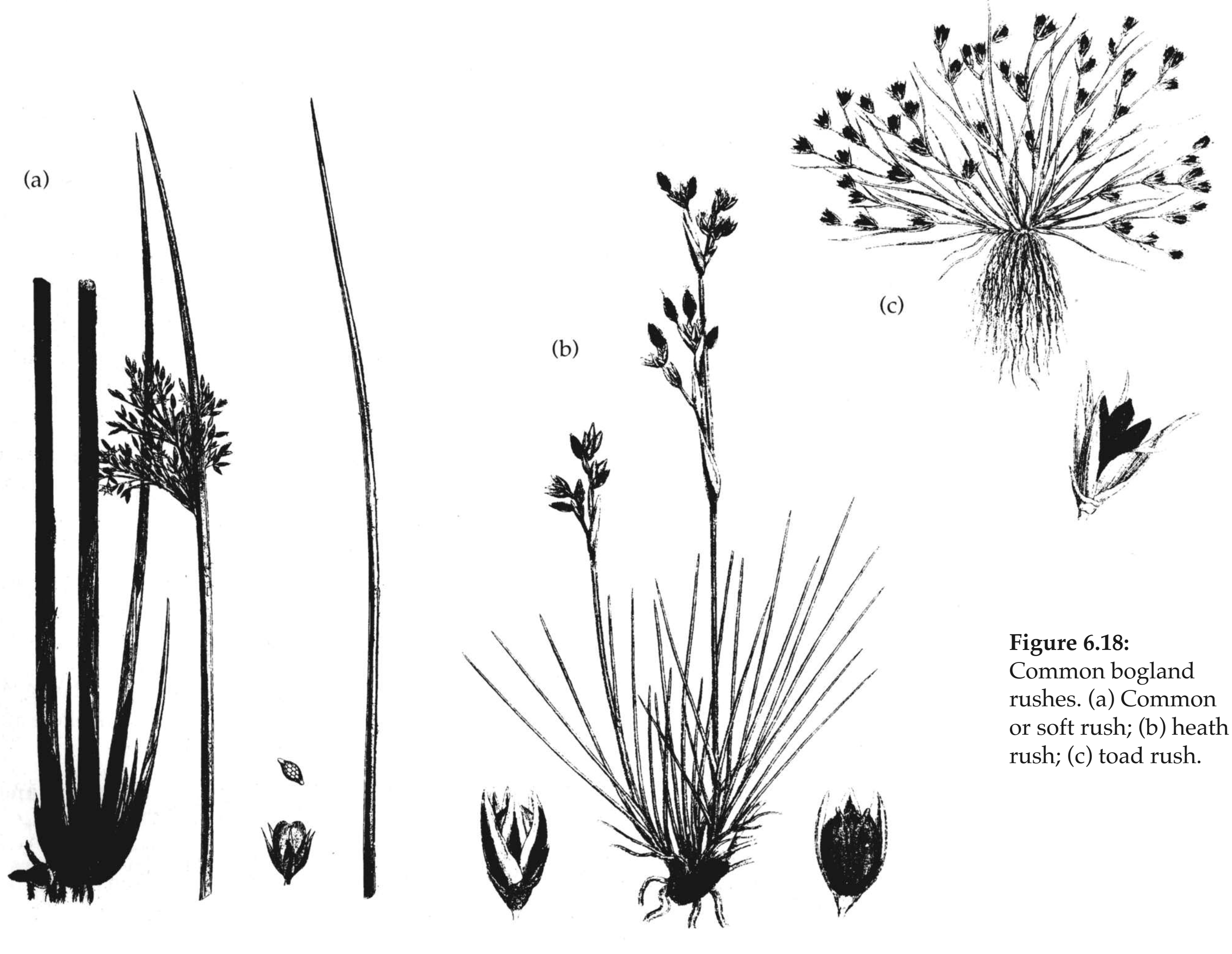


Figure 6.18: Common bogland rushes. (a) Common or soft rush; (b) heath rush; (c) toad rush.

Rannock rush

Rannock rush is not a true rush – it belongs in a family of its own – nor indeed is it a plant the reader is likely to encounter: but it must be mentioned briefly because of the mystery associated with its occurrence in Ireland. Rannock rush is widespread in mainland Europe in bogs that have a permanently high water table. It occupies a characteristic niche in the regeneration cycle, forming a submerged floating mat at the edge of deep pools, advancing into deeper water in much the same way as common reed does on a much larger scale in lakes. It occurs in Great Britain only on Rannock Moor in Scotland, but in spite of the apparent ubiquity of suitable localities in Ireland, it has only ever been recorded from one very restricted location here. And its distinctive peat – which is widespread in European bogs – has never, despite constant search by Frank Mitchell, been recorded from Irish bog profiles. Fr Moore, who found Rannock rush in a soak on Pollagh bog in 1951, pondered long over the mystery of its restricted occurrence without finding a satisfactory solution. Either it had been recently introduced to Pollagh (in the way pitcherplant was introduced to Woodfield and other bogs) or it was a relict species, formerly more widespread but now restricted to this one station. But it cannot have been a recent introduction, because its remains were found to a depth of 175cm in the peat at Pollagh – back to Early Christian times or thereabouts – but below this level there is no trace of it, nor was its surface distribution very much wider in the past than the small area around the bog soak in which it grew in the 1950s. If it had been at all widespread in the past, it would surely have left some trace in the peat archives. For reasons that are not at all clear, therefore, it must simply always have been rare in Ireland.

The orchids of bogland

No fewer than fourteen species of orchids can be found in bogs and fens. Most live in areas of old cutover and in the fringing heath and fen grasslands. Among the commonest and most characteristic plants of these situations are the marsh and spotted orchids.

The early marsh-orchid will be found in marshes, bogs and fens in May and June. Its flowers range in colour from various shades of pink through to lilac or red, and it has leaves that are hooded at the tip and taper gradually from the base. The broad-leaved marsh-orchid flowers from May to August. This is a very variable species, divided into several quite distinct subspecies, some of which are regarded as actual species by some specialists. Broad-leaved marsh-orchid differs from early marsh-orchid in having more or less elliptical lower leaves, whereas they are lanceolate in its earlier-flowering relative.

The two spotted-orchids can be distinguished from the marsh-orchids by their solid stems and smaller flowers, which are usually white or pink in colour, with slender spurs. The heath spotted-orchid is one of the most common flowers of the marshy fields around the bog, and it often invades the drier edges of the actual bog surface. The common spotted-orchid often occurs with it, but is not quite as much at home in the more acidic marshy areas as is the heath spotted-orchid, from which it can be distinguished by a number of features: it is bigger, usually has more heavily spotted leaves, but most reliably the lip of the flower is deeply divided into three lobes, and the middle lobe is as wide and long as the other lobes. The leaves are wide and obovate in outline. In the heath spotted-orchid the middle lobe is usually shorter, and the leaves are narrow and parallel-sided.

Perhaps the loveliest of all the orchids of bogland is the fragrant orchid, which frequents the drier parts of the fringing fen grasslands, and is especially characteristic of bog roadsides and edges, where its tall, elegant, red-lilac flower spikes often occur in large numbers. The fragrant orchids that are found in boggy areas belong to a distinct variety of the species (var. *densiflora)* which is more pleasantly scented, and has longer and denser spikes than the ordinary scented orchid. The flowers have a strong, heavy fragrance and a very long spur, both of which features are adaptations to its pollination by moths. It flowers between June and September, later than most other orchids. The related small-white orchid is a very much rarer plant of wet meadows.

Orchids of the fen grasslands include the two butterfly orchids: the lesser butterfly orchid, and the greater butterfly orchid, the former being the commoner. They are cream-white in colour, and as night approaches they seem to glow against the green background of their surroundings, emitting a sweet clove-like scent as they prepare to welcome their pollinators, which are night-flying moths (and other Lepidoptera to a lesser extent), the only insects whose 'tongues' are long enough to reach the nectar in the long, slender spurs of the flower. The principal habitat of the rare fly orchid is in fens.

The frog orchid occurs in the same places as the butterfly and scented orchids, but its brownish-green flowers are very inconspicuous, melting into the grasses around. It is pollinated mainly by small beetles or short-tongued flies and other small insects that reach the flowers via the stems rather than by flying in from above as bees would. For this reason the flower stalks are short, and the lip of each flower points down and back towards the stem, enabling the insects to climb into the flower more easily from below.

Lesser twayblade is one of the orchid species most characteristic of wet bogs and open moorland, where it grows among heath and heather, perhaps in the company of cranberry, sundews and even bog orchid. It is uncommon and hard to find, occurring mainly on upland bogs in the northern half of the country, although it can be found almost at sea level in the cool, wet climate of the north and west. It somewhat resembles a diminutive version of its familiar relative, the common twayblade, which is frequently found growing on old cutover and other peaty soils, but the two species are not easily confused [**Figure 6.19**]. Lesser twayblade is a much smaller and more slender plant, seldom more than 15cm high; both species have greenish-yellow flowers, with a distinctive snake's-tongue lip, but those of lesser twayblade are tinged red or brown. Both twayblades are pollinated by such small insects as ichneumons, small flies and beetles. The fascinating and intricate pollination mechanism of the twayblades was originally described by Darwin [See panel, **Figure 6.20**].

Figure 6.19: The two twayblade species. (a) Common twayblade; (b) lesser twayblade.

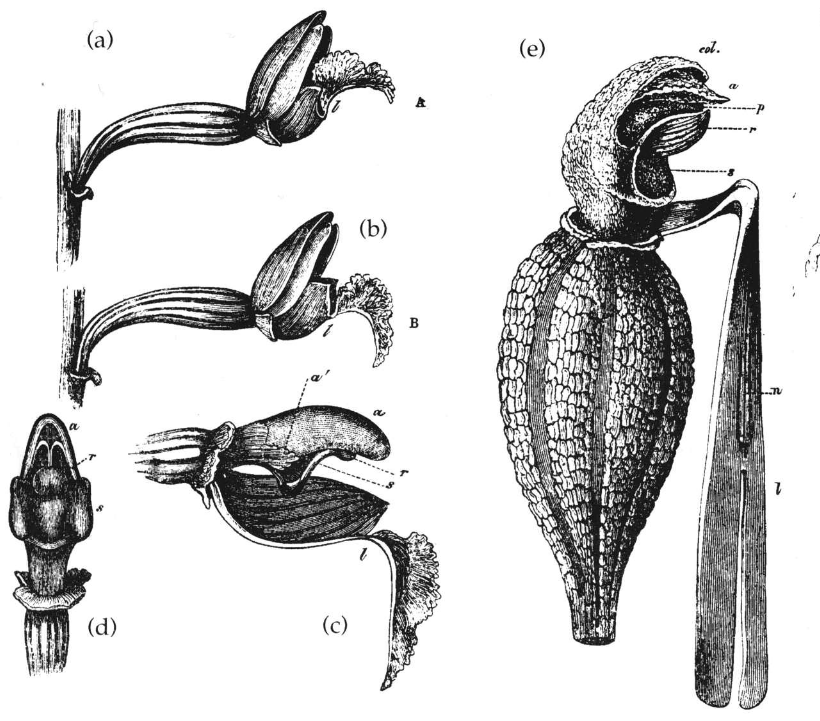


Figure 6.20: Pollination in marsh helleborine and twayblade. (a)-(d) Marsh helleborine; (e)(f) twayblade.

a. anther, with the two open cells seen in the front view (d).
a1. rudimentary anther, or auricle; r. rostellum; s. stigma; l. labellum.
(a) Side view of flower (with the lower sepals alone removed) in its natural position.
(b) Side view of flower, with the distal portion of the labellum depressed, as if by the weight of an insect.
(c) Side view of flower, with all the sepals and petals removed, except the labellum, of which the near side has been cut away; the massive anther is seen to be of large size.
(d) Front view of column, with all the sepals and petals removed: the rostellum has shrunk down a little in the specimen figured, and ought to have stood higher, so as to hide more of the anther-cells.

The enigma of the orchid flower

When students familiar with the structure of flowers encounter orchids for the first time they are invariably confounded, because the structure seems to be completely different from all other flowers. This is because many of its organs have been highly modified in the course of the evolution of this unique family. In many cases organs have become fused together, sometimes with organs of quite different type. But if we could trace the orchid back to a pre-orchid ancestor,. we would find that it had the basic structure of most monocotyledonous flowers, with all its organs in whorls of three: three sepals, three petals, two rows of three stamens, and a row of three pistils in the middle. ('Monocots' are one of the two great sub-groups of flowers; one of their distinguishing features is this tripartite arrangement of the flower parts). The three sepals are still there, relatively unchanged. Two of the petals are still more or less the same, but the third has become very highly developed, and is accordingly distinguished from the others as the *labellum.* But the labellum is different not just because it has become enlarged; early on in the course of orchid evolution two of the outer three stamens were absorbed into its structure. These two stamens have become completely petaloid; this is hinted at in the tripartite arrangement in many orchid labella. In orchids which have spur-like nectaries it is the two former stamens which go into the shaping of them.

The central column of the flower is made up of the three pistils and the remaining four stamens, all generally completely confluent. The third outer stamen (the upper one) is the only one which is fertile. The residues of two of the stamens in the former inner whorl go to form the membranous sides of the 'cup' on top of the column (known as the *clinandrum),* which includes and protects the pollen masses, thus aiding 'their fertile brother-anther' as Darwin put it. The projections which are all that remain of these two abortive stamens are prominent in the bog orchid, which is said to have a 'perfect clinandrum' [**Figure 6.21**]. They are less obvious in most other groups of orchids. The rudiments of the third stamen help in strenghtening the front part of the column. The fertile stamen is little more than an anther, divided into two cells. In most flowers pollen is a fine granular powder; in orchids the grains cohere in masses, often supported by an appendage called the caudicle. These masses with their appendages are called *pollinia.* The pollinia are generally attaehed to the rostellum.

Of the three stigmas, two are confluent (reflected in the bifid structure it often has) and the former upper stigma has been converted into an extraordinary structure called the *rostellum.* It has lost its fertile status, but retains and has developed its capacity to secrete viscid matter. The function of this is to retain the pollen masses - its own pollen - when brought in contact with it. The viscid matter produced by the rostellum dries very quickly. How it works will be seen when the pollination of two of the bog species is described below.

Marsh helleborine

The front part of the lip of the flower (known as the *epichile*) is white, with elaborately frilled and steeply upturned edges, leaving a small, flat platform for alighting bees - honey bees appear to be the main pollinators; the frilly edges are neatly tucked under the upper petals when in bud. The back of the platform rises to a pair of ridges, separated by a median groove and tinged with orange-yellow where the ridges rise from the platform (See Plate 5). The back part of the lip (the *hypochile*) is very different; it is a deep, nectar-containing spoon, with crimson lines streaked down the sides, while the bottom is flecked with egg-yolk yellow. The epichile is separated from the hypochile by a narrow hinge; when a bee lands on the narrow platform this collapses under the insect's weight, keeping it away from the pollinia and stigma while it is feeding. While it feeds, any adhering pollen masses adhering to the insect are in exactly the right position to rub against the viscid stigma. When it lifts its weight from the epichile however, the rebounding lip pushes the bee upwards, so that its head comes in contact with the projecting head of the anther, so that it removes the pollinia. When the insect lands at the next flower, the pollinia are in the right position to adhere to the stigma.

Twayblades

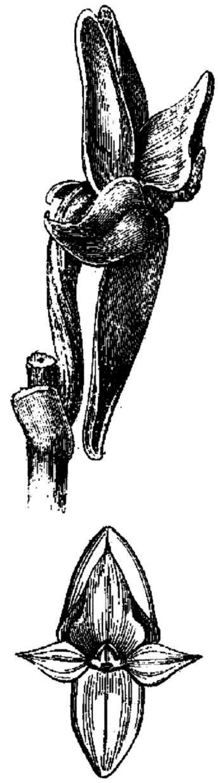
In twayblades the pollinators are small bees and wasps. There is a nectary (n) in a furrow that runs up the middle of the verticallabellum (I), and this produces an abundance of nectar. The visiting insect makes its way up the labellum, licking up the nectar as it goes, paying no attention to the upward narrowing of the labellum. (In lesser twayblade there are curved edges at the base of the labellum, which corral the insect into exactly the best position to bring it into contact with the curve of the rostellum). This restriction of the insect's movement means that when it reaches the top of the labellum its head is just under the curved crest of the rostellum. When it lifts its head this touches the crest, which immediately explodes, and pours out a viscid substance which hardens instantly. Some of this glue inevitably gets on the pollinator's head, and since the tips of the pollinia have been resting against the crest of the rostellum the explosion fixes the stalks of the pollinia to it, with the result that they come away on the insects head as it pulls back.

At the moment of explosion, the rostellum suddenly curves forward and downward until it is projecting at right angles to the surface of the stigma. This makes it difficult for any pollen on the insect to come in contact with the stigma, thereby inhibiting self-fertilisation. Besides, the stigmatic surface has not been very sticky up to this. It only becomes really sticky after the explosion of the rostellum has occurred. The rostellum then moves back into an upright position, leaving the passage to the stigmatic surface open to subsequent pollen-bearing visitors now that its own pollen is safely away. The anther opens while the flower is still in its bud stage, and the front of the pollinia lie against the concave baek of the rostellum, which then moves a little forward. (This is important, because it ensures that the pollen masses are kept back from the explosive region).

Of all the orchids of bogland, the most splendid is the exquisite marsh helleborine, which flowers between June and September in fens, lime-rich cutover areas and silted up marly bogholes. Unlike other orchids, the marsh helleborine spreads by means of underground rhizomes that creep through the peaty soil just a few centimetres under the surface. This may give the impression that the plant is more common than it actually is, because each patch of flowers is usually a single plant. The frilly white flowers are streaked and tinged with crimson, and are pollinated mainly by honey bees, for whose visits the flower is wonderfully adapted. The three sepals are purplish with white edges, and the two upper petals are white, often tinged with purple and with a purple line down the centre. The front part of the lip of the flower (known as the *epichile*) is white, with elaborately frilled and steeply upturned edges, leaving a small, flat platform for alighting bees – honey bees appear to be the main pollinators; the frilly edges are neatly tucked under the upper petals when in bud. The back of the platform rises to a pair of ridges, separated by a median groove and tinged with orange-yellow where the ridges rise from the platform. The back part of the lip (the *hypochile*) is very different; it is a deep, nectar-containing spoon, with crimson lines streaked down the sides, while the bottom is flecked with egg-yolk yellow. The epichile is separated from the hypochile by a narrow hinge; when a bee lands on the narrow platform it collapses under its weight, keeping the insect away from the pollinia and stigma while it is feeding. When it lifts its weight from the epichile however, the rebounding lip pushes the bee upwards in such a way that its head comes in contact with the projecting head of the anther, so that it removes the pollinia [**Figure 6.20**]. When the insect lands on the next flower, the pollinia are in the right position to adhere to the stigma.

The rarest and most elusive member of the family is the bog orchid [**Figure 6.21**]. It has tiny yellow-green flowers the colour of which merges with that of the cushions of sphagnum in which it grows. This camouflage makes it really hard to locate. It grows from two bulb-like swellings, one above the other; the stem is only 2-15cm high, with two to four very small spoon-shaped leaves, and it has no roots. The 'bulb' is covered with special hairs in which the orchid's mycorrhizal fungus lives. It depends on its fungus partner even more than do other orchids, because its habitat is extremely low in the essential nutrients the plant needs. It can be found in flower between June and September, in blanket bog mainly; the tiny flowers often set an abundance of seed, but it also produces bud-like structures that grow into new plants when they are shed, and these are a much more reliable method of propagation for the orchid.

Figure 6.21: In the bog orchid, the labellum is at the top of the flower. This is actually its 'natural' position, but in most orchids curvature of the ovary has reversed this.



Other flowering plants of the bog

Grass-of-Parnassus

One of the loveliest of all the flowers of the wet calcareous grasslands of fens and at the bog's edge is Grass-of-Parnassus [**Figure 6.22**]. The odd English name for a plant that is so obviously not a grass is a translation of a name given to it in the sixteenth century by the early botanist Mathias de I'Obel. It is a perennial with a stout rootstock and characteristic heart-shaped radical leaves. Each plant produces a single flower of exceptional beauty in late summer, with pure white and delicately veined petals. Of the original ten stamens five have been transformed into extraordinary fan or comb-like structures: such 'false stamens' are called *staminodes.* Each has a spathulate base that bears several tentacle-like structures with glistening yellow glands at their tips. These are not nectaries: they merely serve to attract large flies and short-tongued bees that mistake them for nectaries, and whose visits bring about pollination. Nectar is produced by two small green glands on the flat basal part of the staminodes, which also secrete a honey-like scent. The five fertile stamens ripen one at a time over a period of about a week, and as it develops each stamen raises itself to a position in the centre of the flower where it is most likely to come into contact with visiting insects. This movement does not result in self-pollination, because the flowers are protandrous – the stamens mature before the stigmas become receptive.

Figure 6.22: Engraving of Grass-of-Parnassus in G. V. Sampson (1814), *A Statistical Survey of the County of Londonderry.*

Bog asphodel

Bog asphodel **[Plate 3]** is one of the loveliest plants of the bog, especially when its brilliant gold-yellow, star-like flowers extend over a wide area. The flowers are sweet-scented, but they produce no nectar. One of their most unusual features is that the stamens are densely clothed with hairs. Bog asphodel extends its territory by means of an extensive system of slender, branched, intermeshing rhizomes. It dies back during winter, withdrawing all its reserves into the rhizomes, its small overwintering buds poised just below the surface of decayed leaves ready to start out for another busy year once winter is over. Growth in bog asphodel is related to the depth of the water table beneath the surface, which influences the supply of oxygen to the rooting system; where there has been a recent fall in the water table, the plant can become spectacularly abundant.

Although it extends far into the bog, the plant thrives best where there is some circulation of groundwater and nutrients, so it is most luxuriant towards the margins of the bogs. The specific epithet of the plant, *ossifragum*, meaning bone-breaking in Latin, recalls the belief that eating the plant gives brittle bones to cattle. Indeed, one element that is in very short supply on the bog is calcium, which vertebrates and other animals need for their bones and shells. Bog asphodel often frequents rather drier fringes where animals might be likely to graze it, and although eating it will not make the bones brittle, an animal whose diet is confined to bog asphodel and the other plants that grow in this nutrient-deficient environment is certainly likely to suffer from calcium and other nutrient deficiencies.

A number of flowering plants are particularly associated with the higher nutrient peat of cutover raised bog, and are equally at home on blanket bog. They include milkwort, tormentil, lousewort and devil's-bit scabious.

Devils'-bit scabious

No census of common bog plants would be complete without reference to devils'-bit scabious, a plant that often partners purple moor-grass in the species-rich grasslands which develop in areas of abandoned turbary. The plant takes its name from its short rootstock, which ends abruptly, looking just as if the bottom part had been bitten off. The seventeenth-century herbalist Nicholas Culpepper accounts for the name as follows:

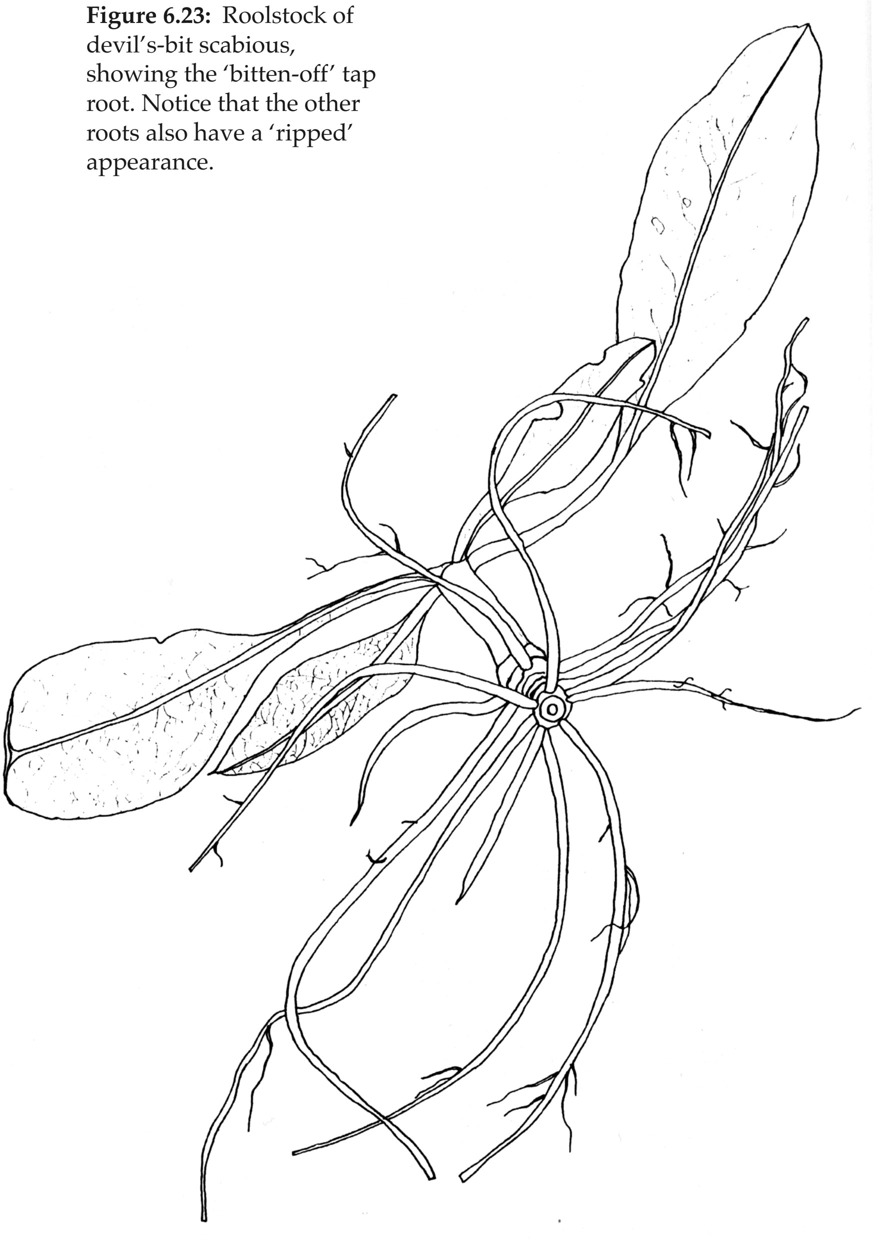
> This root was longer until the Devil (as the friars say) bit away the rest from spite, envying its usefulness to mankind; for sure he was not troubled with any disease for which it is proper.

The plant has a fairly small number of long, thick roots. The flowering stems arise from a rosette of basal leaves that are almost invariably blotched with black. The dark blue (occasionally white) flowers are much favoured by bees and butterflies, and in August and September large numbers of small tortoiseshells, peacocks, red admirals and other butterflies can be seen feeding on them. They have the distinction of being gynodioecious, which means that some flowers are hermaphrodite and others female.

The stamens in the hermaphrodite flowers have striking red-purple anthers, which ripen before the stigmas become receptive.

Devils'-bit scabious is abundant in peaty grassland, wet pastures and areas of poor fen, where it is often co-dominant with purple moor-grass, along with heath-loving herbs and shrubs such as heather and cross-leaved heath, tormentil, sweet vernal-grass, bog asphodel, deergrass and slender St John's-wort. In wetter places it often occurs with bog (meadow) thistle, wild angelica, Grass-of -Parnassus, common reed and other plants of damper places.

Figure 6.23: Roolstock of devil's-bit scabious, showing the 'bitten-off' tap root. Notice that the other roots also have a 'ripped' appearance.



Milkworts

Two species of milkwort [**Figure 6.24**] frequently occur in or around the bog. Their special interest lies in the beautiful flowers, which look rather like tiny orchid blossoms. There are three petals, although there appear to be more, because two of the sepals look just like petals. These are spread out like wings when the flower is ready for visitors, giving it the appearance of a little blue bird in flight. After pollination these special sepals become green in colour, and close together, protecting the developing fruit between them. The stamens are joined to the petals; the filaments of the stamens are coherent, and the corolla is attached to the sheath which they form. The two upper petals are held together over the third, which looks like the lip of an orchid and provides a landing place for visiting insects. The front end is divided into bunches of finger-like lobes, while the back end latches firmly, fantail fashion, into the flower. The weight of the insect opens the latch, so to speak, dislodging the stamens, which are brought into contact with the visitor in the process. There are eight stamens, which open by apical pores. The stigma has a protecting hood.

The milkworts are a large genus of 700 or so species, found nearly everywhere in the world. Both the English and Latin names (the latter derived from the Greek for 'much milk') refer to the belief that cattle that ate the plant gave more milk. The common bog species is heath milkwort, which flowers from June to September. It is smaller and more prostrate than the closely similar common milkwort, but its lower leaves are always opposite (all leaves are alternate in the common milkwort), the flowers are in shorter and denser racemes, and the flowers are nearly always bright blue. The flowers of common milkwort are very variable in colour: blue, purple, pink, white and lilac; it is more characteristic of grassland, and it prefers more alkaline conditions.

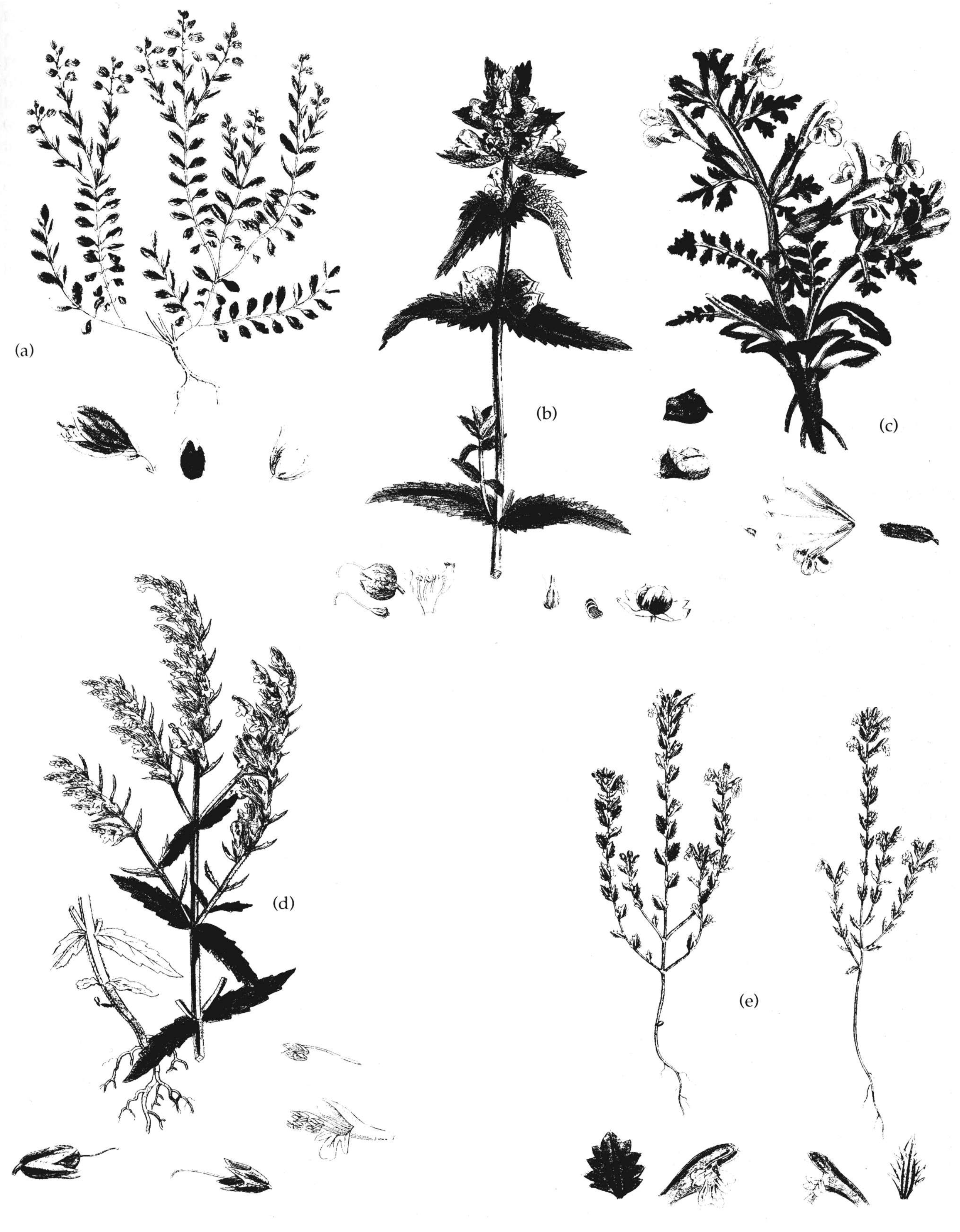


Figure 6.24: Some common flowers on cutover bog. (a) common milkwort; (b) yellow rattle; (c) lousewort; (d) red bartsia; (e) eyebright.

Tormentil

The common yellow-flowered tormentil [**Plate 4**] is one of the most widespread and characteristic plants of cutover bog, and was at one time regarded as a very useful plant. In the early part of the 18th century, a certain William Maple published a treatise advocating the cultivation of tormentil in Ireland and extolling its virtues as a substitute for bark in the tanning of leather. He concluded that 'tormentil roots tan all hydes and skins as effectually, cheaper, and in less time than bark, and is easily propagated.'

Bedstraws

Several species of bedstraw occur in and around bogs. The yellow-flowered lady's bedstraw is a plant of roadsides and grassbanks around bog margins, and marsh bedstraw grows in ditches and old bog workings. Heath bedstraw is a regular member of the community of plants that is associated with cutover bog, along with such species as tormentil and lousewort. It is a strictly calcifuge perennial that produces a prostrate tuft of short stems from which the upright flowering stems are produced.

Lousewort

Lousewort [**Figure 6.24**] is another heathland plant that frequents the edges of the bogs. Its English name may come from the old belief that it encourages lice in sheep. Lousewort supports itself by parasitising the roots of other plants, a way of life it shares with a number of other plants – all relatives – which are found in the semi-natural pastures around the bogs: eyebright, yellow rattle and red bartsia. It is a perennial, with a stocky rootstock that sends out short spreading branches of feathery leaves each spring. It has intricate bilaterally symmetrical 2-lipped pink flowers that are elegantly adapted for pollination by bumble bees.

Columbine

Columbine is a plant that grows in limestone thickets and wet places on calcareous soils; it is one of the most attractive inhabitants of cutover bog where conditions approximate to fen, and by roadsides and bog tracks in areas of turbary. It is a member of the buttercup family, though the elaborate purple flowers, elegantly adapted for pollination by bees, bear little superficial resemblance to buttercups. The concave petals each have a curved hollow tube at the back, and nectar is secreted in a knob at the end of this tube. The stamens mature first, to ensure cross-pollination.

Sheep's sorrel

Sorrels are so called from the sourness of their acidic leaves. Sheep's sorrel is an opportunist, a perennial plant that favours a variety of acid soils, and which quickly establishes itself from seed on bare peat, where it is often abundant.

St John's-worts

Two species of St John's-worts are associated with bogs. Slender St John's-wort is a very elegant plant that is very characteristic of cutover bog and associated grassland habitats. It has yellow flowers, borne on slender, erect stems. The petals are tinged with red, with a row of black glands near the margin. The margins of the sepals also have shortly-stalked black glands, and the leaf is covered with pellucid glands. The second, much rarer species is marsh St John's-wort, which is a rather woolly plant with almost round, sessile leaves that clasp the creeping stems. The function of the hairs is to prevent the plant from being wetted when submerged. It occurs mainly in bogs and marshes in the west and south-east, and is very rarely found elsewhere. Trailing St John's-wort ia also occcasionally found on bare cutover bog.

Bog brambles

Sometimes one comes upon thickets of raspberry-like brambles at the edges of the bog. These belong to a distinct group or 'section' of bramble microspecies, the *Suberecti,* which particularly favour areas of old cutover. As the technical name suggests, they differ from more familiar brambles in having stems that do not arch over and take root, and they are not very prickly or thorny.

Ferns and fern allies

The three ferns that occur on bogs are royal fern, hard fern and bracken. The marsh fern occurs occasionally, but it is rare – although its spores can be very abundant in the lower part of the peat profile. A few other species can be found round the edges of the bogs; broad buckler-fern is common especially around mountain bogs, and narrow buckler-fern occasionally occurs in cutover areas.

Hard fern is especially typical of old bog drains, where it finds suitable conditions of constant shade and moisture. It has separate barren and fertile fronds that are very different from each other in appearance. The royal fern is the tallest Irish fern, almost attaining the status of a tropical tree fern at times [**Figure 6.25**]. The tree-fern appearance is heightened by the stout, tufted caudex or rootstock, which can rise nearly a metre above ground level, and from the crown of which a spray of fronds is produced. These are deciduous, dying back altogether in winter. It needs very damp conditions but is not all that particular about shade; when it finds conditions really suitable it can extend over considerable areas. It grows abundantly in the west along streams and rivers fed with peaty water from upland bogs, and it often


(a)


(c)


(b)

Figure 6.25: Royal fern. (a) Individual plant, showing prominent caudex; (b) portion of frond; (c) young plant in its fourth year. 'Now this was worth coming to see!' The profusion of royal fern in many parts of the west might still provoke Walter Scott's exclamation when he first saw the fern in Killarney.

occurs in profusion in old bog holes in raised bog. On Achill Island it has been known to establish itself as a troublesome weed, difficult to eradicate. When the great Scottish novelist Walter Scott visited Killarney he was singularly unimpressed with the scenery; the only thing that aroused his enthusiasm was the sight of the royal fern which grows so luxuriantly along the river between the two lakes.

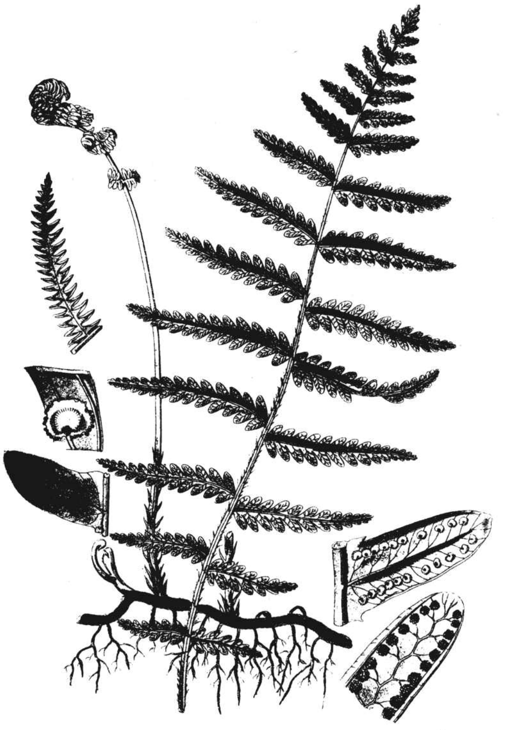


Figure 6.26: Marsh fern. Nowadays the marsh fern is confined to a few localities in the west, but it was very widespread in the peaty fens of Mesolithic Ireland.

Bracken, on the other hand, is an extremely versatile, tolerant and successful plant. It owes its success to a variety of strategies: it is poisonous, not readily susceptible to serious disease, produces a range of chemicals that inhibit potential competitors, and is tolerant of a wide range of climatic and edaphic conditions. It is fire resistant and has considerable genetic variability. On the bog it grows in dry situations, often right out in the open, and once it establishes a hold it is extremely difficult to get rid of. Bracken owes its considerable success to its finger-thick rhizomes, which creep in all directions a few tens of centimetres below the surface. It is deciduous, withdrawing its reserves below ground for the winter. The dense mass of dead fronds inhibits other plants from germinating, and in summer the fronds produce a 'forest' so high and so dense that nothing else can grow underneath.

Nowadays the marsh fern is confined to a few localities in the west, but it was very widespread in the peaty fens of Mesolithic Ireland. Marsh fern is a plant of wet bogs and marshes – it is the only Irish fern which actually grows in water – where it can colonise considerable patches by means of its dark-coloured creeping rhizomes. The delicate fertile fronds are a beautiful light green colour, very delicate, and can be as much as a metre or more high; the barren fronds are only about half as high.

The clubmosses are a fascinating group of vascular plants whose ancestors in the coal-producing swamps of the Upper Carboniferous some 300 million years ago attained the stature of tall trees. They are not related to mosses, in spite of their name. The group lost the dominance it enjoyed during Carboniferous times, and the few that survive today are low-growing and uncommon plants. There are only five species in Ireland, all of which are found in marshy, heathy or boggy places, although only two are common. Fir clubmoss can usually be found scattered here and there on most bogs [**Figure 6.27**]. Its Irish name, *crúibíní sionnaigh* (fox's feet), describes the appearance of the bushy-looking stems very well. It seldom grows more than 15cm high, the stem branching a few times. The relatively long leaves are regularly and evenly arranged all round the stems and all the way along the length. Lesser clubmoss is a small, elegant species that is frequent in fens. The stems are creeping, but erect stems a few inches high are produced at intervals, and these produce sporangia in loose cones in the axils of the leaves.

Marsh horsetail [**Figure 6.27**] is the only common species of horsetail found on bogs, but it plays an important role in certain peatland habitats. Horsetails have very distinctive articulated, ridged stems that are arranged in a radial pattern, whorls of branches arising at the nodes. The cortex of the stem carries out the work of photosynthesis, because the leaves are reduced to chaffy scales. Spore-producing cones are produced at the apices of the branches. Marsh horsetail is often locally dominant in areas of wet cutover bog. It is a perennial plant, usually growing as erect 'forests', although in some situations it has a decumbent habit. In the autumn it dies back to articulated underground rhizomes. Like the clubmosses, it belongs to a tribe of plants which have changed little in essentials since the Upper Carboniferous period of earth history, when giant horsetails tens of metres high grew in situations not greatly different from the preferred habitat of the marsh horsetail today.

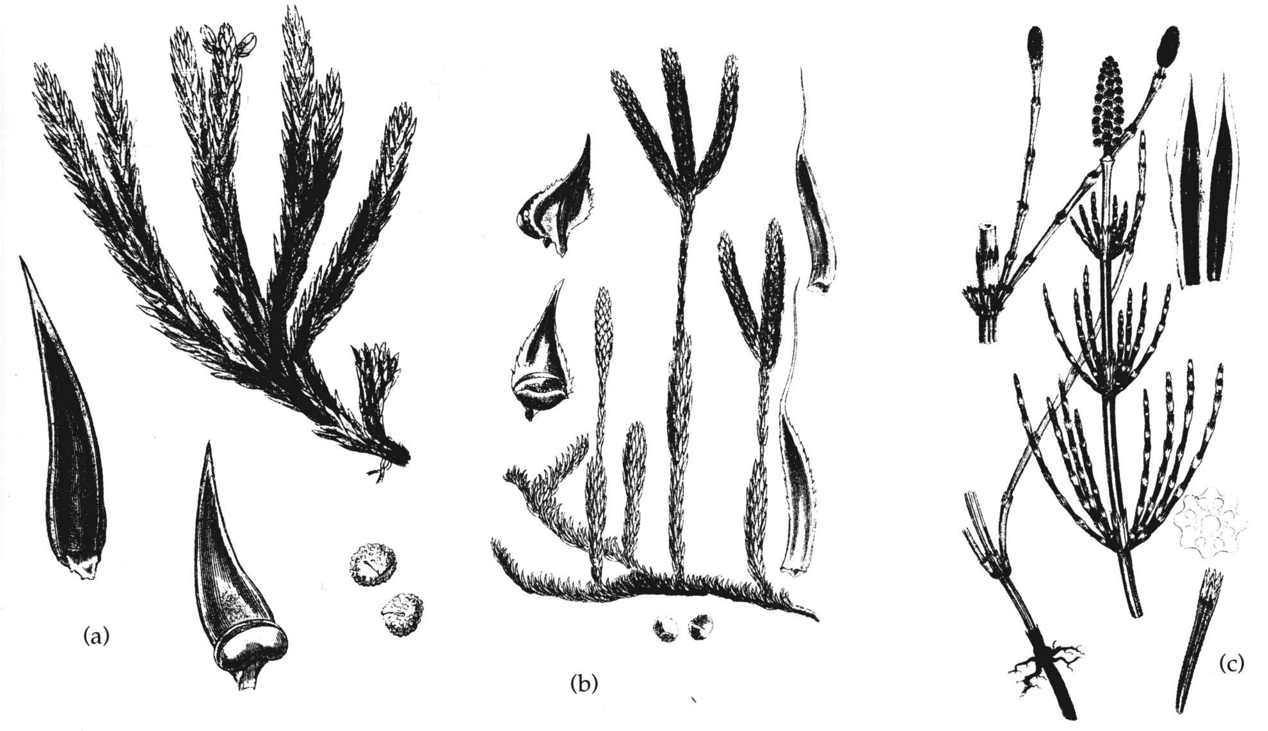


Figure 6.27: Non-flowering vascular plants of bogland. (a) Fir clubmoss; (b) marsh clubmoss; (c) marsh horsetail.

Some aquatic plants in bogs

Bog water has a distinctive low acidity and chemical composition. The acidity is believed to be due to sulphuric acid rather than organic acids – the vague 'humic acids' encountered in the literature on bogs. The fluffy dark brown substance that sometimes builds up at the bottom of peaty waters goes by the Swedish name of *dy*, and is due to the precipitation of amorphous humous gels, often along with bits of the chitinous remains of creatures that lived in the water. Sometimes it contains fragments of *dopplerite*, a precipitate of pure humous gels. This strange substance is translucent, like dark glass, and has a glassy or jelly-like consistency. Indeed, when the glassy form is struck, it breaks with a conchoidal fracture like glass.

Large open lakes, with streams flowing into and out of them, are common in the blanket bogs of the west, and they sometimes cover several hundreds of acres. These usually have stony bottoms, and a very restricted flora, dominated by water lobelia and pipewort and various filamentous algae. Water lobelia grows at the margins of the lakes in blanket bogs all down the west coast. It develops from a mat of runners produced on a short white rootstock. The leaves are produced in radical rosettes on the bottom. In July and August the flowers grow from the centre of these rosettes upwards to the surface; the spikes of slender, drooping flowers, pale lilac in colour, swaying on the water, are a beautiful sight.

In the more sheltered areas where there is often a build-up of sediment, there is a greater variety of open-water species; white water-lily is particularly abundant, along with broad-leaved pondweed, common reed, bogbean, great fen-sedge, various sphagnum species, with common rush and bog myrtle towards the edges. Great fen-sedge is a calcicole, and the abundant stands that occur in the bog lakes and pools of the west seem very odd at first sight. Part of the explanation for this seems to be that the bases released by weathering of the rocks beneath and around the bog counteract the acidity of the bog water. Smaller, shallow, closed lakes usually have undercut peat margins and a peaty bottom, but the vegetation is not all that different from the larger lakes.

The two species of water-lilies, white water-lily and yellow water-lily, are among the common plants of the lakes and pools of blanket bog, extensive rafts of the leaves often covering large areas of open water. White water-lily often dominates the smaller peat-floored pools that dot the surface of the western bogs. Pondweeds *(Potamogeton* species) are found in bogs of all kinds; they grow from perennial creeping rootstocks, producing simple leaves and spikes of greenish wind-pollinated flowers. There are many species and hybrids, often difficult to distinguish. About a dozen species occur in the various kinds of water bodies found in bogs; the most characteristic species is bog pondweed. The floating leaves of pondweeds are home to numerous forms of animal life, and they are always among the most productive of habitats to search for such creatures. Common duckweed is a very characteristic plant of bogholes, often covering the entire surface of the water.

Many larger bog lakes, and indeed many of the small pools, have their own individual names, and these names often pinpoint salient vegetational features or physical aspects that are characteristic of them.

Reeds form a fringe around many lakes, and often cover considerable areas. The reed forests provide shelter for a variety of creatures, including several species of wainscot moths *(Mythimna* spp.), which find a safe and sheltered retreat in the hollowed stems during the day and feed by night. Plant stems in bog pools provide anchorage for freshwater sponges and that minute, seldom-noticed creature which is among the most fascinating of all the animals of the water, *Hydra.* Water plants provide shelter for many small animals during the winter.

Larger animals may graze on the multicelluar algae that are sometimes abundant in bog waters, and numerous small invertebrates feed on what they can find in the peat mud: not only peat particles, but dead plant and animal remains and even fragments blown in from the terrestrial world outside. The consumers of this mixed bag of leftovers include midge larvae, small beetles and certain kinds of entomostraca (the chydorid cladocera).

Bulrush or reedmace is a frequent inhabitant of bogholes in the final stages of silting up, along with the bur-reeds, the two bur-marigolds (nodding and trifid), bogbean, common reed, marsh or bog cinquefoil, purple loosestrife and several sedges. There are two species of bulrush, the most common on bogs being the great bulrush, which has long, narrow sword-shaped leaves sheathing the tall flower spikes. They produce the familiar brown 'mace' of tiny plumed fruits – as many as a quarter of a million per average head. Bur-reeds belong to the same family, and are especially common in drains on the edges of bogs. There are four species, but the two most often found associated with bog waters are branched bur-reed and least bur-reed.

Figure 6.28: Flower and fruits of bog bean.

Bogbean [**Figure 6.28, Plate 4**] is one of the most characteristic plants of shallow, silted-up bogholes and drains as well as natural pools and lakes in bogs. It also plays an important role in colonising more recently cut areas from which a considerable depth of peat has been removed, particularly if it is already growing in the vicinity and can spread into the area by vegetative means. Like most of the plants that grow in these situations, it has a thick, creeping rootstock that ramifies through the peat silt, producing large trifoliate leaves (for which reason it is sometimes called marsh trefoil), and flower spikes of startlingly beautiful white blossoms between May and July. The petals are covered with white tentacle-like filaments whose function has never been clearly established, and there are long-styled and short-styled flowers to assist cross-pollination – a device that is also found in several other kinds of flowers (primrose and purple loosestrife are common examples). The seed needs a period of frost before it can germinate, and it contains spongy air-containing tissues that enable it to float, facilitating dispersal. Seeds of bogbean are often abundant in reed peat.

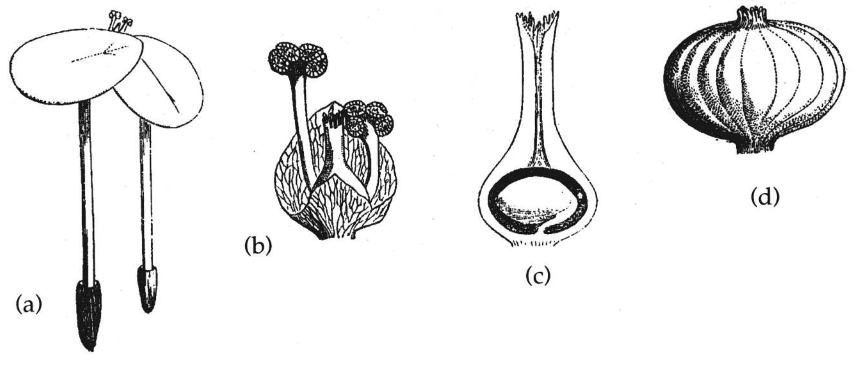


Figure 6.29: Common duckweed.
(a) Two duckweed plants;
(b) single flower;
(c) pistil in section;
(d) fruit (All enlarged; from Le Maout and Decaisne).

Bogholes and drains have their own characteristic plant communities. A range of floating plant species contend for what open water there is. Species to be expected here include whorled and spiked water-milfoils, mare's-tail, lesser and greater bladderworts, common and ivy-leaved duckweeds [**Figure 6.29**], and the slender liverwort *Riccia fluitans.* Plant communities in these situations are especially diverse where the bog drains flow into an area of flooded grassland such as the Shannon callows. Here on occasion one comes on the sight of a boghole entirely filled with frogbit, unforgettable when the plant is in flower in July, and the leaf-carpeted surface is dotted with the flowers, each with three crumpled white petals and a yellow eye.

Two species of *Potentilla* play a special role in bogland ecology, occupying very different niches. Tormentil (*Potentilla erecta*) is a plant of drier areas, and is especially characteristic of blanket bog and cutover raised bog, whereas marsh cinquefoil *(Potentilla palustris)* [**Plate 4**] inhabits old bogholes and drainage ditches, where it sometimes grows in profusion. It has a lifestyle similar to bogbean in many respects, with a stout, woody rhizome that colonises the mud; the rest of the plant dies back during winter. The flower is very distinctive: all its parts are purplish-brown in colour, a star of five prominent sepals alternating with five much smaller sepals. Like bogbean it usually produces abundant seed; its pollinators are a variety of ichneumons, flies and other insects that can reach the partly concealed nectar.

Another characteristic plant of the marshes and fens on the edge of the bogs is ragged robin, which is a perennial, and very easily recognised by its raggy-looking petals. Their appearance is due to the way the five petals are deeply split into four ragged strips; this makes them look torn, especially when they wave in the wind; the flowers are adapted for pollination by butterflies. This is a good plant for looking at some of the devices plants have for keeping off unwanted insects like ants. The stem has a covering of sharp, downward-pointing hairs, but any persistent insect that manages to traverse this formidable obstacle course will then find itself stuck in the minefield of sticky hairs that clothe the upper part of the stem. The Latin name for ragged robin is *Lychnis flos-cuculi. Flos-cuculi* means cuckoo-flower, because the plant flowers in June, when the cuckoo is singing. Other marsh plants common on the wet fringes of the bogs include bog stitchwort, bog pimpernel, marsh valerian, wild angelica, meadowsweet, water avens, water speedwell, marsh speedwell, marsh marigold, lady's smock, brooklime, hoary willow-herb and water forget-me-not. Pipewort occurs locally in bog pools and lakes near the west coast.

Fire and drains

Athough many fires are caused by people, either deliberately or accidentally, bog fires are a normal and natural hazard for the wild plants of the bog. Under natural conditions however they are rather rare events, and though their effects are devastating in the short term, the vegetation soon recovers. A bog fire is relatively superficial; it sweeps over the bog, affecting only the surface, because the amount of woody vegetation is not all that great except in drier areas of the bog where heather is abundant, and the roots of the plants are protected deep in the waterlogged sphagnum and peat. On the other hand, burning favours the invasion of tufted sedges and grasses – hare's-tail cottongrass, deergrass, purple moor-grass – as well as cross-leaved heath and bog asphodel.

Those plants which don't have underground shelters are hardest hit; the epiphytic lichens and liverwort communities on heather, which may comprise as many as 25 species, are completely wiped out, and it takes 30 years or so for them to recover – and 30 years is the normal life span of heather. Mosses which grow in drier situations are also badly hit – especially hummock-forming sphagnum species (notably *Sphagnum imbricatum, Sphagnum fuscum* and *Sphagnum rubellum*).

Plants are slow to colonise the bare surface of burnt peat. Fungi are among the first and most important arrivals, together with the algal complex in which *Zygogonium* is prominent. But if fertiliser is added there is rapid colonisation by bryophytes. Among the first to arrive are the liverwort *Marchantia polymorpha* and the moss *Funaria hygrometrica. Funaria* is an opportunist with a fixed plan of action. Regardless of the physical or chemical treatment, it attains its maximum development in 15-18 months and then declines and disappears. It owes its rapid success in part to the ability of its protonema to spread quickly over the bare ground, in the colonisation of which it is a specialist. Later on these two first arrivals are replaced by other species: particularly *Polytrichum longisetum* (*aurantiacum*), *Campylopus pyriformis, Bryum inclinatum* and *Ceratodon purpureus.*

Drains are usually an essential pre-requisite to turf cutting. They lower the water table in the bog so that the surface becomes drier and easier to work on. If the surface becomes very dry as a result of drainage, as it frequently does at the edge of the bog and along drains, the sphagnum will cease its growth altogether and die off. In situations such as these heather can become very luxuriant. The cladonia lichens thrive under such conditions, and there is a host of different species in the drier parts of bogs (Chapter 9). One of the situations in which they do best of all is on the dry turf cuttings at the side of tracks through mountain bogs, where the cushions of bog lichens can be truly beautiful and quite spectacular.

Bog rosemary often favours the drier edges of raised bog. Bog asphodel is also often more abundant in such situations. The decreased vigour of the sphagnum mosses here gives these other plants more of a chance, and indeed the vegetation becomes rather like that of blanket bogs, where the role of sphagnum is not so overwhelmingly dominant.

The affect of dung and fertilisers

Sheep (or any other animal) dung is an additional source of plant nutrients on grazed bogs, and attracts a considerable range of dung beetles, earthworms and fly larvae that feed on the dung, which also has its own distinctive fungus flora. A clear illustration of the affect of fertilisers on the natural vegetation of the bog is often seen around lone bog pines used as roosting places by birds, under which the vegetation is completely different. The most dramatic example of this phenomenon on record is Lloyd Praeger's description of the Seagull bog near Tullamore, which a hundred years ago had one of the largest breeding colonies of black-headed gulls in the country, and was protected by Lord Digby because of the good service the birds rendered on the farm. Where the gulls had established their great colony, right in the very centre of the bog where it was 'intersected by a maze of pools and dangerous quagmires,' the natural vegetation of the raised bog was completely replaced by beds of rushes (common and sharp-flowered), creeping soft-grass, along with common chickweed, heath groundsel, rape, procumbent pearlwort, sticky mouse-ear and hoary willow-herb. Essentially the same thing can be seen on dry hummocks frequented by hares or grouse. Fertilisers have the same affect, but they are a relatively recent arrival on the farming scene. Manufactured phosphatic fertilisers in the form of Peruvian guano and bone meal only became widely available to farmers around the middle of the 19th century, and the growth of the Co-Op movement later in the century gave a great boost to the use of artificial fertilisers. In some parts of the country peat itself was valued as a manure, mainly because it improved the texture of heavy soils; it was often mixed with other materials. Peaty scraws were cut from the mountains in some areas, and composted for use on potatoes.

Trampling, overgrazing and erosion

There has been increasing concern in recent times about the extent of peat erosion in Ireland. The introduction of EU headage payments for sheep led to stocking rates on blanket bog of up to ten times the normal carrying capacity of the land, which resulted in rapid and widespread erosion of the vegetation and underlying peat. In the more vulnerable areas of Connemara and parts of Kerry, Donegal and Mayo the bog has been churned up into deserts of black slime: in Michael Viney's words, 'greasy black tongues and terraces of naked peat, sometimes (as in the Maam Valley) a whole hillside of degraded commonage oozing down to the road,' extending further and further into the last corners of mountain wilderness all down the west coast. The peat mud is washed away by wind and rain; when it dries the hard flakes and nuggets of baked mud are blown away or carried to the nearest stream by surface runoff, exposing more and more of the bare rock beneath. In spring and summer the silt clogs the spawning beds of trout and salmon, and in winter it often stains the ocean off the mouths of the rivers that carry it from the land.

Little research has been carried out on peat erosion in Ireland. One of the earliest studies was carried out in the uplands of Northern Ireland by Roy Tomlinson, who discovered there that erosion of peat by water occurs quite naturally both in channels that form on level ground and along gullies on sloping ground, but that such erosion does not occur below 300m.

A study by Eddie McGee and Richard Bradshaw has shown that peat erosion is not a recent phenomenon; there is evidence that it has been going on for several thousand years. In lake sediments sampled from Donegal and Wicklow, sphagnum leaves were recorded at horizons that showed increased levels of organic matter over a period extending back 2-3,000 years. These inputs to the lakes from the surrounding landscape did not coincide with woodland clearance, which had occurred much earlier. This suggests that peat erosion is a natural, on-going process with altitude, slope and exposure being the main contributing factors once peat has accumulated to a certain depth, accelerated at times no doubt by prehistoric grazers. This is a slow process however and quite different from the rapid removal of peat seen in recent years, which is almost entirely man-induced. But while we now appreciate that upland peat erosion is a natural process in itself, recent farming practices have severely exacerbated the rate of erosion. This has left us with a legacy of irretrievable damage, where vast areas have been denuded of peat and are often stripped completely due to erosion after the vegetation has been grazed away [**Plate 12**].

Due to the recent crisis of peat erosion, more intensive research effort has been directed at the change of species composition in blanket bog due to overgrazing and trampling. Andy Bleasdale and Micheline Sheehy-Skeffington have recently shown that overgrazing of blanket bog in Connemara results in loss of species diversity and a change from heather-dominated communities to grass-dominated ones, particularly purple moor-grass and mat-grass. This can be attributed directly to overstocking as a result of ewe premiums doled out to Less Favoured Areas. Gerry Doyle and Fiona Dunne looked at the affect of trampling (by both sheep and tourists) and grazing on the vegetation of blanket bog, and noted the way in which aggressive species such as furze may be unwittingly introduced by these activities. Other studies near Killarney National Park have tried to estimate the optimum grazing levels in commonage shared by many farmers. The aim is to discover the carrying capacity of the area before peat erosion starts to occur. There is at present a feeling among farmers that they want to avoid the mistakes of the past as their livelihoods depend upon sustainable farming methods. The Rural Environmental Protection Scheme (REPS) provides extra payments for reducing grazing pressure on extensive areas of commonage, but unless all the farmers involved make a concerted effort, the scheme can have little impact on these upland landscapes.

A significant first step in regaining lost ground in the fight against erosion was the decision late in 1995 to award payments through REPS for the reduction of flock numbers in designated degraded areas. To qualify for REPS before this, farmers had to remove sheep from the hills between November and April, but many did not have the facilities to look after them closer to home during the winter months. Under the new arrangement farmers were paid £31 for each ewe removed from the flock, with an area-based top-up payment of from £60 to over £100/ha up to a maximum of 40ha. This means that a farmer who reduced his flock from 200 to 100 would be paid £3,500 for doing so; a reduction from 1,000 to 500 would qualify for a payment of over £7,500. Some 15,000 sheep farmers qualified for the new payments. Another important element of the scheme was the initiation of a research programme to study the affects of erosion, with funding of £300,000 over four years.

Every time ponderous mammals like humans walk across a bog they cause damage to its plants – not infrequently crushing cushions of cladonia that have taken decades to grow. Even the footprints we leave in apparently resilient carpets of sphagnum may take a year or two to disappear altogether. Tufted species (such as deer sedge, black bog-rush and white beak-sedge) seem to have a selective advantage where trampling is frequent, but the areas of bare peat between the resistant tufts are very liable to erosion in exposed situations, and it may well be overstocking – and perhaps overburning – in the eighteenth and nineteenth centuries that triggered off the extensive 'natural' erosion of upland peat that we see in places like Donegal and Wicklow today. Preferential grazing on heather by sheep also favours the establishment of tufted species. In the end, overgrazing of drier blanket bogs is likely to end in the replacement of the bog altogether by a coarse kind of heathy grassland dominated by mat-grass and heath rush.

The vegetation of bogs: plant societies

In nature, plant species seldom occur on their own, but with other species in communities. Each species has distinct preferences, and the fidelity of species for particular communities is the basis of the most widely-used system of phytosociology, the Zurich-Montpellier system originally developed by Braun-Blanquet. The recognition of plant communities is based on extensive field work over many years, and the assembly of innumerable *relevés,* which are samples of the vegetation in a community recording the *cover* and *abundance* of each species in the sample, as well as environmental variables. Cover and abundance are recorded on one side of the relevé survey card using standard scales, and on the other side as much information as possible about the environmental conditions that characterise this particular community is recorded. Analysis of a large number of relevés will show the relative *constancy* of the different species, and using all this information, different communities can be defined in terms of the species they comprise, and the environmental conditions under which the community occurs. Some species are confined almost exclusively to a particular community: these are known as the *character* species of the community. Other species, which can be found elsewhere, but constantly occur in the community, are called *companion* species. Species that can be used to differentiate between closely related communities on a presence/ absence basis are referred to as *differential* species [**Table 6.1**]. The term ‘diagnostic species’ is used for characteristic species of the community whose precise ‘sociological status’ in the community is still uncertain. Communities are classified within an ordered hierarchical system, and are named after their distinctive character species. The fundamental unit in this classification is the *association,* a concept that is abstract in the same way that ‘species’ is. Related associations are grouped in a common *alliance,* related alliances in a common *order;* orders in turn are grouped into *classes* and classes into *formations.* Associations and other categories are named after one or two of the species considered typical of the assemblage, and given a diagnostic suffix; for example, the association suffix is *-etum.* Unlike the other levels, the class is defined by character species only.

Table 6.1: THE PHYTOSOCIOLOGICAL HIERARCHY

Level	Category Ending
FORMATION	
CLASS	-etea
ORDER	-etalia
ALLIANCE	-ion
SUB-ALLIANCE	-enion
ASSOCIATION	-etum
SUB-ASSOCIATION	-etosum
VARIANT	

It is important to remember that no real community conforms in every detail to the abstract blueprint set out in the definition of any particular association. The association is an attempt by plant ecologists to group together closely similar but not identical communities, and to organise the grouped communities in an ecologically meaningful hierarchy. No two communities are identical, because there is an almost continuous spectrum of environmental variables and a corresponding spectrum of plant communities. So, while it will often be easy to attach the badge of a particular association to real-life communities, there are others for which it will not be so easy. The hierarchical levels are defined in spatial terms only, as if they were fixed for all time. But while many communities are closed and relatively stable, none is entirely so, and very many are transient and transitional. The time dimension is an integral part of the makeup of the real community. Another difficulty is posed by the way in which the ecological and genetic profiles of the defining species vary in different parts of the range of the species. It should also be remembered that associations and other categories are defined almost exclusively in terms of vascular plants and bryophytes: but fungi and algae are also part of the framework of a real plant community. Leaving them out is like trying to describe the universe without taking account of the dark, invisible matter of which it is mostly made.

Two of the classes that comprise the *peatland formation* occur in Ireland. Wet bogs and heaths all over the world are grouped together in the class Oxycocco-Sphagnetea, and dry heaths are assigned to the Calluno-Ulicetea. Character species for the Oxycocco-Sphagnetea include bog rosemary, cranberry, common sundew, several bog mosses, and liverworts like *Cephalozia connivens* and *Lepidozia setacea.* The most widespread order in the class is the Eriophoro vaginati - Sphagnetalia papillosi, which comprises all ombrotrophic peatlands.

Different kinds of bogs are assigned to different orders, alliances and associations. The raised bogs of the Midlands belong to the association Erico-Sphagnetum magellanici, which is characterised in most of north-west Europe by the following diagnostic species:

cross-leaved heath, bog asphodel, *Sphagnum imbricatum* and the liverwort *Odontoschisma sphagni*. Irish plant sociologists consider this a rather unsatisfactory selection because these plants are common in other kinds of Irish bogs too. The differential species provide a more useful distinction: the presence of bog rosemary and cranberry distinguishes the association from Atlantic blanket bog, and the presence of three sphagnum species (*S. fuscum*, S. *magellanicum* and S. *imbricatum*) distinguishes it from mountain blanket bog.

Table 6.2:

THE COMMUNITIES OF BOGS AND HEATHS IN IRELAND

(Condensed from White and Doyle, 1982).

Heaths are included in this synopsis because they are frequently associated with bogs or have developed on former bogs.

BOGS

CLASS **Oxycocco-Sphagnetea**. Bog and wet heath vegetation on waterlogged peat of low pH (3.2-4.2). Originally described by Braun-Blanquet and Tuxen in 1943.

Character species: flowering plants - bilberry, bog rosemary, common sundew, hare's-tail cottongrass; bryophytes - *Sphagnum fuscum, S. magellanicum, S. nemoreum, S. rubellum, S. tenellum, Pohlia nutans var. sphagnetorum, Calypogeia trichomanis, Cephalozia connivens, Lepidozia setacea, Mylia anomala.*

ORDER 1: **Sphagnetalia compacti.** Communities of shallow peat on lower slopes of mountains and of wet cutover.

Character species: flowering plants - cross-leaved heath, deergrass (var. *germanicus)*, heath rush; bryophytes - *Sphagnum compactum, S. strictum.*

Alliance Ericion tetralicis. Wet heath communities of the Atlantic fringes of north-west Europe.

Character species similar to those for the order.

Differential species: tormentil, heath milkwort, lousewort, carnation sedge, devil's-bit scabious.

Association: Narthecio-Ericetum tetralicis. Boggy vegetation of lower hill slopes and cutover bog.

Character species: flowering plants - cross-leaved heath, bog asphodel, heath rush; bryophytes - *Sphagnum compactum.* The differential species of the alliance as a whole are also of diagnostic value.

Association: Lycopodio-Rhynchosporetum albo-fuscae. A rare community in need of further study.

Character species: marsh clubmoss, brown beak-sedge.

Differential species within the alliance: white beak sedge, intermediate sundew.

ORDER 2: **Eriophoro vaginati - Sphagnetalia papillosi.** Communities on deep undisturbed peat in oceanic areas.

Alliance Calluno-Sphagnion papillosi. Communities on deep, wet peat (>2m) in north-west Europe.

Diagnostic species: flowering plants - bog asphodel, white beak-sedge, hare's-tail cottongrass; bryophytes - *Campylopus paradoxus, Sphagnum imbricatum, Cephalozia bicuspidata, Diplophyllum albicans, Mylia anomala, Odontoschisma sphagni;* lichens - *Cladonia portentosa, C. uncialis.*

Association: Erico-Sphagnetum magellanici. Sphagnum-dominated vegetation of hummocks and lawns of raised bogs.

Diagnostic species: in north-west Europe generally cross-leaved heath, bog asphodel, *Odontoschisma sphagni* and *Sphagnum imbricatum;* since these species all occur in other deep-peat associations in Ireland, the diagnostic species need to be supplemented by differential species groups (See text).

Association: Pleurozio purpureae - Ericetum tetralicis. Vegetation of low-altitude (Atlantic) blanket bog in western Ireland.

Character species: flowering plants - black bog-rush; bryophytes - *Pleurozia purpurea, Campylopus atrovirens.*

Differential species within the alliance: flowering plants - tormentil, lousewort, heath milkwort, pale butterwort, purple moor-grass.

Sub-association I: typical sub-association
Sub-association 2: zygogonietosum
Sub-association 3: juncetosum
Sub-association 4: droseretosum
Sub-association 5: scirpetosum (See main text)

Association: Vaccinio-Ericetum tetralicis. Vegetation of mountain blanket bog.

Diagnostic species: bilberry, crowberry, hare's-tail cottongrass.

Differential soecies from western blanket bOl!: bOl! rosemarY. cranberrY.

ORDER 3: **Scheuchzerietalia palustris.** Communities of wet hollows on bogs.

Character species: flowering plants - mud sedge, white be°ak-sedge, bogbean; bryophytes - *Sphagnum cuspidatum, S. apiculatum. S. subsecundum. Cladopodiella fluitans.*

Alliance Rhynchosporion albae.

Character species: Rannock rush, white beak-sedge, brown beak-sedge, oblong-leaved sundew; bryophytes - *Sphagnum cuspidatum,* S. *pulchrum, Drepanocladus fluitans, Cladopodiella fluitans.*

__Association__**: Sphagno tenelli - Rhynchosporetum albae**. Vegetation of permanently waterlogged hollows on raised bogs; less well-defined on blanket bogs. Includes some cottongrass communities of drainage channels.

Diagnostic species: flowering plants - white beak-sedge, brown beak-sedge; bryophytes - *Sphagnum cuspidatum, S. tenellum.*

__Association__**: Scheuchzerietum**. Only known in Ireland from one station on Pollagh Bog, destroyed in the 1960s.

Character species: Rannock rush, mud sedge.

__HEATHS__

__CLASS__ **Calluno-Ulicetea**. Shrub heath vegetation on shallow peaty soils and podzols. Originally described by Braun-Blanquet and Tiixen in 1943.

Diagnostic species: heather, bell heather, common furze, western furze, crowberry.

ORDER 1: **Ulicetalia minoris.** Lowland heaths dominated by furze.

Alliance Ulici-Ericion cinereae. Most Irish lowland heaths belong here.

Character species: western furze, bell heather.

__Association__: Ulici gallii - Ericetum cinereae.

Character species as for the order.

Alliance Ulici-Ericion ciliaris. Heaths with rare *Erica* species.

Diagnostic species: Dorset heath, Cornish heath.

__Association__**: Ulici gallii - Ericetum ciliaris**. Confined to a small area of hollow ground near Roundstone, County Galway, a tiny remnant of what was probably a much wider distribution in warmer postglacial times.

Character species: Dorset heath, purple moor-grass.

__Association__**: Ulici gallii - Ericetum vagantis**. Confined to a nutrient-rich heathy flush at Carrick brawn in County Fermanagh.

Character species: Cornish heath.

Alliance Sarothamnion scopariae. Dry heath vegetation found on the dry edges of some drained or reclaimed bogs.

__Association__**: Calluno-Sarothamnetum.**

Character species: broom, greater broomrape.

ORDER 2: **Vaccinio-Genistetalia**. Heathland of upland and more continental areas.

Diagnostic species: heather, bilberry, crowberry.

Alliance Genisto-Callunion.

Diagnostic species: heather, bell heather.

__Association__**: Calluno-Ericetum cinereae**. Dry *Calluna*-dominated heaths of mountain slopes. These are the grazed sheep and grouse moors, regularly burned and nowadays often planted with conifers.

__Association__**: Antennario-Callunetum.**

Diagnostic species: cat's-foot, heather.

__Association__**: Hyperico-Dryadetum**. Heathy grassland in the Burren etc.

Diagnostic species: slender St-John's-wort, mountain avens, heather.

Alliance Vaccinio-Callunion. Heathlands of high mountain areas.

Diagnostic species: heather, bilberry, cow berry, bearberry, crowberry.

__Association__**: Lycopodio alpini - Rhacomitrietum lanuginosi**. Windswept and dwarfed shrub heath of mountain-tops.

Diagnostic species: Alpine c1ubmoss, dwarf willow, stiff sedge, dwarf juniper, bearberry, cowberry; bryophytes *Rhacomitrium uliginosum*

__Association__**: Herberteto-Polytrichetum alpini**. Moss-dominated communities of steep sheltered mountain slopes in the Kerry and Connemara mountains.

Diagnostic bryophyte species include *Herberta adunca, Pleurozia purpurea, Plagiochila spinulosa, Anastrepta orcadensis, Bazzania tricrenata.* Common species of vascular plants in the association include heather, fir clubmoss, St Patrick's cabbage, greater woodrush.

__Association__**: Arctostyphylo-Dryadetum.** Heath vegetation of higher mountains in the Burren.

Diagnostic species: mountain avens, heather, dwarf juniper, bearberry, crowberry, common wintergreen, lesser twayblade.

Alliance Empetrion nigri. Sand dune heaths.

Diagnostic species: crowberry, creeping willow, sand sedge.

PFLANZENSOZIOLOGISCHE
SYSTEMATIK

BERICHT ÜBER DAS
INTERNATIONALE SYMPOSIUM IN STOLZENAU/WESER
1964
DER
INTERNATIONALEN VEREINIGUNG FÜR VEGETATIONSKUNDE

HERAUSGEGEBEN VON
REINHOLD TÜXEN

A CLASSIFICATION OF THE BOGS AND WET
HEATHS OF NORTHERN EUROPE
(Oxycocco-Sphagnetea Br.-Bl. et Tx. 1943)
by
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VERLAG Dr. W. JUNK N.V. — DEN HAAG — 1968

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INTRODUCTION

etation dealt with in this scheme of classification are
ine: *Sphagnum* spp. dominate in the ground layer; the
aterlogged peat of low ash content (< 5%) and low pH
erm „bog", derived from the Irish word „bogach",
und, was introduced into the ecological literature by
and is now the accepted term in English-speaking coun-
of formation.
vegetation type transitional to dry heath (Calluno–
hich a large number of the bog species persist, but with a
d a less complete cover of sphagna in the ground layer
been included in the same class as the bogs. It is here
de also within the class the transitional vegetation at the
t European boreal bogs.
logical classification of the vegetation of European bogs
ith in the monographs of SCHWICKERATH (1940) and of
49). Besides, summary classifications of the vegetation
l regions have included a treatment of the bogs (NORD-
UN-BLANQUET & TÜXEN 1943, TÜXEN 1955, OBERDOR-
ETZ 1950). Two main tendencies may be seen in these
e first main-subdivision may be made on a geographical-
e bogs and wet heaths of the Atlantic sector with *Erica*
order (or alliance in the older publications), those of the
l sector with *Ledum palustre* form the other (TÜXEN
RDORFER 1957, BRAUN-BLANQUET 1949, NORDHAGEN
1963). In the other systems the first main sub-division
stic: the wet heaths on shallow peat with *Erica tetralix*
in one sub-division, the deeper bogs with pronounced
ance in the other (SCHWICKERATH 1940, DUVIGNEAUD

al sub-division seems to be generally accepted today and
appears in the two most recent attempts at providing a summary classification of European vegetation (TÜXEN 1962, ELLENBERG 1963). A proposal is here made to revert to the ecological-floristic sub-division of the earlier monographs for the following reasons:

Figure 6.30: The approach to phytosociology pioneered on the continent by Reinhold Tüxen was introduced into Ireland by J. J Moore. In particular, Fr Moore produced the first phytosociological classification of the bogs of north-west Europe (in his classic paper of 1968, of which the title and first page are shown here).

Low altitude western or Atlantic bogs belong to the association **Pleurozio purpureae - Ericetum tetralicis**. This is characterised by the presence of the moss *Campylopus atrovirens* and the liverwort *Pleurozia purpurea* and more locally by black bog-rush. The species which differentiate it within the alliance are tormentil, lousewort, heath milkwort, pale butterwort and purple moor-grass. The rare Mackay's heath occurs in this association in west Galway and at Lough Nacung in west Donegal.

There are several different varieties of Atlantic blanket bog, which reflect variations in the depth and nutrient status of the bog. These are assigned to different sub-associations. The commonest and most widespread – the *typical* sub-association – is characterised negatively by the absence of bog rosemary and cranberry. Order character species that are prominent include *Odontoschisma sphagni* and *Sphagnum papillosum*, and sometimes hare's-tail cottongrass, species one associates more with raised bogs. Many of the commonest and most abundant species are *alliance character species* – heather, cross-leaved heath, bog myrtle, purple moor-grass, bog asphodel, white beak-sedge, deergrass, *Campylopus paradoxus (flexuosus), Sphagnum subnitens, Leocobryum glaucum, Cephalozia bicuspidata, Mylia anomala, Cladonia portentosa* and *Cladonia uncialis*. The character species include black bog-rush along with *Pleurozia purpurea* and *Campylopus atrovirens;* large hummocks of *Racomitrium lanuginosum* are also often a characteristic feature. The differential species include tormentil, heath milkwort, lousewort and pale butterwort. Widespread companion species are common cottongrass and the mosses *Sphagnum palustre* and *Hypnum cupressiforme* var. *ericetorum.*

Four other sub-associations can be recognised. In permanently waterlogged depressions and hollows where gelatinous algae thrive, there is a distinct sub-association called the **zygogonietosum**, characterised by the algal complex (which includes up to sixty species of mucilaginous and other algae), *Sphagnum magellanicum* and great sundew. Another distinct community occurs where there is movement of water on the surface, or disturbance by grazing animals, when species like many-stalked spike-rush, carnation sedge and bulbous rush occur in a sub-association called the **juncetosum**. A different community again (**droseretosum**), characterised by oblong-leaved sundew, bog-sedge, and the liverwort *Riccardia pinguis,* often accompanied by brown beak-sedge, is found in runnels and depressions where there is lateral water movement in the surface peat. The fifth type is the **scirpetosum**, which develops where the bog is shallow, and is characterised by species which include the moss *Leucobryum glaucum* and a distinct variety of deergrass (var. *germanicus).*

Another bog alliance that occurs widely is **Rhynchosporion albae**, to which communities of natural wet hollows, pools and flushes both on raised and blanket bog are assigned. *Sphagnum pulchrum* is a characteristic species in these situations, though it is also found elsewhere. A number of sub-associations of raised bog can also be recognised, but they are less well characterised.

The communities of heathy vegetation dominated by heather and furze that develop on shallow peat are assigned to the shrub-heathland class (**Calluno-Ulicetea**), which includes several widespread associations. The diagnostic species for the class as a whole are heather, bell heather, common and western furze and crowberry. Apart from the communities of the bog proper, there is often a mosaic of grassland and wetland communities along the fringes of the bog. These include the wet grasslands of the alliance **Junco-Molinion** in the order **Molinietalia**, the acid grass heaths in the **Nardetea** and the willow scrub communities which belong in the alliance **Salicion cinereae**.[1]

Bog plant communities can also be classified in a variety of other ways. The system now favoured in Great Britain (the National Vegetation Classification of Rodwell and others) recognises three communities and several sub-communities in raised bog vegetation. The most widespread community is the cross-leaved heath - *Sphagnum papillosum* community, which can be subdivided into two as follows:

(a) Situated between hummocks and pools there is a *Sphagnum magellanicum* - bog rosemary sub-community. This is dominated by three sphagnum species: *S. papillosum, S. capillifolium* and *S. magellanicum,* with some *S. tenellum.*

[1] An extensive literature in the field of phytosociology has developed over the last 50 years or so. Readers in whom this brief introduction stirs the fascination which so many naturalists feel for the detail of the phytosciology of the plant communities of natural and modified peatlands can enter this world through the key synopses available in the publications of Gerry Doyle and J. J. Moore, Jim White and Gerry Doyle's *Catalogue Raisonné* of Irish vegetation (1982), and the papers by Austin O'Sullivan on wet grasslands (1968) and of Michael O'Connell *et al.* on minerotrophic wetlands (1984).

(b) On the larger, drier ridges and hummocks there is a crowberry - cladonia community.

Most bog pool vegetation is assigned to communities dominated by *Sphagnum cuspidatum* or *S. recurvum,* along with common cottongrass, cross-leaved heath, round-leaved sundew and white beak-sedge:

(a) *Sphagnum cuspidatum* is dominant in the white beak-sedge sub-community; bog rosemary, common cottongrass and cross-leaved heath are characteristic.

(b) *Sphagnum recurvum* dominates a sub-community named after it. Cranberry is a preferential species, and white beak-sedge is absent.

In more oceanic raised bogs a distinct community is recognised. *Sphagnum auriculatum* dominates this, and *S. cuspidatum* is much less prominent. Bogbean and common cottongrass often occur here.

A refinement of this approach by Lindsay and his colleagues distinguishes six vegetation zones on the basis of position within the surface microtopography, with the water table acting as a base line; three of these zones rise above the water table, three extend below. This system formed the basis for the classification adopted by Leach and Corbet in their survey of the raised bogs of Northern Ireland in 1985-86, which divided the vegetation into fourteen 'informal' communities, essentially on the presence/absence or dominance of certain key species:

1. High hummocks and ridges dominated by crowberry. Heather is often abundant, as are *Sphagnum subnitens* or *S. capillifolium.* Bog myrtle occurs only in this community.
2. High hummocks and ridges dominated by *Cladonia portentosa.* Again, heather often co-dominant. *Hypnum cupressiforme* constant, but sphagnum not prominent. Bog asphodel frequent.
3. Hummocks dominated by *Sphagnum fuscum* and/ or *S. imbricatum.* Heather and crossleaved heath often co-dominant. *Hypnum cupressiforme* and *Cladonia portentosa* much reduced in importance. Bog asphodel and common sundew constant. Especially characteristic of the middle of the bog.
4. Low hummocks dominated by *Sphagnum capillifolium* and/or *S. subnitens.* Heather dominant on higher hummocks. *Sphagnum tenellum* constant but not common. A widespread community.
5. Low hummocks or lawns with *Sphagnum papillosum.* In this community *Sphagnum papillosum* and *S. capillifolium/subnitens* are co-dominant with heather and cross-leaved heath. *Sphagnum magellanicum* frequent, but *Hypnum cupressiforme* and *Cladonia portentosa* less important than in the earlier groups.
6. Lawns with *Sphagnum magellanicum,* often co-dominant with *S. papillosum.* Heather and cross-leaved heath much less prominent. Cranberry and *Sphagnum cuspidatum* frequent.
7. Lawns or pool edges with *Sphagnum pulchrum,* accompanied by *Sphagnum papillosum, S. cuspidatum* and/or *S. auriculatum.* This is the community which occurs on the fringes of pools dominated by *Sphagnum cuspidatum.* White beak-sedge, long-leaved sundew and bogbean also distinctive members of the community.
8. Pools and carpets of *Sphagnum cuspidatum.* This is the characteristic vegetation of pools and hollows. White beak-sedge, long-leaved sundew, bogbean and bog asphodel are all characteristic.
9. Bladderwort pools, often with a patchy cover of *Sphagnum cuspidatum,* together with other pool species like bogbean and long-leaved sundew.
10. Degraded hummocks and ridges dominated by heather and/or cross-leaved heath, with locally abundant cottongrass, black bog-rush and bog asphodel. Little sphagnum. Probably derived from the *Sphagnum papillosum* or *S. capillifolium* communities.

11. Pools with *Sphagnum auriculatum*, often with abundant *S. recurvum.* 'Both these species indicative of lateral water movement or fluctuating water table, and as such generally found on damaged bogs, along drain lines or in pools close to the edge of the uncut surface.'

OTHER COMMUNITIES

12. *Racomitrium lanuginosum* high hummocks.
13. Mud sedge pools.
14. Many-stalked spike rush pools (within *Sphagnum cuspidatum* pools).

There have been some attempts – most notably by John Cross – to apply the Lindsay zones to raised bogs elsewhere in Ireland. Cross characterised the vegetation zones as follows:[2]

Terrestrial zones

Zone T3

Hummocks >20cm above water table dominated by *Sphagnum imbricatum* (occasionally *S. fuscum* and *Leucobryum glaucum).* Heather, hare's-tail cottongrass, crowberry, bilberry, *Hypnum cupressiforme* characteristic. *Racomitrium lanuginosum* on tall hummocks sometimes. [=LC1,2,3].

Zone T2

Lower hummocks or plateaux 10-20cm above water table with *Sphagnum imbricatum* and *S. fuscum,* but more typically *S. capillifolium* and *S. papillosum.* Heather, cross-leaved heath characteristic, with bog rosemary, deergrass and bilberry. Cladonias sometimes abundant. The most widespread zone. [=LC4,5].

Zone Tl

Lawns 0-10cm above water table. Extensive areas in wetter bogs belong here. Dominated by *Sphagnum papillosum, S. magellanicum* and sometimes *S. subnitens* or *S. tenellum.* Common vascular plants include great sundew, common cottongrass, bog asphodel, white beak-sedge and cranberry, sometimes in abundance. [=LC6,7].

The T / A boundary is characterised by a special *Sphagnum pulchurum* community, but this is seldom found in Ireland.

Aquatic zones

Zone ZI

Carpets of *Sphagnum cuspidatum* (occasionally *S. auriculatum)* 0-10cm below the water table. Bogbean and white beak-sedge may be abundant. Lesser bladderwort and *Cladopodiella fluitans* characteristic, and *Sphagnum recurvum* where nutrient levels are somewhat higher. Often widespread on pool margins. [=LC8].

Zone Z2

Peat mud-bottomed hollows 5-25cm below water table, an impoverished version of Zl. Less sphagnum, but characterised by species such as mud sedge, brown beak-sedge and lesser bladderwort. [=LC9,13]. Only on wetter bogs.

Zone Z3

Deeper pools, >25cm deep, with vegetation limited to bogbean.

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[2] LC indicate the corresponding Leach and Corbett communities.

Heather and heath communities

Heather-dominated vegetation (Callunetum) is far more common in upland blanket bogs in the east than it is in the west, but heather grows best in well-drained situations: on dry hummocks and towards the edges of bogs where drainage has dried out the surface peat. Heather (as well as bilberry and cowberry) has a superficial rooting system; the roots do not have the large air channels found in plants that grow in waterlogged, oxygen-deficient parts of the bog. On the blanket bog of the Dublin-Wicklow Mountains, heather is dominant in a zone that lies between the heathy pasture of the lower slopes (where western furze is often abundant) and the deergrass dominated vegetation (Scirpetum) of the higher plateaus, and is – or was – regularly burnt to increase the supply of young shoots for grouse. Many other species occur along with the heather, especially bell heather, mat-grass, tormentil, bilberry, heath rush, green-ribbed sedge and heath bedstraw.

Heather is probably more extensive on the Mourne Mountains than anywhere else in Ireland. Here it occupies virtually all of the higher ground except for the summits over 220m high, which are covered with alpine grassland dominated by sheep's-fescue and the moss *Racomitrium lanuginosum.* This looks quite different from the heather bogs of Wicklow, because the heather on the Mournes seldom grows more 10cm high. In basins and cols the vegetation is dominated by purple moor-grass (Molinietum) and deer-sedge (Scirpetum), and bell heather is locally more abundant than heather. Bilberry sometimes replaces heather as the dominant plant on well-drained slopes, boulder scree and along streams and tracks.

In recent decades overstocking with sheep has seen a widespread decrease in the cover of heather on western blanket bog in particular. In Praeger's day, heather clothed Clare Island almost to the summit; today the cover is thin and sparse. The reduction in heather has led to a decline in the diverse invertebrate fauna it supports, and this has had an impact on animals further up the food chain, such as lizard, grouse, pipit and merlin. One is particularly aware of the impact of sheep where they are fenced out or otherwise excluded, as in the National Parks at Glenveagh and Connemara, or in the Nature Reserves on Mount Brandon and Slieve Bloom, and the effect on the vegetation of their absence can be clearly seen.

Heather played an important role in the development and extension of blanket bog as dry, warm and continental conditions gave way to cooler and wetter conditions some 2,500 years ago. The clearance of woodland from sandy soils provided an extensive new habitat for heather; humic acids produced by the decaying heather combined with iron in the mineral soils to give soluble compounds that were readily leached downwards through these permeable soils in a climate that was becoming increasingly wet. In this way podzolic soils were formed, with an upper leached, *eluvial* A horizon and a lower *illuvial* B horizon. The acidity and low nutrient status of the leached horizons, combined with the often impermeable character of the B layer below, provided conditions where heath and bog communities could become established. Although this process was probably taking place ever since Irish farming started in the Neolithic period, the onset of cool, moist weather conditions in the Sub-atlantic greatly favoured heather, especially as iron tools for more efficient woodland clearance became available at this time for the use of progressive and ambitious farmers.

Societies in change: the plants of modified bogland

Areas of bare peat are a rare opportunity for plants and animals to extend their domain. Once the turf is home and dry, the empty space of the spreading ground is invaded by a host of would-be colonists. There may be disturbance every year for many years during the turf harvest, but this is one of the challenges of the new habitat which new arrivals have to be able to live with. The newcomers arrive from two directions. From one side come the plants of the bog, attempting to regain a foothold in their lost territory, and from the opposite site this new land is open to invasion from field and farm, wood and hedgerow. But this is still a difficult habitat for plants. It may be much drier than undrained bog, but it is still generally very acid, and low in nutrients. A range of factors determine what plants will be successful in taking over the new territory, the main ones being the nature and depth of the remaining peat, the composition and extent of bog vegetation remaining in the vicinity, and the local hydrological regime.

Where only the superficial peat is removed the natural vegetation will often be able to reclaim its lost territory, especially if the area concerned is small and the original bog vegetation surrounds it. Time is another critical factor in recolonisation. When the original bog vegetation is stripped away from extensive areas, recolonisation is a very slow process; after ten years or more there may still be extensive areas of bare peat. Over most cutaway areas, the early colonists are often dominated by the rushes (common rush, jointed rush, sharp-flowered rush and others) and several species of sedges.

Bog asphodel and cross-leaved heath are sometimes dominant in areas from which turf has been cut but where conditions still remain wet. This distinctive community is assigned to an association seldom encountered under strictly natural conditions: Narthecio-Ericetum tetralicis. It is more common in areas of blanket bog, but not infrequent in cutover raised bog. Wherever the water table is still high enough, the bog may begin to grow again, but this does not happen very often. Some of the plants that were more or less confined to the dry islands of the hummocks on the intact bog, or the edges of the bog, have a chance to extend their range where turf cutting has led to much drier conditions. This new vegetation may be dominated by heather on its own, accompanied by the various lichens and mosses that accompany it; or by heather and purple moor-grass, with mosses and cladonia lichens (especially *Cladonia floerkeana*). But these old bog plants have to share their territory with other colonists from the other direction, notably species like bracken and sheep's sorrel that thrive on the bare peat. Once bracken gets a hold it can spread across large areas, and if it becomes established it is almost impossible to remove, because when its thick forests of fronds and stems die back in the autumn, all the food reserves those powerhouses have manufactured during the year are carefully stored away in dense networks of branching cable-like rhizomes underground.

The climax vegetation on cutaway bog is birchwood, and although the fringing birch groves seldom form more than a narrow, discontinuous strip around most bogs, they link up to form an extensive network, which cumulatively covers a very large area. Much larger and more continuous areas of peatland are now planted with spruce and pine, and although this effectively destroys the botanical value of these bogs, the new woods have much mycological interest. These aspects are dealt with in later chapters.

Turraun

Perhaps the best place to see what can happen when cutaway bog is left to its own devices is Turraun, the bog south of the village of Pollagh in North Offaly. Turraun was one of the first bogs to be taken into production by Bord na Móna – in fact it was in mechanical production before the advent of Bord na Móna. The underlying marl was reached in the early 1970s, and production was gradually phased out in the northern part of the bog from 1973. About 120 hectares of the 570 hectare bog complex was abandoned to nature. All that remained was a variable but generally thin layer of peat overlying deep marl. The old bog drains were still there, now cutting deep into the basal marl, and a few higher areas of glacial gravel rose above the general level of the cutover here and there. Part of the area was put under experimental plots of grass and trees, and part was just left to itself to see what would happen.

This was a rare opportunity for wildlife, and very quickly invading plants and animals turned it into a wilderness. There is great diversity in the vegetation today, reflecting different degrees of waterlogging, the nature of the exposed and underlying peat, pH and nutrient levels. After less than twenty years, something like 160 species of flowering plants and ferns had settled in Turraun. Marsh arrowgrass was the first colonist to venture onto the wetter areas of bare peat, making its way underground from its strongholds along the drains. In drier areas the pioneer vegetation is often dominated by extensive carpets of the moss *Campylopus introflexus.* These become unstable after a time and break up, preparing the ground for the invasion of a rich variety of vascular plants. Elsewhere the first life to colonise the bare surface is the extraordinary alga *Zygogonium ericetorum,* which binds the unstable peat dust with a web-like network of fine golden threads.

Wetter areas have reeds, often accompanied by an abundance of gipsywort, and in these damper areas lush colonies of common rush quickly establish themselves. But for most of the drier cutaway, the next stage in the progress of colonisation is grassland. This is quite a distinctive kind of grassland; horsetails often play a dominant role, and such plants as twayblade and knotted pearlwort occur as character species. Nowhere else indeed will one see knotted pearlwort so abundant; in July and August, when in flower, it is a really attractive plant. The uncommon heath groundsel frequently occurs on the bare peat, and the unusual conditions also suit a number of other uncommon species.

But this rich grassland phase is short-lived. Much of the area is evolving to birch woodland, with rusty sallow as a junior partner, and in time the various pioneer colonists are likely to disappear. The area is also a wonderful refuge for animal life, though the only group of animals which has so far been studied in detail is the avifauna. Over fifty species of birds have been recorded, about half of which breed in the reserve, including the rare grey partridge. Part of the area has been flooded by Bord na Móna, in order to increase the attraction of the area for water birds, especially in winter.

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Chapter Seven

Trees on the bog

Mr Kelly of Castle Kelly has drained and improved some bog near the edge of his domain: part of it has been planted with Scotch fir, larch, and alder, which appear in general to have succeeded extremely well. In fact where draining has been sufficiently attended to, there are very few instances of the failure of plantations on bog: The average depth of these bogs is twenty feet.

Richard Griffith's Second Report on the Bogs of Galway and Roscommon. Appendix No. 9 to the *Fourth Report of the Bogs Commissioners* (1814).

Under the conditions which have prevailed in recent centuries, the bogs of Ireland are open, windswept wilderness areas virtually devoid of tree cover. Indeed, the absence of trees is one of the characteristic features of Irish bogs, but peatlands of other kinds in mainland Europe and elsewhere in the world are often naturally wooded. So abundant are buried tree trunks in some of the bogs of Russia that they can only be exploited by liquifying the peat before it is extracted. Tree stumps are of course often found entombed in Irish bogs too: the remains of pine, oak and yew woods that grew around the early fens, and were later swamped by the expanding bogs, or of pine trees that invaded the open surface of the bog during periods when the climate was drier, only to die as wetter conditions returned. Once a bog is drained, pine and birch and willow become established on the peat, and most cutover and cutaway bog would in time revert to birch or pine woodland if left to its own devices. While peatland utilisation for tree plantation developed quickly in the 1960s, forestry moved onto bogs with some difficulty. Prospects are now limited for further forestry development on both blanket and intact raised bogs where peatland restoration following felling of the trees has shown promising results. Better forestry potential exists for the afforestation of cutaway raised bog, using either conifers or native species.

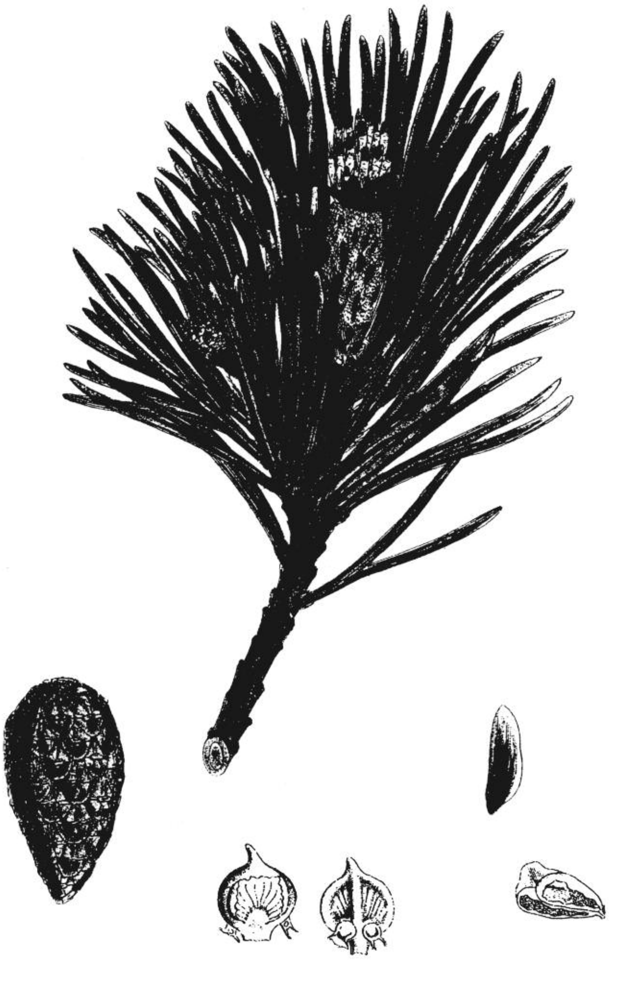

Figure 7.1: Scots pine.

Scots pine [**Figure** 7.1]

Scots pine (*Pinus sylvestris*) is the only native tree that will colonise an Irish bog. However, it needs drier conditions than those afforded by the very wet, actively-growing bogs of recent centuries, so it is to the past, to periods when bog growth was slower and the surface drier, we must look in order to find Irish bogs covered with pine. Or we can look to the future, because with the higher temperatures expected with global warming in the next century, pine will move back again onto those open bogs that survive. There are places where this is happening already, giving us a glimpse of what many bogs will look like in 50 years time [**Figure** 7.2].

Figure 7.2: Invading Scots pine on the edge of Boora bog.

One of the debates which has entertained palaeobotanists for many years is whether native Scots pine survived anywhere in Ireland into the historic period. It is certain that vast quantities of Scots pine seed were brought into Ireland from Scotland in the 18th and 19th centuries, for planting as ornamental and timber trees in what had become a virtually treeless landscape. However, it is hard to believe that occasional native trees did not survive in out-of-the-way places. Declan Murray's palynological study of Clonsast Bog showed that Scots pine was present right through the bog's history, down to 300 A.D. at least; it almost certainly survived on many other bogs as well, although whatever genetic individuality it may have retained will have been swamped in the gene pool of the later introductions. Samuel Waring (1705), a great advocate of the species, while very well aware that most Scots pine derived from introduced seed, believed that native pine still survived in Connaught into the 18th century:

> The Ffirs now mentioned are such as have been produced from Seed brought hither out of *Scotland,* and appear (to those who have seen both) to be the very same species with those yet growing in *Connaught,* which may be a further inducement to us to propagate this kind of Firr-tree, thereby making this Kingdom a Nursery for such Trees, to which it had formerly been a prolifick and indulgent Mother.

When great numbers of Scots pine seedlings sprang up in a newly-enclosed part of the Great Heath of Maryborough (outside Portlaoise) towards the end of the eighteenth century, observers thought they must have come from the dormant seeds of the ancient trees which were at one time frequently dug up in the valleys of the Heath at a depth of four or five feet below the surface:

> there never was known any of this species in that part of the kingdom, except such bodies of them which have been discovered from time to time at the bottom of the adjacent bogs. If this species of pine was ever the produce of this district, **it** must have been in very ancient periods, as the common has been for several centuries a sheep walk, and prior to that appears to have been under agriculture, as the furrows of the plough are every where visible [*Anthologia Hibernica,* January 1794, pp.3-41].

Whatever its origin, Scots pine can be the most majestic of bog plants, even if few trees attain the stature of the venerable Scots pine which still survived in 1866 on open bog near Deal Castle at Crossmolina and was supposed (by the authors of *Cybele Hibernica*, Moore and More, 1866) to be a last relic of the ancient forests … this venerable fir tree, which is probably the same referred to [by James Townsend Mackay] as growing near the foot of Nephin, has been lately fenced in and is carefully preserved by the Earl of Arran …

Birches

Birch returned to Ireland about 12,500 years ago as the grip of the glaciers began to wane. Its advance was briefly checked by the cold snap of the Nahanagan stadial, but it quickly spread across the whole country once it was ice free (Mitchell, 2006). Birch is an opportunist coloniser of open landscapes, its winged seeds germinating easily on open ground, but it is a lover of light and intolerant of the shade of taller trees. Birchwood is the natural climax on many cutaway bogs, and although the fringing birch groves seldom form more than a narrow fringe around most bogs, they cover a very large area collectively and are important wildlife corridors. Birch rarely stakes its claim to the open bog, preferring to hug the drier fringes, although occasionally it will establish itself on very wet bog if there is some access to mineral-rich groundwater. The best example of such a bog birch-grove is on All Saints' bog in County Offaly, which the insect fauna suggests may be of considerable age, even if the individual trees are not.

Ireland has two native species of birch, silver birch (*Betula pendula*) and downy or bog birch (*Betula pubescens*); both occur on bogs, but downy birch is the more common by far [**Figure** 7.3]. Silver birch is a magnificent tree which can grow up to 25m high and a metre in girth, but it is rather rare in the wild. It is a fast-growing tree that reaches maturity in fifty years, and never lives for more than a century. One of the most striking features is the way its bark peels off in strips. The flowers of birch are catkins, pollinated by the wind, and producing enormous numbers of little winged nutlets in autumn. The downy birch is smaller, and tends to be more bushy in its growth habit than the silver birch. The two species are not easy to distinguish, especially when young - and they also hybridise! The main differences are shown in the table below. The analysis of the phenol platyphylloside, a chemical component of the bark, can quickly and surely identify the species in question. This method was used in a survey of feral birch across abandoned industrial cutaway bogs in the Irish midlands and results have shown that the totality of the sampled trees were downy birch.

Figure 7.3: Downy birch.

Bog willows

Bogs are favourite places for several different kinds of willows, but the species which is the most abundant by far is the rusty sallow or sally (*Salix cinerea*) [**Figure** 7.4]. The rusty sallow has oval lanceolate leaves 5-10cm long, slightly folded in at the edges, and somewhat grey-green in colour. The veins under the leaves often have short, rust-brown hairs. It grows especially along bog roads and drains, in marginal fens and cutaway areas. It is the food plant of the puss moth, the eyed hawk - moth and of several other prominent caterpillars. Another common bog willow is the eared willow, which is never more than a bush a metre or two high. It has small, wrinkled leaves oblong in shape, and it prefers marshy ground, such as the soaks at the heads of mountain streams and the fringes of birch woodland. Both willows are very variable, and they often hybridise with each other and with other species that occur in bog drains and by roadsides along the edge of the bog, such as the crack willow, bay willow, goat willow and osier.

TABLE 7.1: TELLING BIRCHES APART

Betula pendula		*Betula pubescens*
	BARK	
Shiny and red - brown when young, becoming white with large black diamonds when mature. Often with small black knobbly plates at base.		Red-brown when young becoming greyish-white when mature, and never with black diamonds. Base of bole often deeply furrowed.
	YOUNG TWIGS	
Glabrous; slender, drooping, with abundant wart-like resin.		Usually more or less hairy; drooping or spreading; glands may or may not be present.
	LEAVES	
Glabrous; rhombic or somewhat triangular, ending in a longish point. Margin sharply and regularly toothed.		Usually with hairs on the veins of lower side; triangular-oval or rhombic-oval, point less prominent. Coarse and irregularly-toothed margins.

Figure 7.4: Rusty sallow.

Another willow that is often found on heath, cutover and blanket bogs in many areas is the little creeping willow. Dwarf willow occurs on high-level blanket bog. This last has a special place, because it was one of the first shrubs to return to Ireland after the Ice Age, and indeed it was common here during the Ice Age itself, growing on the mountain nunataks that still managed to keep their heads above the ice, and it was probably the main shrub on the cold treeless tundra that stretched southwards from the ice front.

The willows used in basket making and thatching were generally known as sallies. In thatching, sally rods were widely used to make scollops for pinning down the thatch; they were used also to make wattles. For basket-making, or for making turf-kishes or lobster pots, osier and purple willow were preferred, because they are much more pliable. There was a time when every house in certain parts of the Midlands had its own special plot of osiers, and there was somebody in every family who could weave willow rods. These sally gardens were looked after as carefully as the vegetable plot. Sally rods had to be harvested every year; they were cut in early winter, and left in bundles to mature. Those who did not have a plot of their own got their supply of sally rods in hedgerows and along drainage ditches. The tradition of growing sallies, and of making the different kinds of baskets or skibs, has almost disappeared, along with the way of life such baskets served.

The Irish word for willow is *sail,* and it occurs widely in townland names: all those which end in *-illoge* and *-allagh* for instance. *Saileach* is the adjective, and *saileóg* and *saileán* are diminutive forms, all of which occur as placename elements. Most of these have nothing to do with bogs especially, because *saileach* can refer to willows of all kinds. Some certainly do however: Monasallagh *(móin saileach)* for instance.

Afforestation of peatland

With the exception of a short drier period 4,000 years ago, trees never grew on Irish peatland and so unlike Fenno-Scandinavian countries, Ireland does not have a history of peatland forestry. Nevertheless, the history of forests and peatlands in Ireland has always been intertwined. Both have contemporaneously experienced rise and fall and have come into conflict both naturally and, more recently, because of human intervention.

Planting on bog is not a new idea. Progressive landlords, spurred on by planting incentives offered by the Royal Dublin Society between 1741 and 1808, experimented with tree planting on bogs in many areas, from the raised bogs of Co. Kildare to the vast blanket bogs in Co. Mayo. The Bogs Commissioners reports (1810-1814) frequently refer to plantations on peat, mainly in the west of Ireland. Experience suggested to the early improvers that the trees which would grow best on drained bog were Scots pine, larch, 'every species of fir', birch, alder, sally and ash, but there was little systematic experimentation. Among the more interesting ventures was the Earl of Charleville's plantation in deepest bog 'near the Glath Bridge' (in Longfield's Bogs Commission district) where fir trees squared from six to nine inches after 20 years growth on bog 10-15' deep. Longfield noted that several feet below the present surface in this bog there was a level 'of ancient timber produced by this bog … … without receiving any nourishment from the clay or gravel'.

The first attempt at afforestation of blanket bog at state expense took place in 1891-4, when an area which included 490 acres of bog at Knockboy near Carna in Connemara was planted under the direction of the Congested Districts Board. Nearly two and a half million trees belonging to sixteen broadleaved and ten conifer species were planted in this windy outpost at an overall cost of £10,000, but the experiment was a total and salutary failure. At around the same time a Danish forester named Howitz was commissioned by Gladstone to prepare a report on the re-afforestation of waste lands in Ireland. Among the more startling of his recommendations was the planting of a shelter belt along the length of the entire west coastline to exclude Atlantic gales and diminish the rainfall to the east, and the planting of five million acres of waste land with every known tree, regardless of rank or fame. Fortunately, the failure of the Knockboy experiment ensured that none of his recommendations were put into practice.

Professor Augustine Henry believed that 'bog plantation should be attempted. People in Ireland before they want to do anything must have a dead certainty. They have a dead certainty in the afforestation of waste land'. He summarised the early experience of planting on bogs in his evidence to the Departmental Commission on Irish Forestry in 1908 as follows:

> A good deal of evidence can be brought forward to show that trees will grow and thrive in Ireland on deep peat-moss - i.e., on peat so deep that the trees never penetrate into the stratum of clay underlying the peat. So far as I can judge, success or failure depends on the amount of drainage. If this is too great, the trees die of drought at their roots; if it is too little, they are killed by the stagnant water. Proper drainage, the addition of soil to the pits in which the young trees are planted, and the help of manures rich in salts of potash, render the plantations successful at the start. Once the young trees have shed their leaves on the surface of the peat, decomposition sets in and the upper layer of peat becomes in a few years converted into forest soil, and continued growth of timber is ensured. In planting peat-bog our main reliance must be on Scots pine, alder and Sitka spruce, with which the plantation should be started. To sum up, bog planting for profit is no chimera; it has been done.

A remarkable experiment on planting deep peat was carried out at Tonduff Bog on the De Vesci estate near Abbeyleix Bog in the years 1908-1912. An area of cutover bog 44 acres in extent with 3m of peat was planted during these years with seeds of maritime pine (*Pinus pinaster*) **[Figure 7.5]**. Maritime pine, which is a native of sandy tracts on the Landes of France, has a very long tap root that helps it to resist the frosts which are so destructive to other species planted on the open bog. Eight years after planting the trees had attained a height of up to 2m and in some cases over 3m, without the application of fertiliser; by this time woodcock had moved into the young plantations. By comparison with this extraordinary growth, Sitka spruce and several other species of pine fared badly. The species was also planted with some success on dunes and bogland at Mullaghmore in Sligo.

Figure 7.5: A photograph from *Country Life* showing maritime pine planted on Tonduff Bog in County Laois in the early years of this century.

Writing in 1934 John Mackay, the most perceptive, enthusiastic and at times acerbic critic of Irish forestry policy of his time, predicted that experimental work would be carried out on all aspects of cultivation on bog, but felt that 'unless so minded, peat afforestation need not concern the Irish people seriously at any time during the next 200 years' - though in fact much of the 'grazed mountain' considered available to forestry at the time was blanket bog. Experimental work initiated in the early years of the present century in the Slieve Bloom mountains gave great hope that mountain land elsewhere might be planted with success, and this has indeed happened in the intervening decades. Speaking of the early spruce plantations on Slieve Bloom, Mackay (1934) wrote:

> The plantations on the Slieve Bloom are small, not more than a few hundred across, 'a cloud no bigger than a man's hand'; yet the spot is destined to become historic ground, for up and down those legend-haunted valleys and refolding hills, lovers of this ancient land may behold with their eyes the first earnest of the coming forests of Ireland; for here, mothered by the growth factors of our soil, planted by one who sees the forest with vision, laid down nineteen years ago by Mr. Crozier, the present head of the Forestry Branch, are the first hostages to the beneficence of this tree, silently lifting themselves with the same inward force and freedom as in their native habitat.

It is fair to say however that peatland forestry was not popular in Ireland and little peatland was planted before the 1940s. Although the Forestry Act of 1946 gave compulsory purchase powers, very little land has been acquired in this way; farmers voluntarily offered up parts of their land for sale to the Forestry Division. This resulted in a patchy distribution pattern of forestry in Ireland. Moreover, turbary rights led to the setting aside of certain areas so that peat cutting could continue locally. Most of the early afforestation was on mineral soils in the east of the country. The Division was not allowed to acquire agricultural land for planting, so the need to meet the greatly increased annual planting targets set in the 1940s forced them to use land less suitable for afforestation: in particular, mountain and lowland blanket bog in the west of Ireland. This had the only advantage of being bought cheaply. After Ireland joined the European Economic Community in 1972, the higher price of agricultural land forced afforestation still further onto blanket bogs, which are just about the only large blocks of land available where forest developers can take advantage of economies of scale. By 1950, 225ha were planted in the west, and by 1960 this had grown to 3,750ha or 32% of the total area of forestry. The somewhat ill-defined objectives of this venture included an element of utilising the "wasteland", providing employment in economically depressed regions and achieving a satisfactory level of productivity, without any rigorous approach to assessing economic viability.

The introduction of new techniques (low ground-pressure vehicles, large plough units, availability of fertilisers) in the 1950s facilitated this westward expansion onto the blanket bogs. Large Cuthbertson plough units were introduced in 1951 which formed a drain for removal of surface water; simultaneously a ribbon-like mound was made with the peat ploughed out from the drain, onto which the trees were planted. Ploughs were of two types, a single mouldboard (which produced one ribbon) and a double mouldboard which produced two ribbons for planting. Many blanket bogs were ploughed in the latter way at a furrow spacing of 4m, which provides planting ribbons every 2m, but this technique has now been largely superseded by mounding. A tunnel plough which provides a closed drain at 75cm has also been used, but there are practical problems. This has also been tried on intact raised bog but the tunnels tend to collapse. The advance of cultivation techniques, together with the availability of inexpensive phosphatic fertilisers made large-scale plantations on blanket bogs possible with the aim to turn treeless and unused (apart from some extensive grazing) expanses of land into productive forests. Central to this was the choice of two particular species: Sitka spruce (*Picea sitchensis*) and contorta pine (also known as shore pine) (*Pinus contorta*). In the 1950s, some foresters argued that the pine should be grown in mixture with the spruce while other foresters believed that contorta pine was a 'pioneer' species to be planted only in advance of a more valuable and more productive crop (i.e. Sitka spruce). A third category, the economists, influenced them all at the end and Sitka spruce was widely planted but always in intimate mixture with contorta pine, the hope being that at least some Sitka would appear in the final crop.

Sitka spruce thrives on sites where purple moor-grass dominates the natural vegetation, but generally fares badly where heather is dominant. Native to western North America, all the way from Alaska to Mexico, it was introduced into Britain in 1831 by David Douglas. Mackay (1934) wrote with an enthusiasm for Sitka spruce that is rarely encountered nowadays. He asks us to regard the tree as God 'fashioned it for our delight':

> See it among the mountains, *eductis in aera per nodos ramis,* tapering to its *fusterna,* smooth and even to the eruption of its branches. There among the smoke-blue hills where it belongs, liberated from forest service, its arms bending from their natural tendency, it is a miracle growing out of the very matrix of the rocks. In mountain scenery the Sitka spruce is one of the most beautiful of living objects. This perfection of form pertains more or less to all the spruces, but none attains exactly the same perfection of loveliness, soothing the surfaces of the mind. This perfection of form is the one absolute bond of unity between the spruces. Commercially they separate on the mountains.

Mackay's lyricism, however, does not reflect personal experience; Sitka spruce does not grow wild in the mountains 'among the smoke-blue hills'.

The other major species, contorta pine (also known as shore pine), is also native to western North America, from the Yukon River in the Klondyke south to New Mexico; in its homeland it grows from sea level to as much as 3,500m above sea level. Although first introduced into Britain by Jeffrey in 1853 it only became popular for afforestation in Ireland in the 1960s. Its particular attraction is as a pioneer species on the poorest soils, where its growth is outstanding in comparison with other species; it is the only tree that will perform well on the poorest of acid peats. It will produce excellent timber on good ground - much better than Sitka spruce in fact - but its productivity is much less than the latter, which is probably why spruce was the preferred option.

A satisfactory level of productivity was indeed partly achieved, especially in low-land blanket bogs, in that yield class estimates were considered higher than predicted at the start of the blanket bog afforestation program. Management techniques had been developed to overcome establishment problems (acute nutritional problems, exposure and risk of windthrow, drainage difficulties due to different peat types encountered). The economic viability of the enterprise, however, has always been marginal despite the availability of EU and state grants. By 1982, 140,000ha of largely undamaged blanket bog had been afforested, increasing to 170,000ha by 1985. By the 1990s the demand for a satisfactory financial returns coupled with increased societal expectations of higher environmental and aesthetic qualities, began to militate against further expansion of State forest on blanket bog. This meant that Coillte virtually ceased all afforestation on blanket bogs. During the same decade however, private afforestation increased dramatically, which has had a significant detrimental effect on large expanses of blanket bogs that had so far remained intact. It has been estimated from spatial analysis carried out by the Forest Service using Teasgac Irish Forest Soil dataset, that in the reference period 1990-2000 the amount of afforestation carried out on peat soils was 80,273ha. However, the afforestation carried out on peat soils as a percentage of the total afforestation has consistently decreased during that period, falling from a peak of 56% in 1990 to 34% in 2000. This downward trend continued to 29% in 2006. In 2007, the Forest Service completed the first National Forest Inventory which showed that 43% (or 301,770ha) of the total forest estate is located on peat soils, of which 218,850ha is on blanket peat.

Ecological change accompanying afforestation

Afforestation brings about profound and largely irreversible changes in peatlands. In addition to the aesthetic effects of planting trees on large open areas such as peatlands, there are the ecological changes due to tree growth and development, and the accompanying cultural practices associated with the plantation, such as the addition of fertilisers. On blanket bog in particular, drainage, the application of fertiliser and the cessation of grazing allow a luxurious proliferation of sedges, rushes, grasses and heather in the early stage of the plantation. The characteristic open peatland habitat disappears together with its typical plant species. As the open ground is replaced by the developing forest stand, the birds of the open bog - species like snipe, curlew, redshank, golden plover and red grouse - disappear, to be replaced by a new suite of species such as hen harrier and kestrel, benefiting from the increase in small mammal populations supported by the luxuriant ground vegetation. Meadow pipits, stonechats and whinchats may also be prominent at this stage.

Once the trees reach the thicket stage (after about 10 years), the extending canopy cuts off light to plants growing at ground level; the ground flora is further impoverished, and the avifauna is replaced by the small number of birds which favour the canopy and woodland edge, such species as goldcrest, siskin and coal tit being especially characteristic. By the time the plantation is thinned (after some 15 years) the vascular plant flora has become very restricted, but there is still a relatively diverse bryophyte flora and a rich and exceptionally interesting mycoflora (Chapter 9). As the plantation matures, red squirrel, pine marten, long-eared owl, sparrowhawk and woodcock may take up residence, and deer can move freely through the trees. Woodland rides have their own characteristic flora, dominated by such species as rosebay willow-herb, foxglove, bracken and bramble, and with New Zealand willowherb on the track itself. In older stands of coniferous forest the invertebrate fauna may reach levels of diversity greater than those characteristic of deciduous woodland. The plantation forest is therefore of very considerable natural interest, but where it replaces natural vegetation this interest is not an adequate replacement in environmental terms.

Drainage, site cultivation, fertilisation and harvesting have direct impacts on surface water quantity and quality, which is a cause of concern and controversy as blanket bogs are mainly located where most streams are of particular high quality for salmonid populations. Some of these impacts are direct (hydrological yield, sediment loads, chemistry), others have more complex origins. In general runoff can become more 'flashy' with afforestation as the water is transported to the streams more quickly, but this effect may be reduced after canopy closure and varies considerably with site-specific factors such as the number of drain ditches present, the peat type and vegetation cover. The acidification of streamwater following afforestation has been a matter of concern since the 1980s and still is. In Ireland, this is principally linked to atmospheric pollution and the fact that tall conifers with large canopies act as pollutants scavengers. Studies established in the regions of acid-sensitive geology (parts of Connemara and Wicklow) have shown that coniferous forests have a great power of interception of rainfall increasing their ability to intercept pollutants as well as sea salts, eventually leading to deposition of these acidifying substances on the forest floor and hence into the soil and water. The geology of these regions is composed mainly of rocks (granite, quartzite and schist) that are slow to weather and are poorly buffered. They have therefore a limited capacity to resist acidifying influences. It should be recognised that most Irish soils are highly resistant to acidification, but caution should be exercised with thin acid soils such as some blanket bogs and heaths, which are located in high rainfall areas and are subject to atmospheric pollution. The Forest Service guidelines for the management of existing forests and for new afforestation projects have been revised including the designation of acid-sensitive catchments (mainly in counties Galway, Donegal and Wicklow). The eutrophication of surface runoff water (due to phosphorus leaching) is another negative impact directly linked to the fertilisation and harvesting of forests located on peatlands.

Once the trees become more established, the water table sinks much further due to increased evapotranspiration (i.e. more water is lost from the soil and the plant to the air). This allows some oxygen into the peat, leading to an increase in the populations and activity of aerobic decomposers. These microbes are responsible for the decomposition of the peat into elementary compounds. Lowering the water table and peat decomposition induce the peat to shrink and subside over a period of years, casting doubt over the long-term sustainability of these plantations. In addition, peat oxidation means that carbon is released to the atmosphere (See Chapter 5).

Forest management is highly intensive in Ireland, with the plantation being managed as a crop rather than as woodland in the traditional sense. Rotations are short and stands are dense; as a result, coniferous plantation forests rarely develop the open character of mature boreal forests with their rich harvest of fruits and fungi. Sitka spruce may well be (to recall Mackay's encomium) 'one of the most beautiful of living objects' in nature, but in the regimented short-rotation plantations to which it is confined in Ireland it is never allowed to develop this majesty. The failure to plant in a way that shows sensitivity to contour, landform and local ecological variation, or to scenic or aesthetic considerations, means that the woods themselves are not allowed to develop any kind of organic relationship with the landscapes in which they are planted. When the tree crop reaches maturity, it is normally harvested by clear felling. This drastic forestry operation has a very negative short-term visual impact in addition to the aforementioned ecological impacts.

Finally, an important consideration is that the naturally treeless peatlands of Ireland are unique at our latitudes. Because they cover such large areas, blanket bog in itself constituted a type of landscape. The openness of the landscape disappears when trees block a wide view in all directions, and the straight lines in plantations introduce an artificial element into a natural landscape. Plantation forestry is therefore much more invasive than it would be in a country like Finland, where peatland forestry concentrates on increasing the productivity of existing forests growing on peat soils through drainage and the addition of fertilisers.

In response to all these issues, the forestry industry has developed a broader outlook than simply maximising timber production from these sensitive soils. There is a growing body of technique and expertise that enables the forester to mitigate the negative impacts of forestry on natural habitats, landscape and water resources and to enhance the positive. Guidelines to good practice in this regard are well established and are clearly outlined in the publications of the Forest Service through the Code of Best Forest Practice (2000a) and various other environmental guidelines relating to water quality, landscape, biodiversity, archaeology, aerial fertilisation and forest harvesting. Because most forestry development is sponsored by grants, the State should be able to control adherence to the procedures and standards outlined above. In most cases, there is the possibility of considerable mitigation of the negative impact by allowing the areas of greatest diversity to remain unplanted: groves, streams and their verges, roadsides, depending on the unique mosaic of the particular area.

The conservation concern

Bogs have suffered from a plethora of disturbances, and it is argued that as little as 85,00ha (11%) of blanket bogs and 25,189ha (8%) of raised bogs remains relatively intact. It has to be added that there is considerable disagreement about the actual figures, but what is beyond question is that tracts of undisturbed bog are now rare because of a combination of peat cutting, over-grazing, burning and afforestation.

Blanket bog has been most affected by afforestation, with forests now covering 218,850ha of blanket bogs, or 28% of the original area. The International Mire Conservation Group in 1986 identified the blanket peats of Ireland and Britain as of 'unique and of global importance', and the importance of Ireland's blanket bogs has been recognised by the European Parliament in its Resolution on the Protection of Irish Bogs in 1983.

Small areas of raised bog, mostly cutover areas, were planted at the same time as blanket bogs back in the 1950s. Little attempt has been made to afforest intact raised bog (2% of the total raised bog resource) and what little was attempted was not very successful. Given the fact that these peatlands are fast disappearing, efforts are being made to conserve them at national level and it is now Government policy not to grant-aid the afforestation of intact raised bog.

Like agriculture, virtually all afforestation is subsidised. This is largely because afforestation represents the reconstitution or restoration of a lost resource, and must take account of the soil degradation consequent on that loss. On the other hand, *ongoing* forestry (reforestation) is not subsidised, unlike agriculture in this respect, and is not likely to be. It is now widely accepted that from the economic perspective - the planting of blanket bogs was a marginal proposition without substantial investment of EU funds. More recent plantings have been grant-driven thanks to the Exchequer funds. Such plantations took place on bogs which are of considerable value from other perspectives. Peatland afforestation is a land use option which should not be governed solely by the economics of forestry. There are other major considerations, among them the realisation that the future development of rural Ireland depends fundamentally on the protection of the natural and cultural assets of the environment, and the attainment of an appropriate balance between resource development and conservation.

From the forester's point of view, planting on areas considered *unsuitable* for agriculture makes little sense except where external financial support is provided or political or social considerations are allowed to intervene. From a silvicultural perspective the emphasis should be on the acquisition for forestry of land *marginal* to agriculture. Most planting is now taking place on agricultural land that is being forced out of production by changing EU policies. This increased planting on *more* productive land coupled with the new EU agri-environmental packages will lessen the pressure to plant on bogland. It was initially thought that the 1996 Irish Forestry Strategy would put pressure back on the state-own bogs: in the *Strategic Plan for the Development of the Forestry Sector in Ireland, Growing for the Future,* the Government aimed to plant 25,000ha of plantations per annum from 1996 to 2000 and 20,000ha per annum up to 2035. However, the targets have failed by 34% in the period 1996 – 2002 and current planting rates are even below 10,000ha per year. In 2006, 8,012ha were planted, of which 2,323ha (29%) was on peat soils.

Planting should not take place in areas of blanket bog whose natural diversity would be lost through afforestation, or whose unique character would be destroyed by planting.

Where planting is being considered in areas of very great scenic sensitivity, such as North Mayo or the bogs west of and in the vicinity of Maam Cross in Connemara, exceptional sensitivity to landscape character is required. These considerations apart, most blanket bog areas are capable of accommodating some forestry if - and only if - the forests are properly and sympathetically designed, in a way that allows the landscape to absorb the forest. The concept of Indicative Forestry Strategies (originally advocated by Goodstadt in Scotland), which classify areas as 'preferred', 'potential' or 'sensitive', is an important development now being applied to Ireland. The Forest Service is currently drafting the Indicative Forest Strategy, which is a GIS-based system that identifies areas most suitable for planting primarily on the basis of environmental considerations and soil-productivity. The map-based environmental constraints have been supplied from a variety of state organisations, such as the National Parks and Wildlife Service, the Fisheries Boards, the EPA and the local authorities. The forest productivity map was compiled in co-operation with Teagasc and is based on soils and elevation, displaying the potential rate of growth for trees throughout the country. With the motto of 'planting the right tree in the right place', the IFS also provides key aspects of design that include consideration of the sensitive relation of forest edges, roads and planting compartments to the topography by avoiding straight vertical or horizontal lines, avoiding the planting of foreground locations where this would restrict the view and increasing the diversity of species. This strategy is reinforcing other environmental and resource planning policy such as the requirement to carry out an environmental impact assessment on intended forest areas over 50ha. The EC (EIA) Amendment Regulations (S.I. 538 and 539 of 2001) significantly lowered this threshold from 70ha (before 2001) and 200ha (before 1996) in an effort to curb some of the detrimental effects of cumulative afforestation. Provision is also made for the possibility of sub-threshold EIA where a project is likely to have significant effects on the environment. It is also now a requirement to manage at least 20% of all new plantations for biodiversity, allowing the foresters to include broadleaved species, and different conifers such as larches, western red cedar, western hemlock and Douglas fir on peatlands.

From blanket bog to conifer plantation and back again

In a paper presented at the Coillte, EU-Life end-of-project conference on peatland restoration in October 2007, Tim Crowley claimed that out of the 240,846ha of Coillte-own forests located in the west of Ireland, 136,576ha (57%) is on peat soils (mostly blanket bogs). Overall, Coillte owned 175,136 ha of blanket peat, representing 40% of the total Coillte forest estate (445,000ha) and 84% of these blanket bogs have been afforested. Most of these forests have been planted on previously undisturbed peatland. By the 1990s the demand for a satisfactory financial return, coupled with increased societal expectations of higher environmental and aesthetic qualities, began to militate against further expansion of blanket peatland afforestation. By the turn of the twentieth century, the environmental, financial and silvicultural problems associated with blanket bog forestry led to a reversal in attitudes and a move towards peatland restoration by taking the trees out of the bog. Coillte have to be commended for their new work on restoring just under 2000ha of blanket bogs and a further 570ha of raised bogs thanks to the support of funding from the EU LIFE-Nature Programme. These former bogs were dominated by conifer forests and located within or adjoined Natura 2000 sites that have been designated because of the high quality bog habitat they support. The main restoration work involved all or some of the following operations: felling the conifers, blocking the drains, fencing against sheep and preventing the regrowth of unwanted trees/shrubs. Some bogs have already started to grow again, displaying a luxuriant mat of *Sphagnum* mosses. The speed of recovery of the bog ecosystem has been greatly enhanced where the initial forest crop was small and young. It has been shown in other countries such as Finland that the longer the bog has been drained, the more difficult it is to fully recreate the original state. Time may yet to be best healer for these scarred landscapes. It might be the case that restoration leads to a 'new natural state', different from the original habitat but nevertheless recognisable as some other peatland habitat type, yet to be classified. By giving more importance to the ecological and landscape value of their sites, Coillte has set a standard to follow. The next step is to evaluate the sustainability of these management options in the mid- to long-term and to seek regulatory approval. It is anticipated that bog restoration will be the preferred management option for significant areas of conifer plantation on blanket peat in the west of Ireland, requiring the Forest Service to revise the Forestry Act of 1946, currently stipulates that reforesting is mandatory following tree cutting. Given the appropriate funding, blanket bogs will be able to spread again in the Irish landscape.

It is clear that we have moved away from the notion that the only objective of a forest is to produce a timber crop. It is now widely recognised that afforestation brings with it many more benefits than just yielding wood. The husbandry of this renewable resource is now part of a broader environmental awareness. A forest has many uses and values, for instance it provides areas for amenities, creates new jobs in rural areas and more importantly perhaps has the potential to participate in the regulation of climate (through the carbon cycle). Careful planning and design can accommodate multiple land use and maximise community benefit from both forestry and bogs. We have the option to rectify our mistakes and choose the proportion of land that should be devoted to different uses (e.g. wilderness, native forests, tree plantations, pasturelands, farm crops, roads, cities etc.).

Forests and bogs have come and gone over the history of this island due to the natural climatic oscillations and in recent times because of human activities. Another twist is about to happen when climate change consequent on global warming will allow pine to invade what open bog surfaces survive into the next century.

The future of planting on cutaway raised bog

Peatlands have played a major role in the re-forestation of Ireland during the twentieth century. However, it is clear that further afforestation of both blanket and raised bogs will be very limited, if not terminated, in the twenty-first century. The attention now seems to be solely drawn onto the potential to develop forestry on industrial cutaway raised bogs.

From the 1960s onwards, the afforestation of industrial cutaway peatlands was perceived as offering great potential. In theory, prospects were promising on the assumption that these cutaways were homogeneous in botanical origin and in character, drainable, available in large, accessible units and that they ought to be productive without any requirements for cultivation. The early plantations on sod-peat cutaway peatlands were considered highly successful, a finding that provided much of the impetus for plans to afforest Bord na Móna cutaway peats. The first planting trials were located at Clonsast's 'Trench 14' which was the first cutaway 'field' to become available for the purpose. Afforestation experiments commenced in 1955, and clearly demonstrated the capacity of some species (Sitka spruce, lodgepole pine and grand fir) to achieve growth rates consistent with economic viability. With necessary phosphatic fertilisation and peat depth less than 1.2m, early results suggested that Sitka spruce would be the most promising species, capable of attaining a yield class in excess of $22m^3$. ('Yield class' is an index of potential maximum mean annual stemwood volume increment expressed in m^3/ha/annum). However, the results upon which this optimism was founded were misleading. The growing medium presented by the residues of sod-peat harvesting (like Trench 14) was not representative of the cutaway areas that were subsequently made available for forestry, where the peat was milled and the remaining peat layer had distinctly different properties. In 1979, the Interim Report of the Inter-Departmental Committee stated

> … it is obvious that this type [sod peat] of cutaway bog is suitable for afforestation. Forestry research has not yet been initiated on milled peat cutaway. It should now be undertaken in co-operation with the Forest and Wildlife Service … The combination of peat type, peat depth and subsoil in Bord na Móna milled peat cutaway bog is extremely complex. It is clear that the varying combinations must be treated separately as they present different problems.

In 1987, the decision to transfer existing Bord na Móna cutaway peatlands to the Forest Service was taken by the Minister for Energy, who intended to afforest '…all existing Bord na Móna cutaway bogs which are suitable for this purpose.' The minister also stated that 'This will apply to any cutaway lands which are at present available for planting and also to those areas which will become available in the future as Bord na Móna bogs are exhausted for turf production purposes…' (Minister for Energy, speaking in the Dáil in October 1987). By then, foresters were well experienced in planting sod-peat cutaways but little was still known of the forestry potential of milled cutaways. Coillte took over this afforestation scheme and by 1992 had planted 4,000ha of cutaway peatlands leased from Bord na Móna, of which *c.*2,400ha were on milled cutaway peatland in the midlands, *c.*1,000ha on milled cutaway blanket peatland in the west of Ireland and 570ha on sod-peat cutaway. The main tree species planted in the midlands were Sitka spruce (accounting for 76% of the total plantings) followed by lodgepole pine (10%). Norway spruce and oak made up 2% each. Sitka spruce did not live up to its promise, mainly due to late spring frosts. Other species failed also due mainly to competition with vegetation, nutrient deficiency, deep remaining peat layer, drainage and pest damage. This last refers to an insect, the pine shoot moth (*Ryacionia buoliana*), which has been found to affect entire plantations of pine species, mainly lodgepole pines, in the Irish midlands and in other places around the country.

Despite Coillte's efforts to establish trials investigating cultivation, fertilisation, herbicides and species provenances, there has been a progressive recognition of the serious problems encountered on milled cutaway peatlands. Between 1996 and 2006, the planting on industrial cutaway peatlands was halted and some 250ha was planted for research purpose as part of the BOGFOR research programme, a joint venture between the Forest Service, Coillte and Bord na Móna and that was managed from University College Dublin.

Renou-Wilson and her co-author have compiled the results of eight years of research on all aspects of cutaway peatland afforestation, confirming that forestry development on certain industrial cutaway peatlands is possible although the economic viability has yet to be clearly demonstrated. The researchers first confirmed that although cutaway raised bogs might appear to be uniform, they do, in fact, contain a great deal of heterogeneity. Small-scale variation in peat properties greatly influences the establishment and growth of trees and has consequences for the choice of silvicultural practices. This means that the adoption of a single afforestation blueprint for this land is not appropriate and foresters need, first, to identify the best suitable cutaway sites and second, consult a suite of establishment techniques in order to choose the ones best tailored to the site. It was concluded that tree planting was possible only on cutaway peatlands that were gravity drainable and so excluding a lot of 'worked' bogs that are currently pumped for peat harvesting or where the surface lie below the level of the Shannon. Woody fen peat and shallow or well aerated *Phragmites* peat with good drainage were generally considered good sites for planting a variety of species. Only pine species survived in deep *Sphagnum* peats, which should be generally avoided.

It is thus clear that only a proportion of the total cutaway peatland area will ever be suitable for commercial forestry. The area that might be suitable has been estimated by Bord na Móna to be between 16,000 and 20,000 ha. This total area will only gradually become available over the period 2005-2025, with the greater part only becoming available towards the end of this time period.

A great number of species were planted (10 conifers and 12 broadleaves). Without a nurse crop, Sitka spruce suffered severely from repetitive late spring frosts. Researchers confirmed indeed that frequent late spring frosts occurred in the low-lying cutaway peatlands in the Irish midlands, with temperatures falling below zero as late as June. Norway spruce was the most successful conifer species for cutaway peatlands due to the reduced risk of damage by late spring frost but it is not 100% risk free. Planting under a nurse crop (natural birch but also planted birch, alder or larch are ideal for this) has been found to be the best system to limit the risk of frost damage and significantly increase the early growth of species such as Norway spruce, Sitka spruce and pedunculate oak. Of the broadleaves species, common alder (*Alnus glutinosa*), which is an excellent native pioneer species for the cutaway bogs, grew faster and uniformly over a variety of cutaway sites, quickly establishing a forest cover. While it is not a commercially-attractive tree, it can be chipped and used as energy, fuelling a growing market. Birch could also fall under this 'biomass for energy' category. Of the birch species tested, silver birch grew better, especially on good cutaway sites. The main problem the foresters met with broadleaves species, especially birch, alder and oak, is that they can be severely damaged by the growing population of hares. While pines have been found to be misshapen by the pine shoot moth (*Ryacionia buoliana*), certain pine species, including Scots, Corsican and Macedonian pine have been found to be more resistant, although being very much climate-dependent. Both birch and Scots pine have the advantage of being key species in ecosystem development, which can broaden options for future uses of the cutaways. Groves of birch, alder or Scots pines planted alongside naturally regenerated scrubland can provide new areas for amenity and biodiversity as well as being aesthetically pleasing.

Trees undoubtedly have a key role to play in the cutaway landscape of the future. It now seems likely that regimented spruce trees will not play as prominent a role on cutaway as had been supposed, and while research may substitute high-yielding species that are less frost-sensitive, the role of silviculture in the overall context may still be relatively small. A mosaic of woodland types will take shape on much of the new land available. Some of this will be allowed to develop spontaneously where ecology and the criteria of the landscape architect indicate that this is the most *productive* land use in the broadest sense. Biomass may have a certain role to play in the after-use of cutaway peatlands but it is not consequence free. The possibility that a considerable percentage will be devoted to rotation coppice biomass, using fast-growing willow and other species, will be considered more fully in the final chapter.

The planting of native and naturalised species for a mixture of amenity (including tourism-related) and practical purposes is likely to assume a much greater role as our focus on what the design of the cutaway needs to achieve sharpens with experience and the passage of time, and we become more attuned to the possibilities. The exploitation of the raised bogs has transformed the economies of the communities in which they are located. The price has been the spending of a finite resource. This not only sows the seeds of socio-economic problems that will germinate in a not too-distant future, but it represents the loss of the places that enshrined much of the ecological diversity of these areas, and of access to the experience of nature for the communities which live in them. The challenge of the future is not merely to sustain, enhance and restore as much as possible of the natural diversity for ecological/scientific reasons, but to ensure that the people who still live in this landscape in 50 years time, in a century's time, will have access to a home landscape that is not impoverished in terms of human experience, of access to the natural world, but is rich in its ecology, a place where the planning upon which we are embarking now will have ensured the maximum of richness of eco-diversity and richness of human experience. Trees, the plants that dominate the ecosystems of the world today and constitute the framework of rich cultural landscapes, are the key to this. A challenge with which we are faced now is the establishment of a forum and an authority to ensure that this future landscape richness will be achieved, which will be not only fully sensitive to the arguments of competing claimants for new land, but well informed on all the possibilities represented in the cutaway, including those which relate to the broader social and economic objectives, and imaginative and sensitive also in its design of our children's future landscape.

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Chapter Eight

Mosses and Liverworts (Bryophytes) on the bog

Mosses are useful to the insect tribe, countless numbers of which find homes among their branches, and roam about in their shades as in mighty forests, looking with their thousand eyes upon the wonders of their leaves, and sunning their wings of purple and of gold, and burnishing their shining armour upon the polished columns of their urns.

Frances Tripp, *British Mosses* (1888).

General Ecology

For most people with a general interest in natural history, mosses and liverworts are a difficult group at the best of times. Although the differences between bryophyte species are as real and obvious as the differences between species of flowering plants, they are on a different scale; mosses and liverworts are mostly small plants whose colour schemes are normally confined to greens and yellows and browns of infinite variety, but are seldom startlingly distinctive. It often requires a hand lens or microscope to see all the features that enable species to be reliably separated, and few of us have the time, or the patience to approach the natural world at this level. Not that all this should deter anybody who is really interested: with real enthusiasm and determination it takes very little to begin to appreciate the wonderful world of mosses. It is difficult to convey to the uninitiated how wonderful and beautiful and endlessly varied these plants are. But then, the same is true of so many different groups of smaller plants and animals.

Mosses are found in great abundance on the bog, from its wettest to its driest parts, achieving high levels of cover and productivity. This is because they are adapted to low nutrient conditions and are often the pioneering colonists of bare peat surfaces. Because of their simple anatomical structure they can obtain their nutrients directly through the single layer of cells that makes up their leaves. They also provide a platform for bigger plants to grow on, forming a moist, protective cushion in which seedlings can germinate. The most important mosses on the bog – indeed, the most important *plants* on many bogs are the bog mosses, belonging to the genus *Sphagnum.*

The Bog Mosses: Family Sphagnaceae

Muscus hic nulli ex terrestribus similis est, sed fadem habet propriam, nec alibi quam in udis at paludosis nascitur.

J. J. Dillenius, (1719). *Catalogus plantarum sponte circa Gissam nascentium. Cum appendice*. Frankfurt-on-Main.

Sphagnum is a large genus, and the only one in its family. It is found in bogs and fens throughout the world. The sphagnum mosses (which Bernard Mullins quaintly described as 'this peculiar aquatic vegetable' in his mid-nineteenth century account of the nature of bogs) are among the most remarkable and highly specialised of all the plants of bogland.

In many bogs they are the dominant plants: one of the few habitat types in the world where the lowly mosses have the edge over vascular plants. Not only is sphagnum the most important of all bryophytes in terms of its total bulk, but it is very likely there is more carbon in sphagnum than in any other genus of plants - most of it dead. Once conditions have allowed the sphagnum mosses to establish their initial hold on the bog they have ways of maintaining their dominance, and play a critical role thereafter in controlling the hydrology and acidity of the bog.

The natural history of sphagnum

The general body form or anatomy of all sphagnum mosses is very distinctive [**Figure 8.1**]. Each individual plant has a head called a *capitulum* from which the branches rise. These branches are in bunches of four or five at intervals down the stem, with some

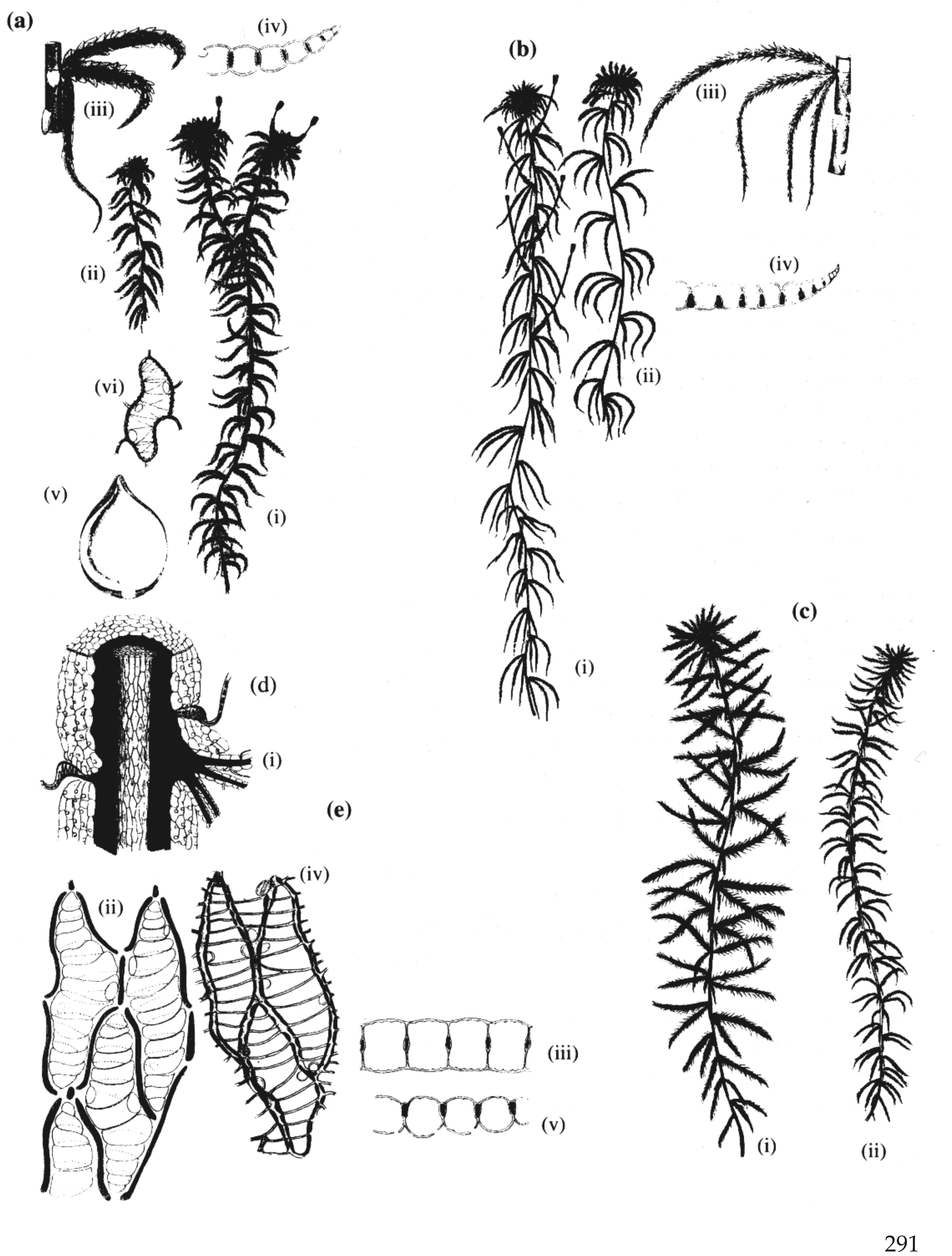


Figure 8.1: Some species of sphagnum.
(a) *Sphagnum papillosum*. (i) The female plant; (ii) part of a male plant; (iii) part of a stem showing a branch fascicle; (iv) transverse section of a branch leaf; (v) a branch leaf; (vi) a single cell, highly magnified.

(b) *Sphagnum cuspidatum*. (i) female plant; (ii) male plant; (iii) part of stem with branch fascicle; (iv) section of branch leaf.

(c) Two other forms of this very variable species: (i) var. *brevifolium* and (ii) Var. *torreyi.*

(d) General structure of sphagnum stem and leaf. (i) Vertical section of the stem, passing through two leaves and a branch fascicle; (ii) cells in a branch leaf of *Sphagnum cymbifolium*; (iii) transverse section of the same leaf; (iv) cells in a branch leaf of *Sphagnum acutifolium*; (v) transverse section of the same leaf.

hanging down and some spreading out. The hanging branches aid capillary action, and their leaves have less chlorophyll than those in the spreading branches. The structure of the stem consists of a central weft of thick-walled strands surrounded by one or more layers of empty *hyaline* cells. Many species have a distinctive cushioned growth habit. Mature sphagnum plants have no rhizoids because they get their water supply not from the ground, but from falling rain.

The leaves are one of the most extraordinary features of sphagnum. The leaves on the branches are different from those on the stems. In each leaf there are large, non-living (hyaline) cells that look like balloons or interconnected bubbles. When viewed from above the hyaline cells are seen to be surrounded by green photosynthetic cells that are generally sausage-shaped. When viewed in cross-section on the other hand, the photosynhetic cells look barrel-shaped, and are surrounded by the hyaline cells. The shape and relative position of the green cells on the upper and lower surfaces of the leaf are particularly diagnostic in different species [**Figure 8.2**]. The walls of the large dead cells have pores through which water can enter or leave freely, and they are strengthened with coils of thickening material called fibrils, which prevent the hyaline cells from collapsing under hydrostatic tension. It is these cells that are responsible for conducting water and nutrients. The subtly different patterns and details of the cells are quite distinctive in different species, and provide one of their most important diagnostic features. Each species has a distinctive colour spectrum but there is – unfortunately for the would-be sphagnum expert – overlap between the colour spectra of different species. Recent studies have shown that there is quite a lot of genetic variation in sphagnum. The colours are secondary pigments, and are quite stable when the plant is dried.

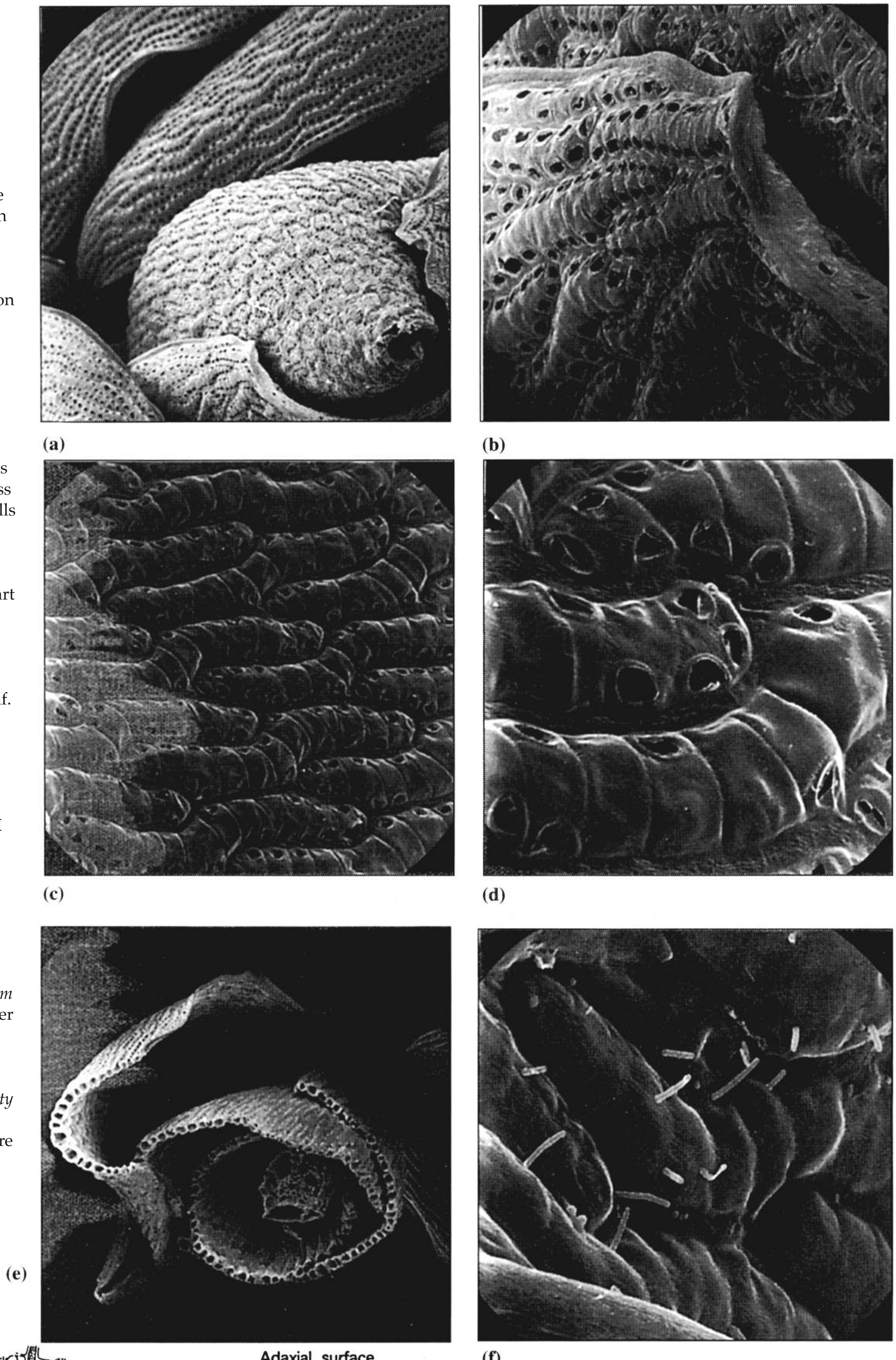
Their peculiar leaf structure gives bog mosses a water-holding capacity which is twenty times their dry weight, although most of the water in a cushion of bog moss is not held *inside* the leaf cells but in the interstices of the moss carpet, between the tightly packed stems and leaves, and this constitutes a unique aquatic environment that has its own distinctive fauna and flora (See Chapter 12). Because of this extraordinary absorptive capacity, sphagnum was widely used during the First World War - and other wars – for staunching blood and to make dressings for wounds that were much superior to cotton wool. During the First World War sphagnum was actively collected by the Society of United Irishwomen, which formed units to collect the moss and gather it in special 'sphagnum collecting centres' [**Figure 8.3**]. From these centres it was taken to 'sphagnum dressings sub depots' where it was manufactured into dressings and supplied to hospitals, mainly in Ireland, England and France, but also as far afield as Italy, Egypt, Salonika, Palestine and India. Sphagnum is four times as absorbent as cotton wool, so it could be left on wounds longer, and stayed comparatively dry for much longer. Because of the porosity of the leaves the dressing also kept the wound cooler, and it was mildly antiseptic by nature. Altogether nearly a million tons of sphagnum were gathered from bogs throughout Ireland, which must have had a very considerable impact on their ecology. Elsie Henry, wife of the eminent botanist Augustine Henry, was honoured with an OBE for her work on the use of sphagnum in surgical dressings.

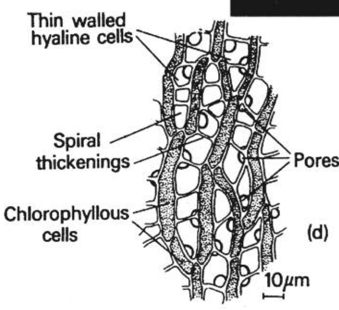
Like other bog plants sphagnum is adept at husbanding its meagre income of nutrients, constantly moving its reserves to actively-growing parts. Sphagnum has the ability to flourish in conditions where nutrient levels are very low: its nitrogen concentration is only about 0.6% and its phosphorus concentration only 0.03% compared with 'higher' plants, whose nitrogen content is usually about 2%. In fact, the construction of the green and hyaline cells varies depending on the nutrient status; in a low-nutrient solution, the green cells can become more elongated, with a corresponding enlargement of the hyaline cells, both serving to increase the absorptive surface area. This very flexible response to changing environmental conditions is partly responsible for sphagnum's dominance of its environment.

Unlike most other plants, most species of sphagnum are not dependent on the soil for the raw materials they need. They get their nutrient supply from above, in the rain,

Figure 8.2: Scanning electron microscope photographs of the leaf of *Sphagnum auriculatum* var. *auriculatum*. Several views are shown, to help give a clearer impression of the three-dimensional structure. (a) Looking down on the apex of the shoot. (b) Higher magnification of a leaf apex. (c) Leaf surface showing curved surfaces of worm-shaped hyaline cells with pores and cross folds. The living cells are down in the valleys between. (d) Higher magnification of part of (c). (e) Cross section to show structure in third dimension. (f) Underside of leaf. Note the furry surface, finger-like projections and absence of pores. **(Photographs by Miriam Cotter, EM Unit, UCC)**.

Compare the drawings below, which show the arrangement of the cells in the leaf of *Sphagnum fimbriatum* (seen from the upper surface), and a section of the same leaf (from Bell and Woodstock: *Diversity of Green Plants*). Compare also Figure 8.1.





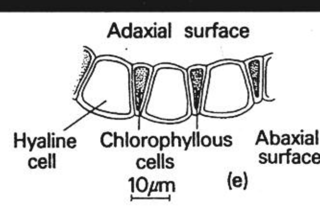


Figure 8.3(a): Map showing the centres set up during World War 1 for the collection of sphagnum moss by members of the Society of United Irishwomen, who combed the bogs for moss during the war years.

Figure 8.3(b): The Sphagnum Sub-Depots where the collected sphagnum was manufactured into surgical dressings.

and this makes them independent of groundwater for their resources: a trick the plants turn to good advantage in establishing their dominance on the bog. The notion that sphagnum obtains its nutrients from the air is not entirely new. At the end of the 19^{th} century, Hugh Leonard wrote that 'the ash of the peat appears to be due to the plants growing on the surface collecting their inorganic food from the atmosphere.' However, it does get some help, because there is some evidence that certain species contain symbiotic nitrogen-fixing cyanophytes – blue-green 'algae' – in their cells. Epiphyllous cyanophytes (forms living on the leaves) may also play an important part in supplying them with nitrogen.

But the most important chemical trick developed by sphagnum, and found in other bryophytes to varying degrees also, is its capacity to tie up ions in the surrounding environment, thus changing its chemical make-up. This is known as direct ion exchange – swopping H^+ for K^+, Mg^{++} and Ca^{++}, in that order of preference. It manages this by means of specialised chemicals in its cell walls (unesterified polyuronic acids, which can constitute up to a third of the dry weight of sphagnum), enabling it to exchange hydrogen ions mobilised by the moss inside the cell, for the scarce mineral ions in the water outside. It was once thought that sphagnum released its own organic acids without any exchange with the environment, but recent experiments have shown that pH is not lowered by sphagnum unless there are other ions present in the solution. It may be a different story further down the profile, where decomposition and degradation take place under anaerobic conditions. Its great water holding capacity and its ability to control the pH of its environment ensure the maintenance of the waterlogged acidic low nutrient habitat to which it is so well adapted. It is also a feature that makes bog mosses particularly useful for monitoring pollution in cities and other industrial complexes, where moss bags are suspended on trees above the pollution source and allowed to absorb the metal (e.g. lead) being emitted. The sphagnum is first acid-washed to displace its metal ions, so that the binding sites are protonated in readiness for exchange with the pollutant. Metal absorption by sphagnum has been shown to be linear with time for up to ten weeks.

The growing bog surface can also record changing pollution levels. Many species of sphagnum are themselves susceptible to pollution, and recent studies have shown that some of them are becoming rarer due to the increasing levels of pollution in the air. Photosynthetic cells in the leaves become enlarged if there is an increase in nitrate levels: the hyaline cells almost disappear, and their cation exchange capacity may be lowered. This may also explain why certain species that were common in the past, as shown by their abundance lower down in the peat profile, are now rare. Ozone has a detrimental affect on photosynthetic capacity, particularly on submerged species, and increased CO_2 levels lead to larger hyaline cells. Sulphur dioxide is tolerated well by *Sphagnum recurvum; Sphagnum magellanicum* is also more pollution tolerant. This may be a reason why they are more common in bogs today than they were in the past.

Reproduction

At a certain stage in its life, sphagnum reproduces sexually, producing spherical spore capsules for long-distance aerial dispersal. Most species are unisexual, with male and female sex organs produced on separate plants, usually in late autumn or early spring. Biflagellate antherozoids (sperms) produced by the male plants swim through the water film in search of egg sites on the female plants [**Figure 8.4**]. The spore capsule is very distinctive, but almost identical in different species. Bog mosses are at their most attractive at this stage. Most fruit in summer, a few going into autumn, and the myriads of tiny globe-like spore capsules are all massed together, the brown of the capsules contrasting with the yellow or green of the leaves beneath.

The capsules are about 2-3mm across, borne on little stalks called pseudopodia that are short at first, but elongate as the capsules ripen, to lift them into the air. Each capsule has a little lid, the operculum, and on dry sunny days this is blown off like a cork from a popgun, and the ripe spores are shot several centimetres into the air, which disperses them. What happens is that the ripe capsule, which is spherical to start with, shrinks as it matures, so that the pressure inside rises to as much as 4-6 atmospheres, eventually blowing off the lid. If the capsules are submerged by rising water, the spores can still escape through a hole in the base of the capsule, where it was attached to the pseudopodium, or the spores may simply germinate inside. *Sphagnum palustre* is one of the few species that fruits frequently, while others produce spores seldom or perhaps never. Sphagnum germination is still something of a mystery; the very young plant seems to require high concentations of nutrients to develop further. In particular, the concentration of phosphorus available to the plant under natural conditions – the short supply of which is always a limiting factor on sphagnum growth – seems to be something like 10,000 times too low!

Figure 8.4: Sex in Sphagnum

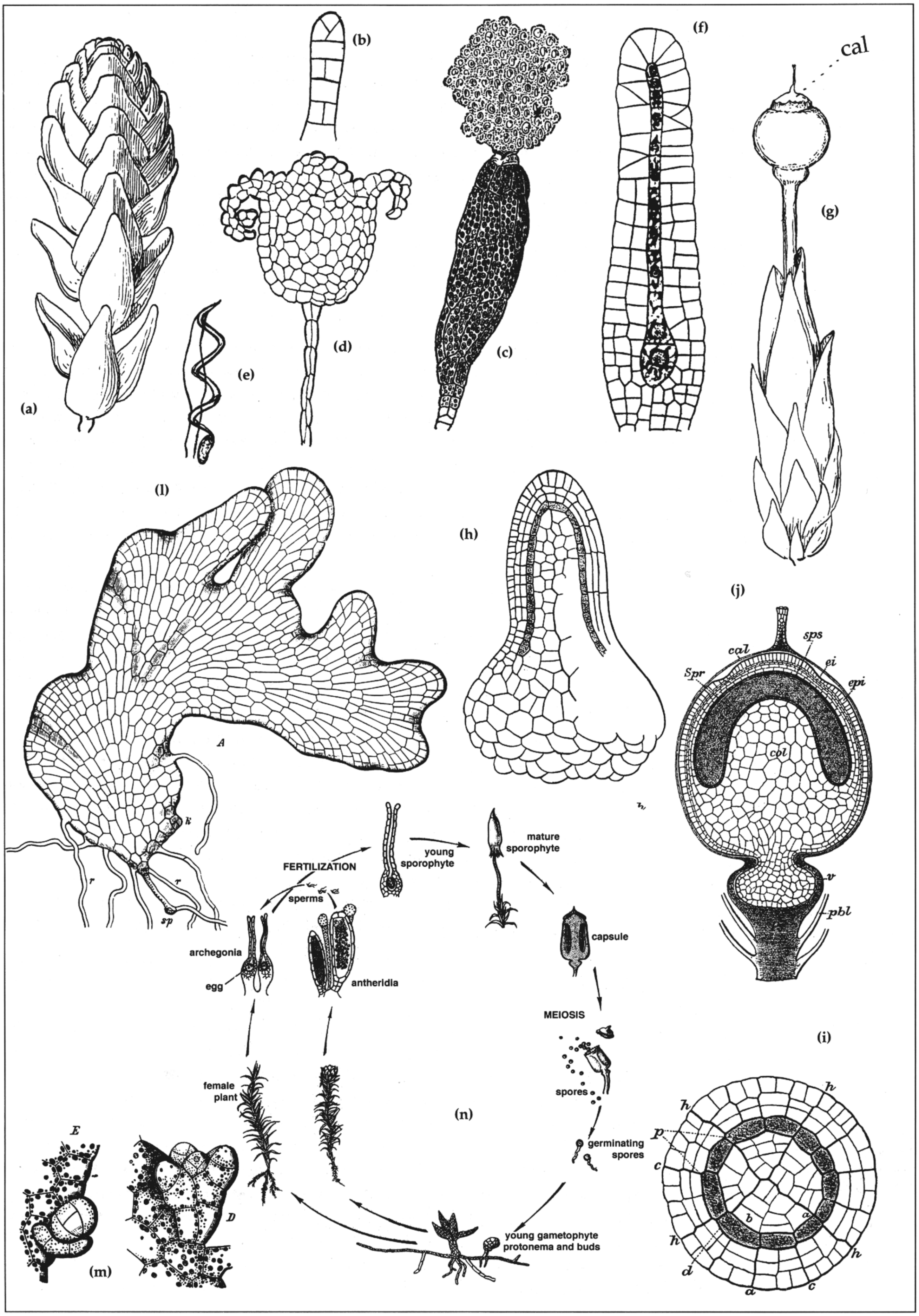
The little flasks in which the sperm cells develop are called *antheridia,* and these are produced in the sheltered axils of leaves at the top of short stems, forming catkin-like structures that are often colourful. The sperm cells are long, thin and coiled, with two long cilia for swimming. At the end of each sperm is a little vesicle containing a single starch grain; this falls away when the sperms are liberated. The egg cells develop inside stalked *archegonia,* which are produced at the apex of some of the short branches. Each has a long twisted neck made up of six rows of cells, with a canal in the middle. The leaves surrounding a group of archegonia later enlarge to form a protective *perichaetium.* Antheridia and archegonia are never found on the same branch; in some species they are produced on different branches of the same plant (*monoecious* species), in other species on different plants (*dioecious* species).

Fertilisation usually occurs in early spring. The sperms find their way to the eggs by swimming through the water film that always envelops the plants, and make their way down the central canal of the neck of the archegonium to fertilise the egg in the flask (*venter*) at the base.

Development of the resultant embryo results in the production of a spore capsule (*sporangium*), in which tetrahedral spores develop. When the capsule is ripe, a stalk develops to lift it up through the perichaetium into the air. The ripe capsule opens by a circular lid. Air pressure builds up within the capsule as the ripening spores dry, eventually becoming sufficiently high to dislodge the lid with explosive force, and shooting out the spores so that air currents can disperse them.

The spores germinate to produce a flat thallus-like *protonema,* one cell thick and up to a few centimetres across, which is attached by rhizoids to the substrate. The familiar sphagnum plant is produced from a bud that develops on the protonema. Nuclear division *(meiosis)* takes place during spore formation. This means that the familiar moss plant is haploid – each cell has only a single set of chromosomes. The diploid phase is very restricted. In animals and most land plants the opposite is the case.

(a) Male catkin of *Sphagnum cymbifolium.*
(b) Antheridium of *Sphagnum acutifolium* at an early stage of development.
(c) A different moss genus (*Funaria*) showing the release of sperms from the antheridium.
(d) Antheridium of *Sphagnum acutifolium* after the sperms have been released.
(e) Single sperm (magnified around a thousand times).
(f) A nearly mature archegonium of sphagnum. The bottom part is the venter, containing a single egg cell *(ovum)* at the bottom, the single *ventral canal cell* above it, and above that the column of nine *neck canal cells.*
(g) Spore capsule of *Sphagnum acutifolium;* cal: calyptra.
(h) Section down the middle of a young sporangium.
(i) Transverse section of same. Notice the bell shape of the spore producing tissue.
(j) Section through a nearly mature sporangium.
cal: calyptra.
spr: spore-cavity.
sps: spore sac.
epi: epidermis.
ei: furrow in the wall where the operculum will separate.
ps: pseudopodium.
v: vaginula.
pbs: perichaetial leaves.
col: columella.
(k) Sphagnum spores
(l) Protonema of *Sphagnum cymbifolium,* several months old.
sp: wall of spore.
rr: rhizoids.
k: first stage of a shoot.
(m) Young buds with primordial leaves developing on the protonema.
(n) The life cycle of a moss (*Polytrichum*).


(a)
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cal
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(l)
(m)
(n)
A
k
r
sp
FERTILIZATION
young sporophyte
mature sporophyte
sperms
archegonia
egg
antheridia
capsule
MEIOSIS
spores
germinating spores
female plant
young gametophyte protonema and buds
sps
cal
ei
Spr
epi
col
v
pbl
h
p
c
b
a
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D

Ecology

Many different species grow together in the sphagnum carpet, varying in colour, growth form, leaf shape and various anatomical details. But these rather subtle differences between the species are just the surface expression of deeper and more significant differences in water-holding capacity and tolerance of acidity or of drying, because each species occupies a slightly different niche on the bog surface. While possessing all the peculiar advantages that adapt the sphagnum mosses as a group so wonderfully to their boggy situations, each species is peculiarly adapted and specialised for a slightly different set of conditions. Thus, some species grow only in pools, while others grow on the drier hummocks, some species do better in slightly less acid conditions and so on. The sphagnum species that inhabit rather drier situations (like hummocks) are compact or cushion-like, with leaves in imbricated ranks, and they are often brown or reddish in colour. These are adaptations that help them to cope in these drier situations.

Altogether there are perhaps 300 species of sphagnum worldwide, the bulk of which grow in the North Temperate and Boreal zones. The main reason for the close similarity between so many species is that the basic form and chemical strategy of the bog mosses are so successful in the waterlogged environments in which these plants dominate that they vary very little. And yet, each species is a specialist, each adapted for a different niche on the bog, but the differences between the species are not always obvious anatomical differences; these are generally allied to subtle chemical differences about which we know very little at present. But slight as the differences may be, under the right circumstances they are real enough to give a competitive advantage to the species that possess them.

Some 25 or so species are known to occur in Ireland; some of these can be found in almost every bog, whereas others are rare. Green mats of *Sphagnum cuspidatum* (drowned kitten moss) dominate the pools on the bog. The aquatic species of sphagnum provide a sort of platform on which the less hydrophytic species can develop. *Sphagnum magellanicum,* a species with a distinctive purple-reddish colour, occurs near the end of the pool cycle as the hummock begins to build [**Table 8.1**].

Hummock-forming sphagna are often brown or red in colour, and produce a mucous substance in their capitula to prevent desiccation. The commonest hummock-forming species are *Sphagnum capillifolium, Sphagnum fuscum,* and *Sphagnum imbricatum. Sphagnum capillifolium* is easily recognised from its distinctive red colour, and small, closely-packed leaves. *Sphagnum imbricatum* is so called from the overlapping tile-like arrangement of its leaves and shoots. The densely-packed cushions of bronze-coloured *Sphagnum fuscum* occur near the end of the hummock cycle (See Chapter 5). Other species often found in the hummocks are *Sphagnum papillosum, Sphagnum tenellum* and *Sphagnum plumulosum,* which dominate the middle stage in hummock development.

There is a good deal of overlap in the environmental preferences of the different species in the hummock-hollow complex so characteristic of raised bogs. The species at opposite ends of the complex are more specialised in their ecological preferences than those which occur on the slopes in between, or on the sphagnum lawns. Species in the hollows grow faster, which enables them to exclude would-be competitor species. The species characteristic of the hummocks have a dense tussock habit which is an adaptation to the drier conditions there; this assists in raising water by capillary action, and it also makes it difficult for other species to get a 'toehold'. When the water table falls in summer the hummock comes under stress because in raised bogs the water table behaves as a planar surface, in spite of the hummock-hollow microtopography. The blanket of moss on the hummock also insulates the inside, so that it heats up and cools down more slowly. This means it can store less heat then hollows can. Hollow species on the other hand are better able to cope with desiccation. When the water table falls in dry summer weather the *Sphagnum cuspidatum* in the hollows often dries out and forms a white skin that keeps the plants and water underneath cooler by c. 2.5°C on a warm day and reduces evapotranspiration. This causes short-term undulation of the water table – as does heavy rain. Lawn species are rather higher in nutrients than hummock-hollow areas. These variations in microclimate and other factors are very important to the microfauna and flora within the sphagnum.

Table 8.1

Ecological preferences of different sphagnum species

Aquatic species with high mineral requirements (e.g. fens)
Sphagnum inundatum
Sphagnum platyphyllum

Aquatic species with low mineral requirements
Sphagnum plumulosum
Sphagnum cuspidatum

Species growing in situations of intermediate moisture:
Relatively high mineral requirements
Sphagnum amblyphyllum
Sphagnum contortum
Sphagnum squarrosum
Sphagnum subsecundum
Sphagnum teres
Sphagnum warnstorfii

Relatively low mineral requirements
Sphagnum angustifolium
Sphagnum cymbifolium (wide range of acidity)
Sphagnum papillosum
Sphagnum apiculatum
Sphagnum balticum
Sphagnum tenellum

Most important hummock formers
Sphagnum tenellum
Sphagnllm papillosum
Sphagnum rubellum
Sphagnum plumulosum (subnitens)

(After Tansley, 1939)

So both the hummock and hollow species are particularly well adapted to their places at either end of the complex. Only when the summer water table shifts for a considerable length of time do the species on the slope in between have an opportunity to extend their territory up or down.

Another very common Irish species is *Sphagnum subnitens,* which is tolerant of a wide range of conditions, and is found in most bogs, occuping a niche somewhat above the level of standing water. It is shade tolerant and is often found in woods. It is a variable species which often looks rather scruffy. In colour it varies between pale apple green and salmon pink, and it has a characteristic greasy appearance when wet and a metallic or rainbow sheen when dry.

With few exceptions, sphaghum species cannot tolerate water that has flowed over calcareous rock or soil. Water with high calcium levels also have a high pH, but it is the combination of high calcium *along with* high pH that is lethal. Most species are also intolerant of shade. *Sphagnum squarrosum,* which has leaves sharply reflexed from the leafy shoot, is one of the few that can. Neither can they tolerate high mineral concentrations, though some are more tolerant than others. We have seen earlier the way the cell wall operates a chemical exchange mechanism, enabling it to absorb nutrient ions, and replacing them with hydrogen ions from inside the cell and thus keeping the surroundings acid. Where the water is higher than normal in mineral content, the sphagnum flora is usually dominated by members of the rusty-brown Subsecunda section (there are six different sections in the family), which have relatively high mineral requirements and base tolerance. On the other hand *Sphagnum cuspidatum,* the commonest of the aquatic species of bog pools, has a low mineral requirement and a low base tolerance.

A figure often quoted for the rate of peat accumulation is 20-80cm per 1,000 years. However, where sphagnum is dominant, the rate of growth may greatly exceed this. Hummock sphagnum shoots can extend by something like 3.5cm a year, and aquatic species by as much as 40cm, and although compression will limit this to an upward growth equivalent of 1-4cm a year, it makes it difficult for vascular plants to keep up and compete. At the beginning of the 19th century, Richard Griffith observed moss peat in one particular bog over a period of twenty years, and calculated that it was accumulating at a rate of 2" (5cm) a year. *Sphagnum subsecundum* has also been known to grow at a rate of 5cm/year. The productivity in continuous carpets of sphagnum ranges between 100 and 600g per m^2 per annum; on blanket bog rates of 150g for hummocks, 500g for lawns and 800g for pools have been recorded by Clymo and his colleagues. A study of sphagnum productivity in Northern England estimated that net production of dry matter by *Sphagnum papillosum* was 3t/ha/yr, compared with 2 t/ha/year in adjacent grassland and 13 t/ha/yr for a pine forest in Southern England. This suggests that growth and production by sphagnum can sometimes be comparable with other plant communities from the same area.

The higher productivity and growth of the pool species (primarily *Sphagnum cuspidatum)* might seem to lend support to the idea that the pool must eventually overtake the slower-growing hummock, as predicted by Osvald's regeneration complex hypothesis. This does not happen, because the decomposition rate of *Sphagnum cuspidatum* is also much higher than that of the hummock species. The greasy, almost structureless peat of *Sphagnum cuspidatum* is very distinctive and easily recognised; in large bogs which are being milled, the three-dimensional picture provided by the bare 'palaeobog surface' of the milling fields, crossed at regular intervals by deep drains, makes it easy to map out ancient pool patterns for which the cusp-shaped occurrences of *Sphagnum cuspidatum* peat provide easily identified markers.

The sphagnum carpet can be thought of as a miniature forest, which we normally view in the way an aeroplane would view a tree forest canopy. But for the creatures who live in this miniature forest it is very different. The canopy is made up of closely interwoven sphagnum heads among which small animals can move about. But since the stalks are much narrower than the crowns of the moss plants, the creatures who live down in this stalk layer can move about more freely in a dark and dense mid-forest layer, more or less shut away from the dazzling world above. Apart from the darkness down here, it is much cooler, with much less diurnal variation in temperature – maybe 5°C, whereas at the surface it might be 30°C or even more; there is also a great difference in relative humidity and in the amount of air movement. The moist canopy is also a heat insulator. So it is a very different world from the world above, and this is reflected in the quite different faunas that inhabit the two domains. The sphagnum forest has, moreover, a watery floor, because the water table in a sphagnum carpet is normally about 15cm below the surface, although this fluctuates widely with the seasons: and below the waterline there is a different world again (See Chapter 12).

The peat of the bog has its own 'fossil' flora. Two of the most prominent mosses in the peat – indeed, they are often overwhelmingly dominant – are *Sphagnum imbricatum* and *Sphagnum fuscum.* Sometimes one is dominant and sometimes the other. Yet neither of these is commonly found on bogs today: they are generally regarded as rare and decreasing. Some of the rarer species which are still with us are also likely at some future time to be confined to the fossil moss flora of the peat, because their habitat is being lost as the larger and wetter bogs disappear. One such is the rare *Sphagnum pulchrum,* a striking bright orange species characteristic of the alliance Rynchosporion albae in the wet hollows of raised and blanket bogs: a habitat which is particularly sensitive to activities (such as drainage and afforestation) that lower the water table. On the other hand, *Sphagnum magellanicum,* which is one of the commonest species today in raised bogs around the edges of pools and on low hummocks, is rare in the peat profile. It follows *Sphagnum cuspidatum* in the hollow to hummock succession, and it also colonises bare peat surfaces after bog fires. Its increased importance is a result of human influence on the bogs.

Polytrichum: Family Polytrichales

One of the most distinctive and easily recognised of all mosses is *Polytrichum* (thread moss), which is conspicuous and common in and around both raised and blanket bogs, though again, it is not the easiest of tasks to distinguish the separate species, of which at least six are common [**Figure 8.5**]. It grows in quite different sorts of habitats from the sphagnum mosses. In raised bogs it seems to favour areas of cutover (especially wooded areas), whereas its favourite locality in blanket bog is on the banks by the sides of bog tracks, where miniature 'forests' of the moss are often found.

One of the unusual characters of the genus as a whole is the way the upper surface of the leaf is covered with an armour of minute plates of photosynthetic tissue called lamellae, which grow at right angles to the leaf blade. In section, each lamella consists of a chain of five or six cells, the terminal one of which is different from the others (it usually has a number of bumps), and is often distinctive for the species. *Polytrichum* also has a well-developed system of root-like rhizoids, emphasising the fact that unlike the bog mosses (which don't have rhizoids) it draws its nutrients from the peat. It is closer to 'higher' plants than sphagnum, because it has a primitive vascular system that contains specialised *hydroids* for conducting water, and *leptoids* for mineral uptake. There are separate male and female plants. The male reproductive structures look almost like miniature fields of red flowers; these 'flowers' contain rows of antheridia – sausage-like structures that contain the sperms. The antheridia burst when they are ripe, ejecting the sperms into the surrounding film of water. The sperms have two flagellae and can easily be seen under a light microscope, as they struggle and wriggle through the water in search of the nearest archegonium, which encloses the female egg. The archegonium helps by emitting a chemical attractant to guide the sperms. Later on, the fertilised archegonium develops into a spore-containing capsule. The spore capsule is a fascinating structure, easier to appreciate than in most mosses because of its large size. While it is ripening the capsule is covered by a very hairy pointed cap called a *calyptra,* which simply lifts off, and is blown away by the wind when the right time comes. The capsule itself works rather like a poppy capsule in the way it dispenses its spores, but the censor mechanism it uses to shake the spores out a few at a time in dry weather is rather more complex than in the poppy [**Figure 8.5**]. There is a membrane called an *epiphragm* stretched tightly across the mouth of the capsule, and round the rim there is an elaborate mechanism called the *peristome* that consists of either 32 or 64 interlocking teeth. The peristome opens in dry weather, and the spores – of which there can be up to two million in each capsule – are then shaken out through the small gaps between the teeth.

Polytrichum aloides is the smallest common species; it often occurs on bog road cuttings, where a similar species, *Polytrichum nanum,* can also be found. The two can be distinguished with a hand lens because the capsule in *Polytrichum nanum* has a papillose surface. *Polytrichum aloides* is one of the earliest species to appear on bare peat. *Polytrichum urnigerum* is like a somewhat larger version of *Polytrichum aloides,* and it tends to occur in similar places, but it can usually be distinguished by its distinctive pale, glaucous green colour. It is also a common plant on old walls.

Polytrichum juniperum also grows on stone walls, but is more characteristic of areas where bog or heath fires have occurred, as it is one of the earliest colonisers of bare burnt areas. It grows to 5cm, and has characteristic bright red stems and capsule stalks, and reddish leaf tips. The absence of teeth from the leaf margin distinguishes it from *Polytrichum commune* and *Polytrichum formosum,* with which it might sometimes be confused. *Polytrichum piliferum* looks like *Polytrichum juniperum,* and grows in similar situations, but is easily distinguished by the long, hoary grey-white points at the tips of its leaves.

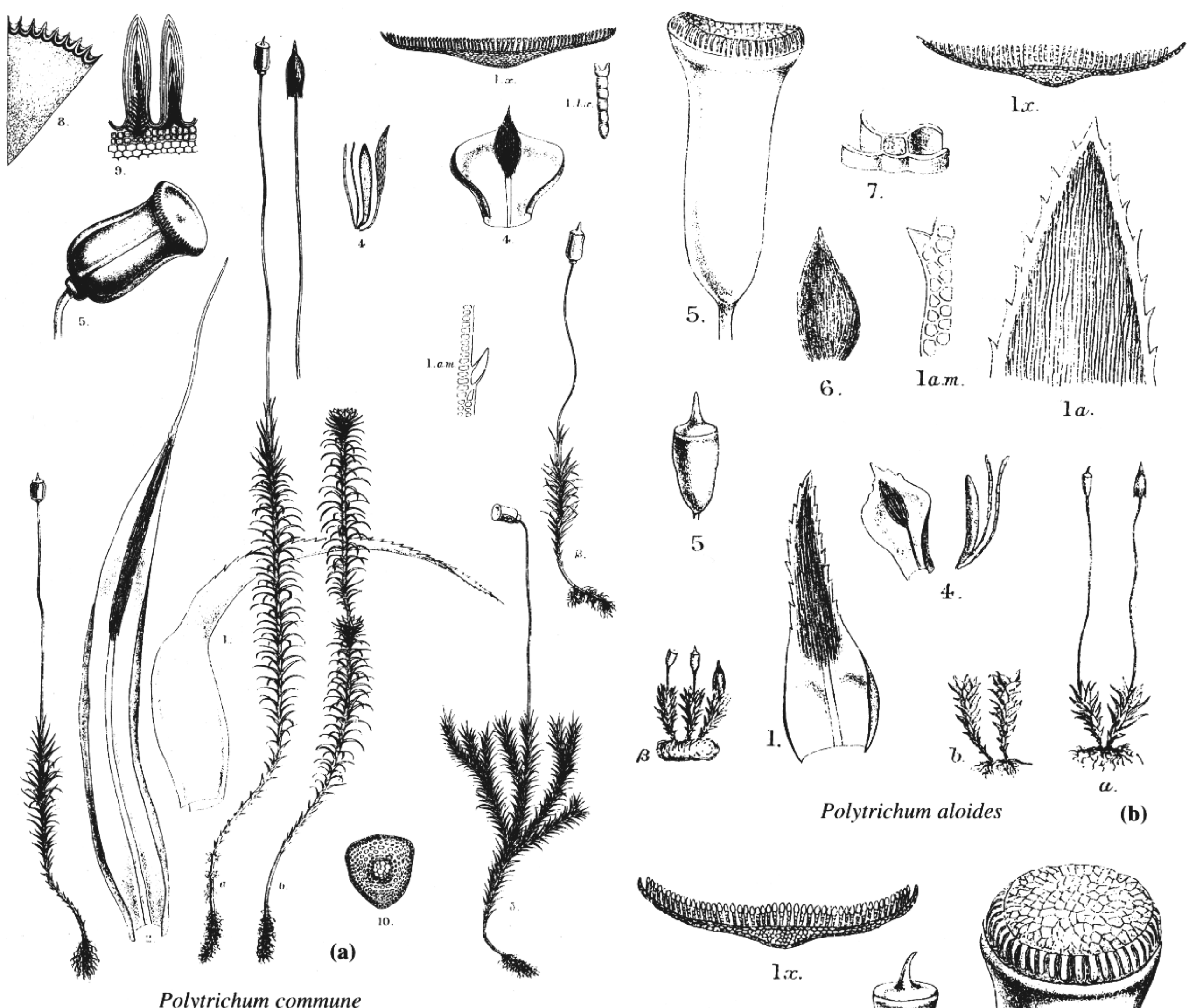
Polytrichum commune is the tallest species, and its luxuriant carpets of dark green are a very familar sight along bog roads. The closely-massed stems often grow to 20cm and more, and the leaves may be a centimetre in length. There is another species of *Polytrichum* which is very similar, though not nearly so tall as a rule. This is *Polytrichum formosum,* which is more typical of woods. The difference in height will usually separate the two species, but the distinctive terminal cells of the lamellae are a more reliable distinguishing character.

Several species of *Pogonatum* are common along forest trackways on blanket bog especially. They look like diminutive thread-mosses (*Polytrichum*) and often occur with them.

Other mosses on the bog

Several species of *Campylopus* are characteristic of peatland habitats. *Campylopus pyriformis* and *Campylopus paradoxus* are widespread colonists of bare peat (often along with *Polytrichum* and the little moss *Pohlia nutans).* The most important bog species is *Campylopus atrovirens,* which forms very distinctive blackish green velvety mats up to 10cm high, and is one of the most easily recognised of blanket bog mosses. It is also one of the two character species of the Transitional Sub-type of raised bog. Another species of *Campylopus* that is now a notable feature of cutaway bog is *Campylopus introflexus,* accidentally introduced into Ireland in the 1940s. In spite of its recent arrival, it has spread widely and become very common, occupying an important niche in the re-vegetation of cutaway peat. It can easily be recognised by its long white hair points, which bend backwards on drying to form a star-like shape when viewed from above. The moss helps to consolidate the surface of the bare peat by forming large, uninterrupted carpets. These extensive carpets are unstable and break up at a certain stage. The cracks and spaces thus formed constitute a benign microhabitat in which seedlings can germinate, and the decaying moss provides compost.

One of the commonest mosses wherever heather is dominant is *Pleurozium schreberi,* whose luxurious tangles often festoon the ground under the shelter of undisturbed heather plants. It is easy to confuse with certain other species (notably *Pseudoscleropodillm purum),* but it can usually be distinguished from other mosses in the same habitat by its bright red stems. A special variety of the very variable and almost ubiquitous *Hypnum cupressiforme* is also very common under heather, often creeping up the lower stems; this is the variety *ericetorum,* which is sometimes regarded as a distinct species *(Hypnum jutlandicum).* Tussocks of the attractive moss *Leucobryum glacum* can often be found on very dry hummocks.



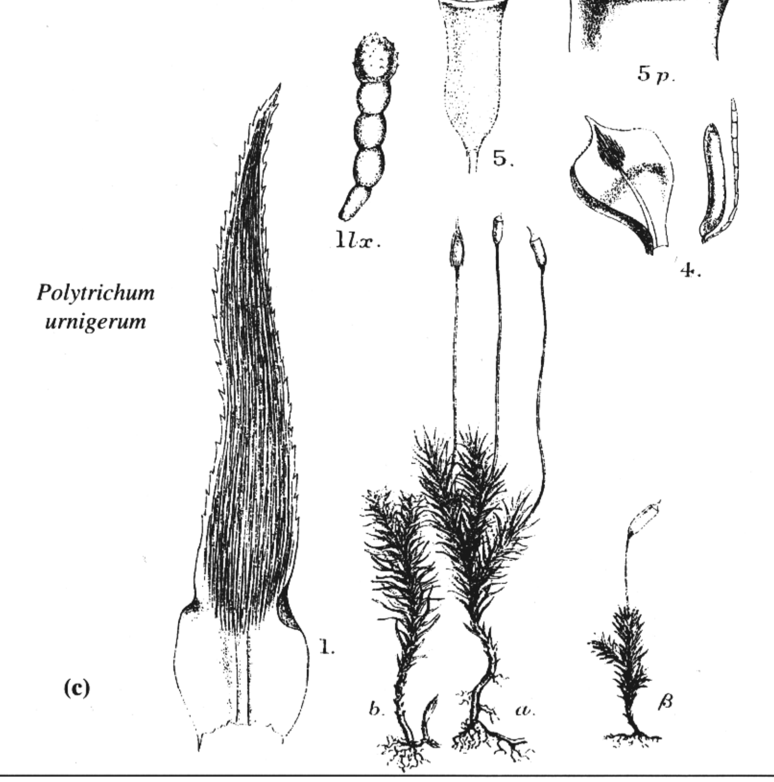
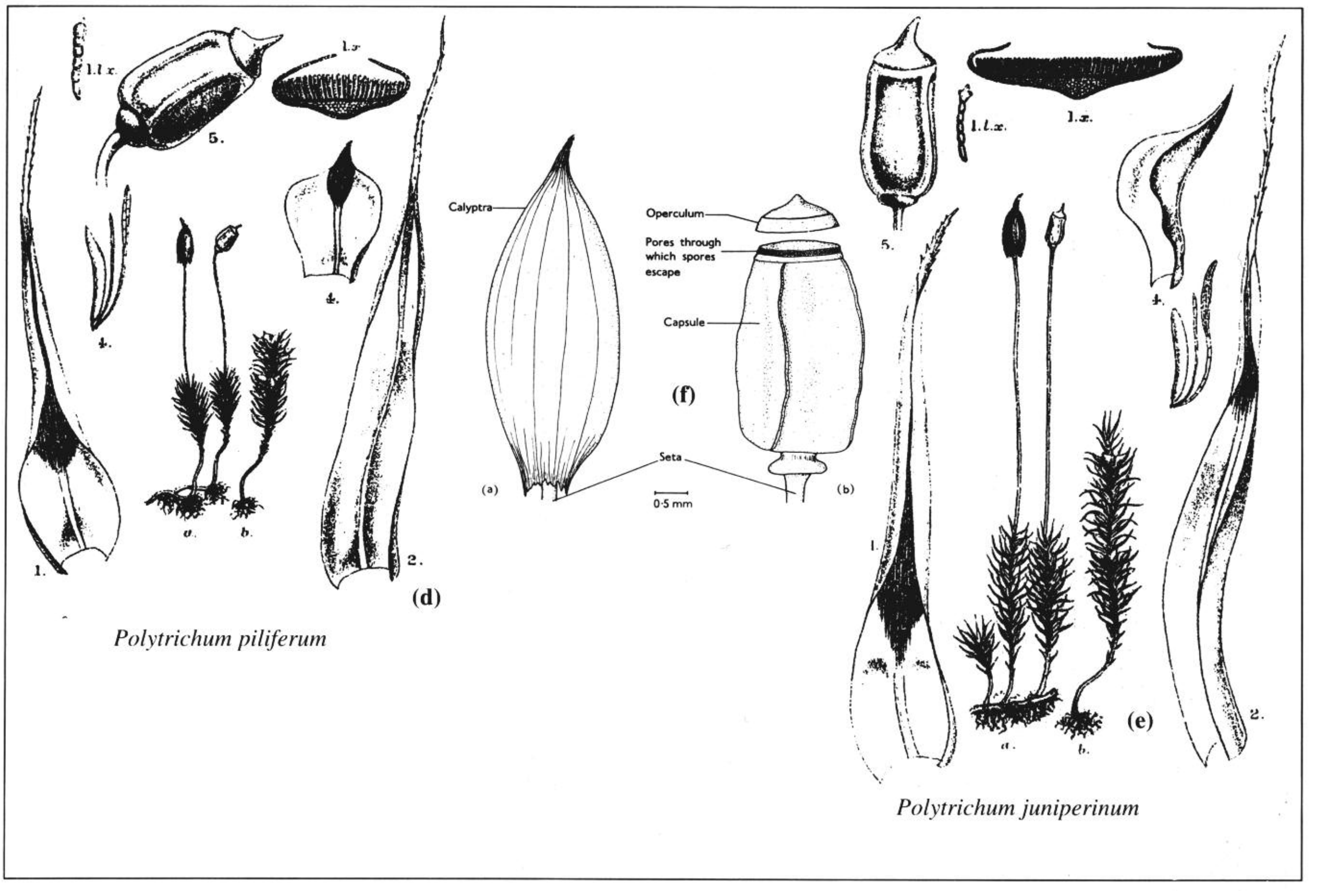


Figure 8.5:
Polytrichum
(a) *Polytrichum commune*.
(1) Single leaf, magnified. Transverse section of leaf and of one of the vertical lamellae.
(1a) Apex of the leaf. (1aa) Areolation of same, seen from the back. (1am) Areolation of margin.
(2) Perich. bract. (4) Bract, antheridium and paraphyses. (5) Capsule. (6) Calyptra.
(7) Transverse section of columella.
(8) 1/8 part of the epiphragm, internal face.
(9) Two teeth, internal face, crest removed from one.
(10) Transverse section of stem.

Some other species, showing both male and female plants.
(b) *Polytrichum aloides*.
(c) *Polytrichum urnigerum*.
(d) *Polytrichum piliferum*.
(e) *Polytrichum juniperinum*.
(g) Capsule of *Polytrichum juniperinum*,
(i) before removal of the 'hood' or calyptra;
(ii) after removal: operculum removed to show pepper-pot mechanism. See details of the different species shown above.



Liverworts [Figure 8.7]

Ireland is extremely rich in this family of plants, and produces a *number of remarkable species, which are true indicators of the climate of the country. These minute vegetables, some of which are scarcely visible to the unaided eye, tell of heat, moisture, and other climatal circumstances, much more accurately than the flowering plants of the country do, and show that the south-west of Ireland approaches in climatal conditions some sub-tropical parts of the world.*

David Moore (1876): *Report on Irish Hepaticae*

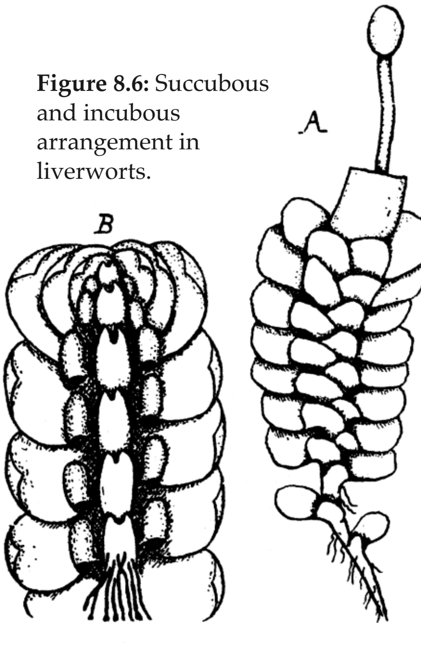


Figure 8.6: Succubous and incubous arrangement in liverworts.

Virtually all the liverworts of bogland are of the leafy kind, small inconspicuous plants that seldom catch the eye. These belong to the order Jungermanniales. The stems have three rows of leaves, but early on in their evolution most of the leafy liverworts took to a creeping habit, and one of the three rows was reduced to small scale-like structures called underleaves *(amphigastria),* leaving two rows of obvious leaves on the upper surface of the axis. These leaves are only one cell thick, and are often deeply lobed, a feature never seen in mosses in this part of the world. The leaves overlap each other like venetian blinds. When the bottom of one leaf rests on top of the next – as in a closed venetian blind – the arrangement is described as *succubous;* when the arrangement is the other way round it is described as *incubous* [**Figure 8.6**].

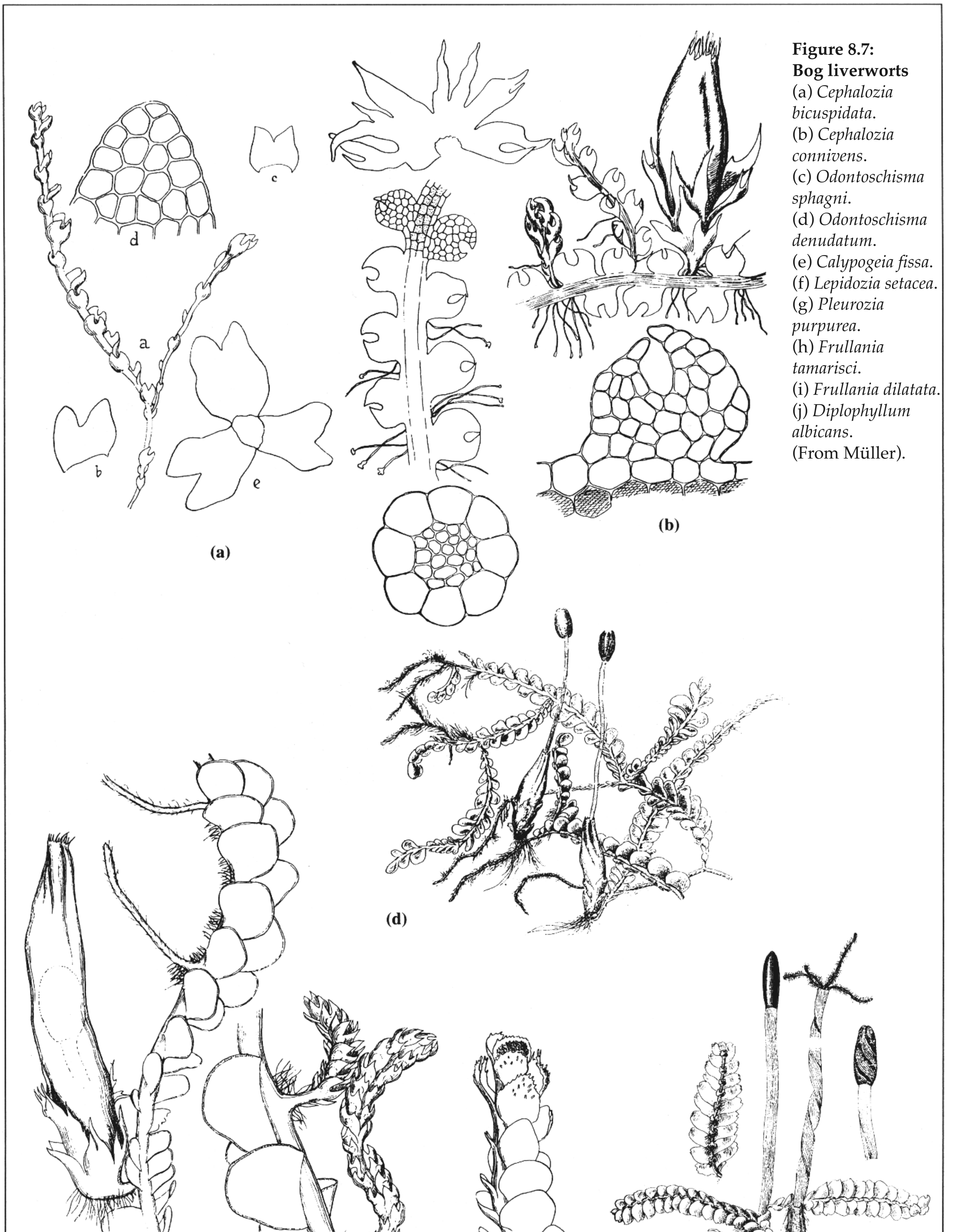
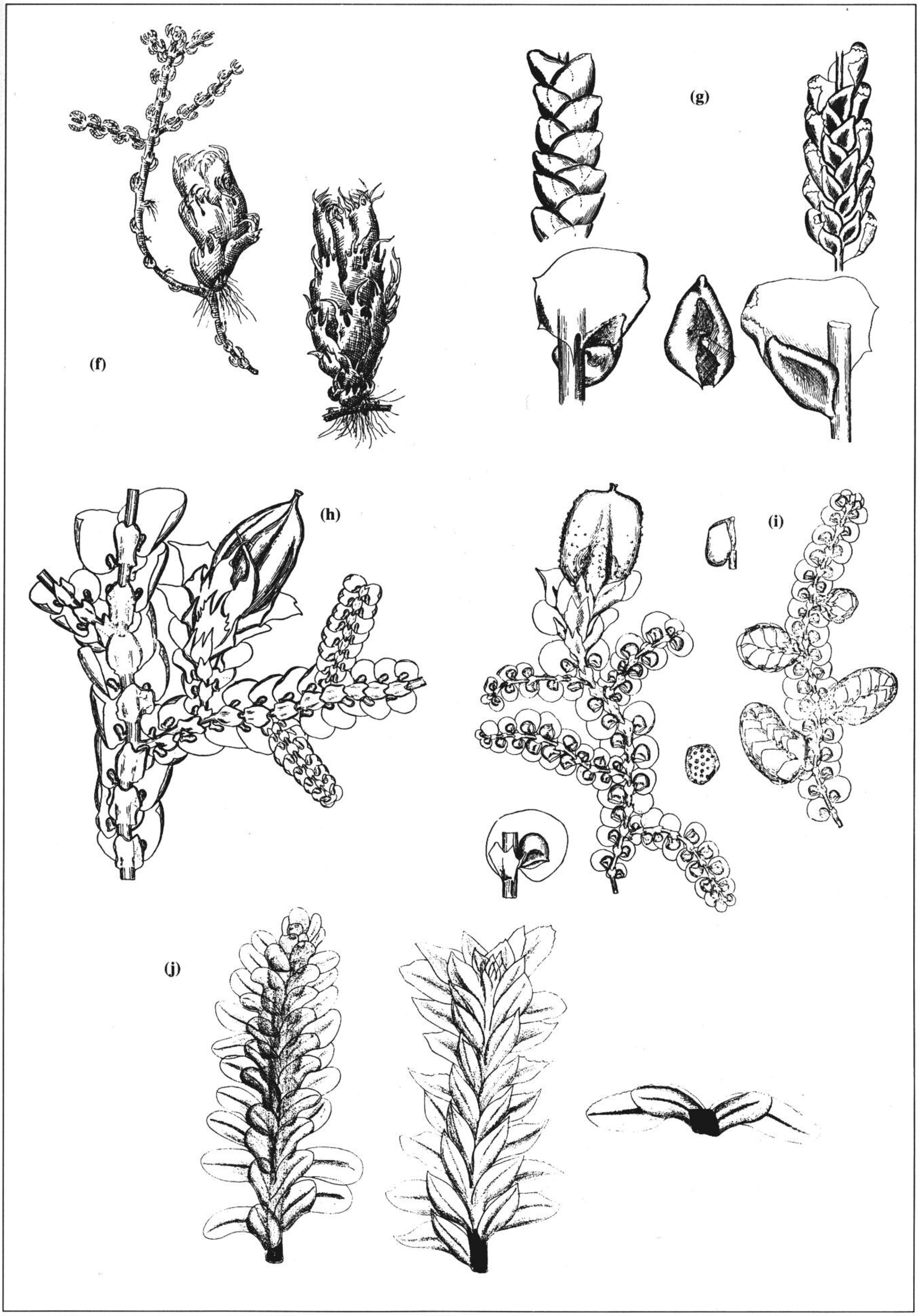


Figure 8.7: Bog liverworts
(a) *Cephalozia bicuspidata*.
(b) *Cephalozia connivens*.
(c) *Odontoschisma sphagni*.
(d) *Odontoschisma denudatum*.
(e) *Calypogeia fissa*.
(f) *Lepidozia setacea*.
(g) *Pleurozia purpurea*.
(h) *Frullania tamarisci*.
(i) *Frullania dilatata*.
(j) *Diplophyllum albicans*.
(From Müller).


(f)
(g)
(h)
(i)
(j)

Although they are seldom a conspicuous component of the vegetation, some of the leafy liverworts are very characteristic bog plants, and in particular of the sphagnum carpet. Indeed, in wetter bogs these little liverworts can grow so luxuriantly that they smother the sphagnum. In almost every bog the little creeping stems of *Odontoschisma sphagni* will be found forming loose tufts in and around the cushions of sphagnum. A closely related species that is widespread but not so common is *Odontoschisma denudatum.* One way in which it differs from its ubiquitous relative is that it bears tiny bright pale green bud-like vegetative reproductive structures at the tips of its shoots. These little structures, which are very characteristic of these liverworts, are called *gemmae,* and when they become detached from the parent plant, each one is able to develop into a new plant. Several other kinds of liverworts often occur along with *Odontoschisma sphagni.* The most frequent are *Mylia anomala* (whose upper leaves always bear an abundance of gemmae), and *Lepidozia setacea. Calypogeia fissa* forms pale green patches on wet peaty banks and similar habitats; two other species often found in such situations are *Cephalozia bicuspidata* and *Cephalozia connivens.* Very tiny *Cephaloziella* liverworts often form a green or brownish film on bare peat.

One of the most distinctive and important liverworts of bog is *Pleurozia purpurea,* which forms very attractive and conspicuous purplish-red tufts, like a bunch of copper-coloured worms, particularly on blanket bogs, and on raised bogs of the Midland Subtype, of which it is one of the indicator species. It is a bigger and more robust plant than most other leafy liverworts, with stems up to 15cm long that bear two rows of closely overlapping and most extraordinary leaves. There are two lobes to each leaf, a larger, upper or *antical* lobe, which is concave and toothed at its cleft apex, and a smaller, deeply concave and lower (*postical*) lobe that looks just like a little hood or sac. At the bottom of this sac there is a tiny hole that allows water to enter, but it has a valve mechanism that prevents it getting out again. This elaborate structure is a device for conserving water, but it has been postulated that it may also function as a trap for small animals – as similar structures do in related tropical liverworts.

This extraordinary leaf arrangement is more elaborately developed in liverworts belonging to the genus *Frullania.* Here the postical lobes are modified to form little helmets or upside-down pitchers, which as in *Pleurozia* are probably mainly intended to catch and store water, though there is also the possibility that they trap small animals and use their protein to supplement the meagre nutrient supply the rainwater provides them with. The commonest of several species of *Frullania* that occur on bogs is *Frullania tamarisci,* which often forms a reddish-olive to deep purplish-brown or copper-coloured mat on old heather stems [**Figure 8.8**]. *Frullania dilatata* is very common on the bark of trees; there are three other species (*Frullania teneriffae, Frullania fragilifolia* and *Frullania microphylla*) that are more or less confined to the west.

One of the most enigmatic liverworts on the bog is surely *Cryptothallus mirablis.* This liverwort lives entirely underground and is parasitic: it has no chlorophyll, but gains its nourishment from mycorrhizal fungi. It is creamy brown in colour, and has small chubby finger-like lobes about 2mm wide and 10mm long. *Cryptothallus* is believed to be an uncommon species; it has been recorded from underneath large, loose sphagnum hummocks, in wet flushes, and sometimes (in the west) in birchwoods, but its apparent rarity is probably due at least in considerable part to its hypogeal habit, which makes it very difficult to find.

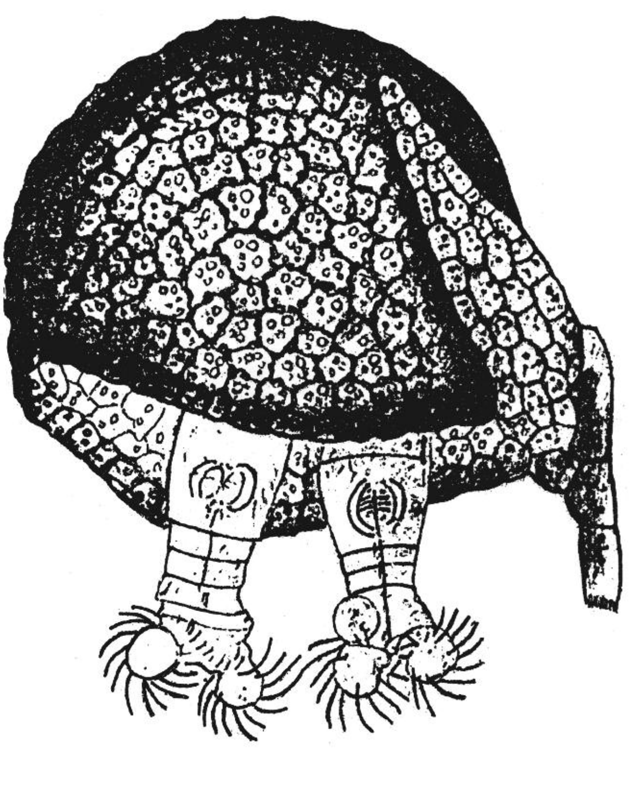


Figure 8.8: Helmetcole? P. Janzen's wonderful drawing of one of two species of rotifers which spend their lives in the helmets of *Frullania* (from Müller; x150). In *Frullania* each of the two lateral rows of leaves are completely divided. The *antical* lobe is large and expanded, but the *postical* lobe is a helmet-like upside-down pitcher, with a little projection called a stylus near its attachment.

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Chapter Nine

Fungi, lichens and algae on the bog

To the naturalist – especially the botanist variety – the barren heath is an exhaustible mine of riches; and even now [in autumn) when the floral glories are dimmed, there are almost endless riches of another kind from which to cull a few that will delight his sense of beauty and his thirst for knowledge.

Edward Step, ***The Harvest of the Woods***

FUNGI

Fungi constitute one of the five great kingdoms of life (the **Mycota**). In modern classifications, the Mycota are divided into five major groups or phyla. The **Zygomycota** include such common moulds as *Rhizopus* and *Mucor;* in this group the hyphae lack cell walls or septa and sexual conjugation by compatible hyphae leads to the formation of resting spores (zygospores). In the **Ascomycota** (popularly referred to as ascomycetes) spores are produced in groups of (usually) eight inside special sacs called asci; in the **Basidiomycota** (the basidiomycetes) they are produced in fours (usually) on the outside of structures called basidia [**Figure 9.1**]. The **Deuteromycota** (formerly known as *fungi imperfecti*) are not a natural phylum; they are a sort of 'limbo phylum' for fungi whose sexual generation is unknown, so that they cannot be assigned to other phyla. The fifth phylum in the Mycota is the lichens (**Mycophycophyta**).

Fungi differ fundamentally from green plants in their lack of chlorophyll, so they cannot synthesise their own food, and in having cell or hyphal walls that are made of chitin rather than cellulose. Although they exhibit enormous diversity and specialisation, all the different ways of living that fungi have evolved can be grouped into two main life-styles. The largest group is the *saprotrophs* (saprophytic fungi, those fungi that break down the bodies of dead plants and animals. They utilise the raw materials and energy in them for their own needs, playing a vital role in the re-cycling of carbon, nitrogen and other nutrient elements that otherwise would remain locked up in dead organic remains indefinitely. The second group is the *parasites,* which obtain their nourishment from living plant and animal tissue. Here we can recognise three groups: *commensal fungi* that, as it were, feed on the crumbs from the host's table without doing any damage or giving anything in return; *mutualistic fungi* that give something in return for what they obtain, often co-operating closely with the host; and antagonistic fungi that damage or kill the host. Two categories of mutualistic fungi are of great importance in bogs: *mycorrhizal fungi,* which were introduced in Chapter 6, and *lichens.* A lichen consists of an alga and a fungus living together so intimately that together they constitute a new, distinctive organism, different from either symbiont, and one that has greater ecological versatility than either partner alone.

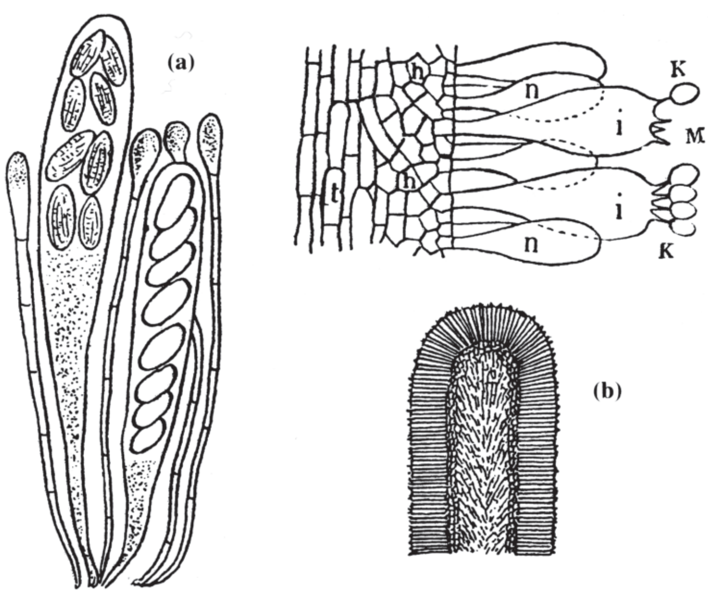


Figure 9.1: Asci and basidia.
(a) Asci and paraphyses of an ascomycete. (The paraphyses are the hair-like structures between the spore-containing asci).
(b) Fragment of the gill of a basidiomycete showing trama (t), subhymenial layer (h), basidia (i), with Spores (k), sterigmata (m) and cystidia or barren basidia (n).

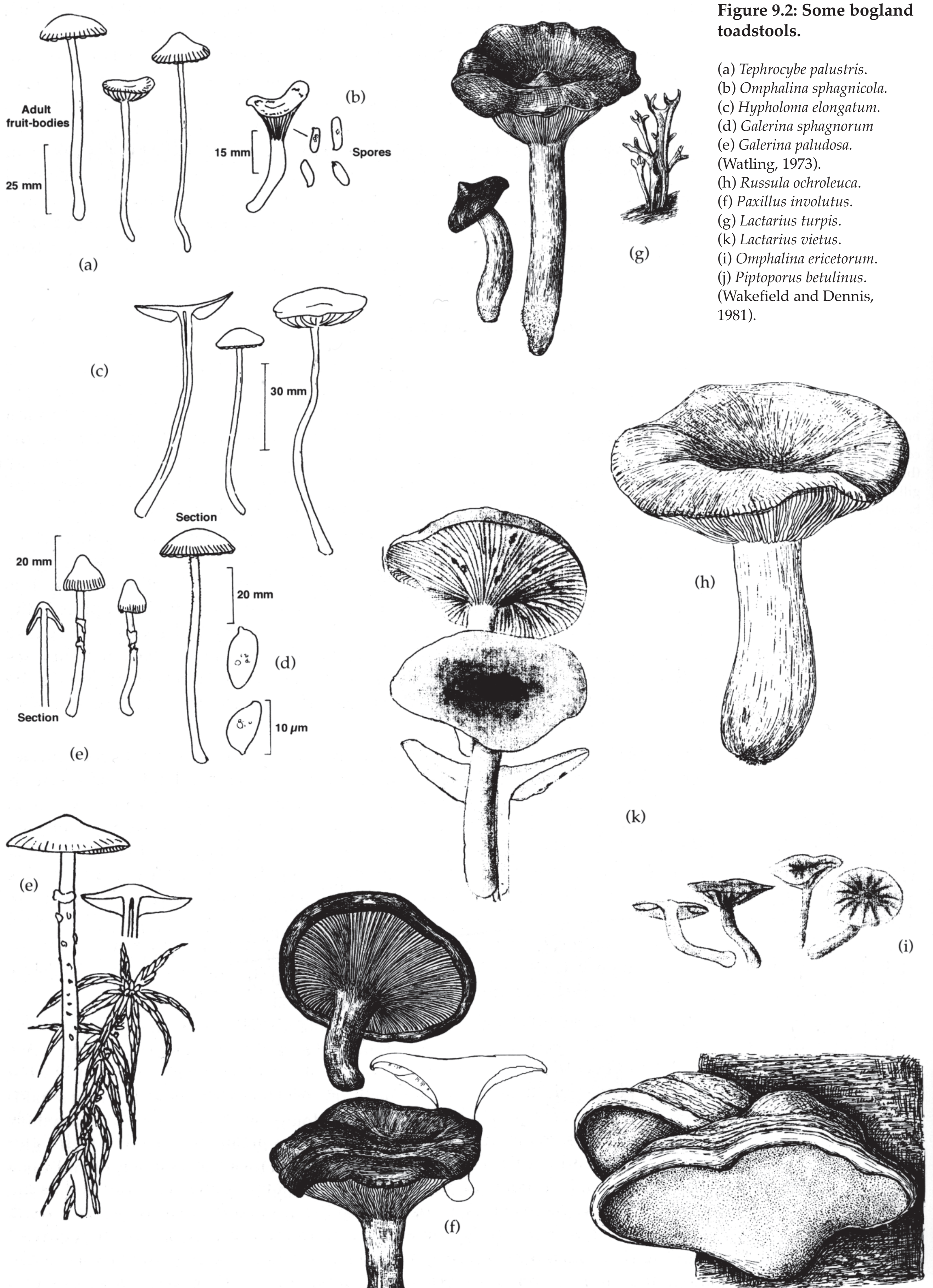


Figure 9.2: Some bogland toadstools.

(a) *Tephrocybe palustris*.
(b) *Omphalina sphagnicola.*
(c) *Hypholoma elongatum.*
(d) *Galerina sphagnorum*
(e) *Galerina paludosa.*
(Watling, 1973).
(h) *Russula ochroleuca*.
(f) *Paxillus involutus*.
(g) *Lactarius turpis*.
(k) *Lactarius vietus*.
(i) *Omphalina ericetorum*.
(j) *Piptoporus betulinus*.
(Wakefield and Dennis, 1981).

Fungi play a vital role in the upper layers of the peat soil, but it is only those that produce prominent fruiting bodies at the surface which attract our attention as a rule. A fungus consists of a system of colourless threads called a *mycelium*, which it uses to feed; the component threads are known as *hyphae.* At some stage in its life it produces reproductive spores on specialised structures called sporophores. The most conspicuous fungi are the mushrooms and toadstools, shelf and bracket fungi, nearly all of which belong to the Basidiomycota. These fruiting bodies are produced by the hidden colony of the fungus during a brief invasion of the open atmosphere, and are wonderfully adapted for aerial spore dispersal. The rest of the year is spent out of sight in soil and humus and wood. Here, great numbers of different agarics, boleti, puffballs and bracket fungi and all the others live out their different lives, obtaining the raw materials and energy they require from the living and dead tissues of plants and animals.

Mushrooms and toadstools in bog woodland

The terms toadstool and mushroom really mean the same thing, but 'mushroom' is perhaps best confined to the common field mushroom and its relatives (all belonging to the genus *Agaricus*). Toadstools occur in greatest profusion and diversity in association with trees, and perhaps more than any other group of organisms they epitomise the mystery and magic of the woodlands. And although we now have an impressively comprehensive understanding of the botany and ecology of the flowering plants, ferns and mosses of woodland, we still know little of the ecology of woodland fungi.

The birchwoods that fringe many bogs tend to be botanically unrewarding, but for the mycologist there is great interest here. They are the favoured habitat of the fly agaric (*Amanita muscaria*) [**Plate 6**]. Because it is beautiful, poisonous and hallucinogenic, it is hardly surprising this is one of the best-known of all toadstools, finding a place in the folklore of most cultures, but strangely not of Ireland. This may be because its favourite haunts – birchwoods and conifer woods – have become widespread habitat-complexes here only in recent centuries. Another common amanita of the birch woodlands is the edible tawny grisette (*Amanita fulva*), which has a delicate chestnut-coloured cap with prominent striations at the margins.

The edible brown birch bolete (*Krombholziella scabra*), is one of several bolete species commonly associated with the tree [**Plate 6**]. Another very common birchwood species is the brown roll-rim (*Paxillus involutus*). Many species of milk-caps (*Lactarius*) occur, frequently in large numbers. Three are particularly common: the woolly milk-cap (*Lactarius torminosus*), the rufous milk-cap (*Lactarius rufus*) – which is actually cultivated on cutover peat in Finland – and *Lactarius quietus.* The ugly milk-cap (*Lactarius turpis*) is also common. Several species of russula (brittle caps) are common under birch, none more so than the common yellow russula (*Russula ochroleuca*); other common yellow birch russulas are *Russula claroflava* and *Russula betularum.* The most common cortinarius species of birchwood is usually *Cortinarius palaceus,* a lovely little scaly brown toadstool with a conical or bell-shaped cap that always has a distinctive sharp umbo.

One of the great mycological thrills of the bog in autumn is finding *Cortinarius violaceus,* which it is occasionally met with in the fringing birchwoods. This is one of the most distinctive, beautiful and easily recognised species in an otherwise very difficult and large genus of toadstools. It is also one of the species which appears in Group B of the Red List of European macrofungi, which comprises species characterised in Europe as a whole by 'widespread losses, evidence of steady decline, some national extinctions, medium-level concern'. The entire fruit body is deep violet in colour: cap, stem and gills, although as they mature the gills become dusted with the rust-brown spores. The fruit bodies can be up to 15cm across and as much in height, and they have a faint smell of cedar wood. The cap is covered with a woolly down that cracks into fine scales as the toadstool matures. The stem has a conspicuously bulbous base and is covered with woolly fibrils. *Cortinarius* species are important mycorrhizal toadstools, and *Cortinarius violaceus* seems to have a specific relationship with birch.

Cantharellus infundibuliformis, often found growing among birch litter, is an edible relative of the much-prized chanterelle (*Cantharellus cibarius*). The brown colour of the wrinkled fruiting bodies conceals them among the dead leaves and twigs; the dull colour of the cap is in almost startling contrast with the yellow stems, which are usually characteristically flattened. Two common associates of young birch are poison pie (*Hebeloma crustuliniforme*) and the deceiver (*Laccaria laccata*). Poison pie is brownish-white and usually occurs in groups; it is poisonous. The deceiver is so-called because of its great variability.

Though less in evidence because its fruit bodies are produced underground, the bog false-truffle (*Elaphomyces*) is a common member of the birchwood mycoflora. The fruits of the bog false-truffle are small, wart-covered balls 2-5cm in diameter, yellowish-brown in colour, in which the spore-containing sacs or asci are produced in a scattered fashion rather than in a definite layer. It is generally only noticed when the fructifications of *Cordyceps ophioglossoides* appear; this latter is a fungus that lives as a parasite on the buried truffles, producing its own club-shaped fruit bodies above ground. These are olive-black, with yellowish stalks [**Figure 9.4, Plate 6**]. Another larger ascomycete that is very common in the birchwoods is the gum-drop or jelly-baby fungus (*Leotia lubrica*), whose gelatinous club-like fruit bodies often occur in platoons in the birch litter in early autumn [**Plate 6**].

Most of the common toadstools growing in the birchwoods are mycorrhizal fungi. Some of them establish the association with their host tree at an early stage, forming mycorrhizae as soon as they germinate, and inhibiting the growth of competing fungi. Others establish themselves at a later stage, when the trees are older. In other words, there is a complicated succession of birchwood toadstools, the details of which are only beginning to be understood. *Hebeloma, Inocybe* and *Laccaria* are among the early-establishing mycorrhizal fungi.

Cenococcum graniforme is another characteristic ectomycorrhizal fungus of birchwood. It occurs widely in mor soils throughout most of Europe, but is especially characteristic of northern birchwoods in peaty soils. *Cenococcum* is sometimes so common a component of the birch litter that it must play an important part in the breakdown of the surface peat. It also turns up occasionally deep down in the peat profile. It spends part of the year as a ramifying network of mycelial threads among the surface litter and upper peat, and as summer approaches and conditions become drier it forms its resistant *sclerotia,* which germinate from autumn onwards as conditions become damper. These sclerotia look like little hollow pellets of shot of different sizes, from as little as 0.2mm to as big as 7mm, black and with a slight sheen, and brittle like coal in texture, lying on the surface or among the birch litter and peat. *Cenococcum* never forms conidia or spores of any kind, so it cannot be classified like other fungi; in systematic terms it is a true *Sclerotium* (i.e. a fungus that only produces mycelium and sclerotia).

It is interesting to notice that the bog pines found under the peat are frequently accompanied by fossil bootlace rhizomorph strands of honey fungus (*Armillaria*), a parasite which is particularly hazardous to young trees; perhaps this is another factor which needs to be considered when analysing possible reasons for the decline of Scots pine in Ireland.

Broad successional groups of fruiting mycorrhizal fungi can be identified in the woods. Under lodgepole pine (widely planted on peat soils) this proceeds from *Laccaria* to *Paxillus/Lactarius/Cortinarius* to *Inocybe/Russula;* and in Sitka spruce – also widely planted: see Chapter 7 – from *Laccaria* to *Paxillus/lnocybe/Cortinarius / Lactarius.* The saprotrophic agaric flora changes also. *Nolanea cetrata* and species of *Clitocybe* and *Collybia* seem to be more characteristic of lodgepole pine stands, whereas *Marasmius androsaceus* and an abundant *Mycena* flora characterises Sitka spruce. The earliest stages under birch (and *Pinus radiata*) are characterised by a *Hebeloma/Thelephora/Laccaria* succession. The places occupied by different genera in this succession seem to depend in part at least on whether they can establish mycorrhizae directly from spores. *Hebeloma, Laccaria* and

Inocybe do so and apparently prevent mycorrhiza formation by other species, whereas *Lactarius, Cortinarius, Leccinum, Russula, Amanita muscaria, Elaphomyces, Scleroderma citrinum* (common earth-ball) and *Suillus luteus* (a common conifer bolete) do not.

Fungi on the bog

The bog itself has its own very distinctive mycoflora. In the wetter parts, several hygrocybe species occur, one of the commonest being the beautiful *Hygrocybe cantharella,* one of whose distinguishing features is the contrast between the orange-red to scarlet cap and the lemon-yellow gills, though the colour becomes washed out as the toadstool gets bigger and older. Another scarlet species often met growing with sphagnum is *Hygrocybe turunda.* The fungi of moss cushions are much in evidence both in the bogs themselves and the surrounding woods. Prominent among these because of its orange-yellow colour is *Mycena fibula.* More memorable still is a delightful little ascomycete one sometimes finds among wet sphagnum in old bog holes and drains; this is *Mitrula paludosa,* whose bright orange clubs emerging above the pale green of the sphagnum are an unforgettable sight [**Plate 6**].

There are several toadstools that are specifically associated with sphagnum, though the nature of their relationship with the moss is not yet fully understood. *Hypholoma elongatum* grows in troops among sphagnum, taking its Latin name from its long stems. Long stipes are characteristic of several strictly sphagnicolous species; they need them to push their fruiting bodies up through the sphagnum carpet, so that the spores can be carried away by the wind. *Tephrocybe palustris* is found only with sphagnum, where it often kills off the surrounding moss. Several *Galerina* species are associated with sphagnum; *Galerina paludosa* is the commonest, but *Galerina tibiicystis* and *Galerina sphagnorum* are also met with. *Omphalina* species are regular inhabitants of sphagnum carpets, obtaining their living by breaking down sphagnum remains. *Omphalina sphagnicola* grows only in sphagnum bogs. The white bog omphalina (*Omphalina ericetorum*) – which is most frequent on bare peat - also grows in wetter areas, among sphagnum, cranberry and the like, where it tends to be fleshier and more straw-coloured than in drier situations. This species is of special interest in that it sometimes forms an association with the widespread jelly alga *Palmella botryoides* to constitute a basidiolichen (a lichen in which the fungus partner is a basiodiomycete; in most lichens the fungi are ascomycetes). This species has been recorded on a number of bogs in the midlands, but is probably more widespread. Other characteristic bog species include *Collybia palustris, Pholiota myosotis* and *Stropharia sphagnicola.*

Many species of smaller toadstools that in uncut bog lie hidden away in the heather and sphagnum are more easily noticed on the cutover. Several are especially prominent on bare surfaces around bog holes and other cuttings, and on burnt areas. Perhaps the most common is the white bog omphalina (*Omphalina ericetorum*), which often seems to favour vertical peat faces. It is often accompanied by *Galerina sphagnorum,* an elegant little brown toadstool that dries to a creamy colour. *Laccaria proxima* is sometimes met with on bare peat, as are two species of *Hypholoma: Hypholoma ericaceum* and *Hypholoma udum.* The greyish-brown gills of *Hypholoma udum* often have distinctive black spore blotches as they mature. At least one species of *Entoloma* (*Entoloma helodes*) may be expected on bare peat. Some of the species associated with birch extend into the dry margins of the bog, none more frequently than the brown roll-rim (*Paxillus involutus*) [**Figure 9.2**].

The moor club (*Clavaria argillacea*) is also very characteristic of areas of bare peat; it is the only common club fungus on the bog, and it plays an important role in peatland ecology because of its mycorrhizal partnership with heather [**Plate 6**; See page 209]. It can sometimes be found fruiting abundantly in late autumn on bare peat near heather, in both raised and blanket bog. The fruit bodies usually occur in clusters and are club shaped, sometimes branched towards the top and usually furrowed, and generally flattened except at the tops which are more cylindrical. They grow up to 6cm above the surface of the peat, although there are usually several more centimetres of much more slender stalk buried in the peat. The lower part of the fruiting body is bright lemon-yellow and shiny, delicately striate and furry towards the base. The aerial part is generally yellow, buff or ochre in colour, darkening somewhat with age, especially at the tips, which turn brownish.

One of the commonest and most unmistakeable little toadstools in every bog is also one that, because of its size and habitat, the casual naturalist is quite likely to pass over. This is the horse-hair toadstool (*Marasmius androsaceus*), which grows in abundance, particularly in autumn, on decaying heather stems; it has a tiny pale flesh-coloured cap and very distinctive black, wiry stem [**Figure 9.3**]. An inconspicuous but characteristic little fungus – another ascomycete – which is probably often overlooked is *Pseudoplectania sphagnophila;* whose fruit bodies look like diminutive birds' nests growing on the alga-covered peat and among the sphagnum in the springtime. The inside of the cup is black and smooth, but the underside is shaggy.

Although bogs in general work on a tight and largely self-contained nutrient budget, visiting animals make a significant contribution in the form of dung. This may be a waste product from the animal's perspective, but it still contains reserve of nutrients that are utilised and recycled by a special galaxy of small, diverse and often very beautiful coprophilic fungi. Dung has its own ecological mini-succession, because different fungi are involved in different stages of the breakdown process.

Figure 9.3:
Marasmius androsaceus
on dead heather stem.

Fungi living on bog plants

A frequent parasite of bog rosemary is rosemary tar spot (*Rhytisma andromedae*), which is a close relative of the very common tar spot fungus of sycamore (*Rhytisma acerinum*), belonging to a group of mainly leaf pathogen fungi, the Phacidiales. The jet-black blotches on the leaves are the *stromata* of the fungus, and are composed of fungal hyphae and leaf cells cemented together by a black, tarry secretion of the fungus. Within the stroma, the apothecia are produced late in the season, and spores are produced just when the new leaves are developing and are ready for infection. Another tar spot fungus (*Rhytisma salicinum*) is often seen on willows.

Bog plants husband their resources more carefully than plants that live in nutritionally affluent circumstances. Plants like bog cotton and purple moor-grass carefully withdraw and store away as much as they can in the way of nitrogen, potassium and phosphorus from their leaves before they die back in winter – which makes their surface remains a less nutritious substrate for decomposer organisms. Nevertheless, there are fungi that break them down. Half a dozen species of microfungi are found only on heather, and there are several other parasitic species that are less specific (plurivorous species). One of the commonest is the elegant little ascomycete *Dasycyphus virgineus,* whose tiny white fruiting cups are ubiquitous on fallen heather stems in autumn. Black bog-rush and bog myrtle each have several species which are confined to these plants, and black bog-rush also has a dozen or so plurivorous species living on it. Another group live only on sedges and rushes, such as bog-cotton. Black bog-rush, heath species and bog asphodel appear to be more immune to attack than most others. One species that occurs widely on bog myrtle bark in the west is *Mycoglaena myricae.* So specific is this association between fungi and higher plants that anonymous ascospores are characteristically associated with specific plants in pollen profiles. Indeed, this association is so specific that when the spores occur on their own they are taken as a reliable indicator of the presence of the higher plants with which they are associated.

Prevention of decay can be looked on as part of the sphagnum strategy for retaining control of its environment. Its acid and watery resting place does not encourage microbial activity, and the plant also contains phenolic substances – notably a substance called sphagnol – which inhibit microbes. But even sphagnum has its attackers: over half a dozen species of fungi occur only on sphagnum, and eight more occur only on thread mosses (*Polytrichum* species).

Many bog lichens, especially cladonias, produce usnic acid – a powerful antibiotic to prevent decay. Nevertheless, over thirty microfungi can be found on lichens that grow on the bog. One of the richest hosts for microfungi is *Cladonia uncialis;* others include *Lecanora, Peltigera, Ramalina, Parmelia, Cladonia* and *Hypogymnia. Xanthoria parietina,* a large yellow leafy lichen, which is often found on trees at the edges of the bog, is host to a very destructive pathogen, *Xanthoriicola physciae,* which turns the yellow-orange thallus jet black. One of the most colourful and delightful little fungi on the bog is the bright pink *Marchandiomyces corallinus,* which is found on leafy lichens such as *Physcia* and *Parmelia,* which grow on small branches and twigs.

Fungi in the peat

Although both fungi and bacteria are relatively common in the surface layers of the peat, fungi gradually decrease with depth and are generally absent altogether below 75cm or so. Although it is relatively impoverished both in total number of species and actual abundance, peat has a characteristic fungal mycobiota, dominated by species that are specialised for living in highly organic soils. They are most abundant in undisturbed bog, becoming more restricted on cutaway peat, although the fungus flora becomes enriched in new ways as plants move in and colonise the cutaway area.

Peat contains an abundance of materials that are utilised as food sources by a multitude of fungi, but are normally unavailable because of the anaerobic environment within the peat. However, whenever any opportunity arises, there are many fungi there waiting to exploit it. There are two distinct components to the fungus flora of peat. First of all there are the cosmopolitan fungi, which occur in normal soils all over the world; these have only a minor role to play in peat, although their spores are always present, waiting for the opportunity that reclamation or any other change might present them with. These include such fungi as *Aspergillus fumigatus, Fusarium culmorum, Mortierella elongata, Mortierella parvispora* and various species of *Penicillium, Cephalosporium* and *Trichoderma.*

But there is another quite different group of fungi that are not found in many places outside the bog, a specialised peat mycobiota able to colonise and utilise the substrates in peat which other fungi find difficult to use. These special peat species are strongly antagonistic to other fungi, and they show several adaptations to life in peat. Unlike most fungi, they have spores which can germinate readily in acid peat. This specialist group includes a number of species of *Penicillium* and *Phialospora, Oidiodendron griseum, Torulomyces lagena* and *Mortierella sossauensis. Oidiodendron* and *Phialospora* are specially adapted for acid and highly organic substrates of many kinds; *Mortierella sossauensis* appears to be confined to uncut sphagnum peat, where it is believed to be associated with heather. At least a dozen species of the mould *Mortierella* were recorded from peat in Lullymore, where they may be involved in the breakdown of heather roots, and the leaves of sphagnum and *Leucobryum.* The greatest variety of species occurs in the uncut bog, and some species are found only here, such as *Mortierella sossauensis,* and several species of *Coniochaeta* and *Trichoderma.* Species of *Phialospora* are involved in the breakdown of the pieces of wood that occur in the peat, and *Torulomyces* is especially characteristic of buried reed (*Phragmites*) material.

Fungi do not readily colonise the cutaway area; even after ten years the microbial populations of cutaway peat areas are still impoverished. There is however much activity in the rhizospheres of plants on the cutaway bog. Fungi that are characteristic of this complex of habitats include *Oidiodendron griseum, Torulomyces lagena* and various species of *Cephalosporium, Penicillium* and *Phialospora.* Each one of the plants that occur in the early stages of colonisation (such as coltsfoot, marsh arrow-grass, sharp-flowered rush and horsetail) has its own characteristic root-surface mycobiota. This is the only place on the cutaway one is likely to encounter the moulds *Pythium, Alternaria* and *Gliocladium,* along with an abundance of sterile forms that are not easily named. When cutaway is cultivated, most of the indigenous fungi disappear, though species of *Penicillium* and *Trichoderma* continue to be important components.

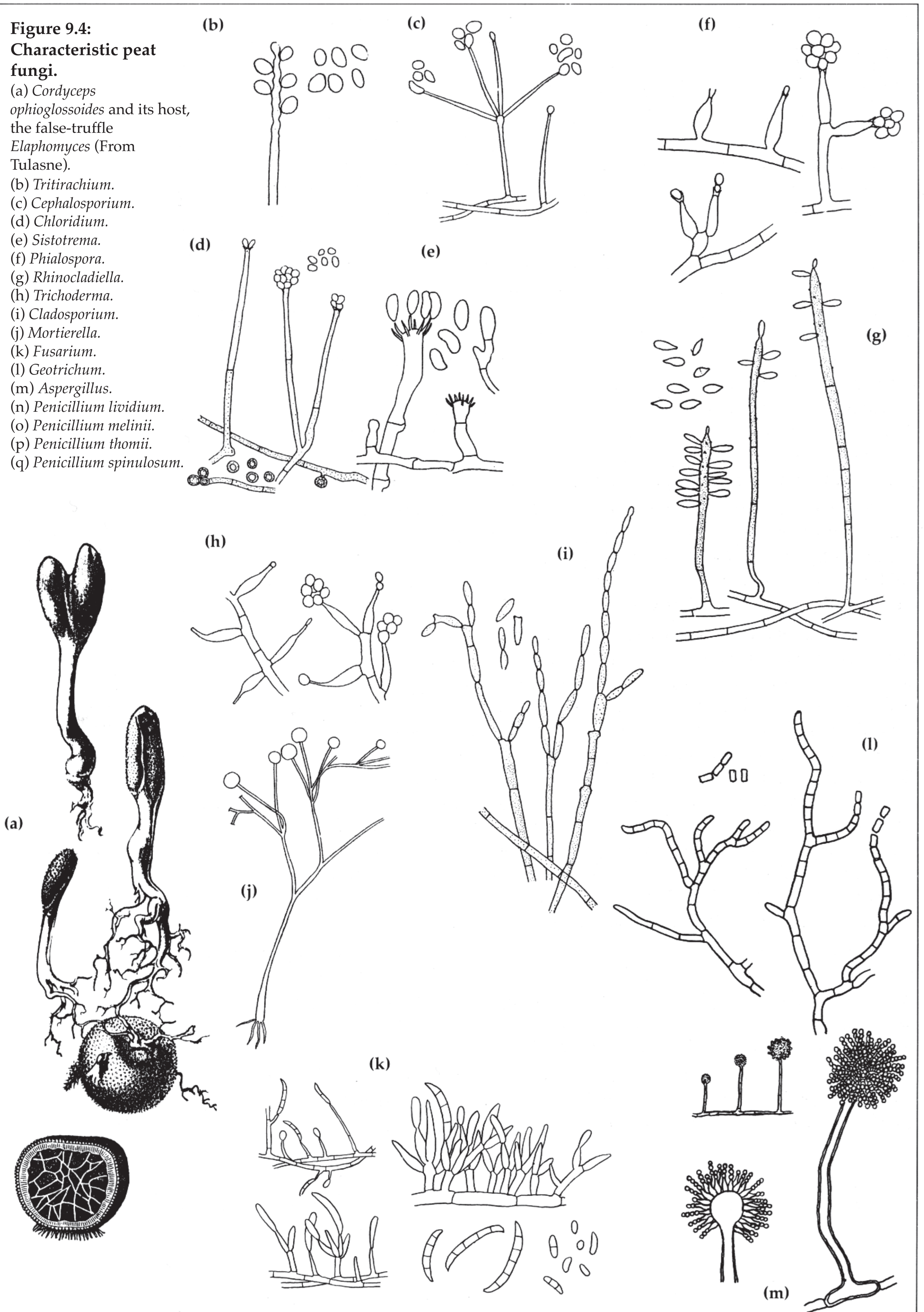
In the early 1950s, J.J. Moore of UCD studied the fungi occurring in two different kinds of peat in the Dublin-Wicklow Mountains. One was spongy heather peat on Tibradden Mountain, and the other deep deer-grass peat from the bog that runs along the Dublin-Wicklow border above Glendhu. By far the commonest fungi here were various species of *Penicillium,* together with different kinds of *Mucor, Mortierella* and *Trichoderma.*

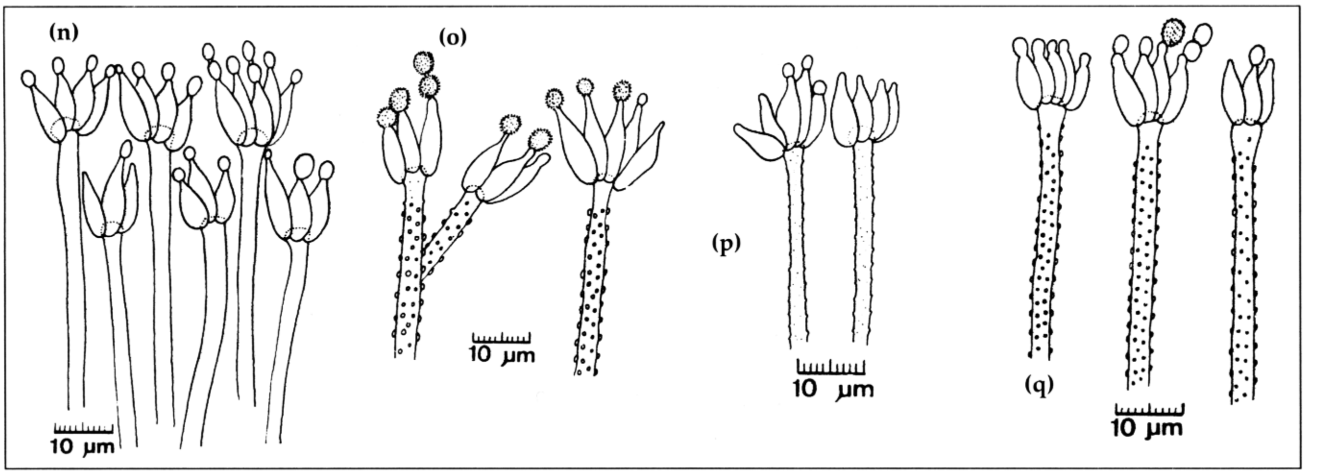
Out of a total of 61 species isolated, 29 in the heather peat and 23 in the deergrass peat, eleven were common to both types, and seven of the eleven were species of *Penicillium.* There were in addition over twenty species without spore-producing structures that would enable them to be identified. *Penicillium* of course is well known for its production of antibiotics, and the frequency of *Penicillium* in peat soil goes a long way towards explaining why outside fungi find it hard to colonise such soils. In the upper 10cm or so of the heather peat, the mycoflora was dominated by four *Penicillium* species: *P. lividum, P. melinii, P. thomii* and *P. spinulosum* [**Figure 9.4**]. *Penicillium lividum* dominated the surface peat, but below the surface this was replaced by *P. melinii. Trichoderma viride* was also very common in the surface peat, together with *Mucor Ramannianus* and species of *Mortierella.* The lower levels were dominated by an unidentified species that Professor Moore labelled M10. The mycobiota of the deer-grass peat was quite different, although *Penicillium* species again dominated.

Most of these fungi are saprotrophic, but some decomposition of ageing or dying sphagnum leaves by species of *Cladosporium, Mortierella, Penicillium, Geotrichum* and *Tolypocladium* also takes place. Most of this activity takes place in the upper 15cm or so of the sphagnum carpet. Below this, the activity of the fungi is inhibited by the acid, anaerobic conditions actively maintained by the bog mosses.

Among the most important fungi of peat are those which form mycorrhizal associations with plants, which depend on their fungal partners for their welfare. These have been discussed in Chapter 6.

Figure 9.4: Characteristic peat fungi.
(a) *Cordyceps ophioglossoides* and its host, the false-truffle *Elaphomyces* (From Tulasne).
(b) *Tritirachium.*
(c) *Cephalosporium.*
(d) *Chloridium.*
(e) *Sistotrema.*
(f) *Phialospora.*
(g) *Rhinocladiella.*
(h) *Trichoderma.*
(i) *Cladosporium.*
(j) *Mortierella.*
(k) *Fusarium.*
(l) *Geotrichum.*
(m) *Aspergillus.*
(n) *Penicillium lividium.*
(o) *Penicillium melinii.*
(p) *Penicillium thomii.*
(q) *Penicillium spinulosum.*





Bacteria in the peat

In spite of their importance in soil processes, not very much is known about the bacteria of peat. In fens they occur at all levels in the peat profile, but in the acid peat of bogs bacterial communities are in general greatly reduced, although the surface layers have a relatively abundant microbiota. When soil conditions are improved by reclamation however, bacteria rapidly increase in numbers.

Neither aerobic nor anaerobic free-living nitrogen-fixing bacteria play the important role in peat soils that they play in most other soils. This is probably due in part to the low pH of peat, which is sub-optimal for the activity of the central enzyme in the process of nitrogen fixation, nitrogenase. Blue-green bacteria play little part in the peat flora either, although they may be important constituents of the microflora of moss carpets and possibly even enter into loose symbiotic assocations with certain mosses. Several species of *Peltigera,* a genus of lichens that is common in bogs, contain nitrogen-fixing blue-green bacteria as one of their 'algal' associates.

Symbiotic nitrogen-fixing bacteria are inactive in very acid peat, but they are very important in the nutrition of some plants of fen and cutover bog. The fixers here are actinomycetes. The most important examples of plants that have an association with these nitrogen-fixing actinomycetes are bog myrtle and alder; in alder the actinomycete is *Frankia.*

Microbial activity slows down dramatically once the litter has become incorporated in the peat, so that plants like heather and bog cotton can retain their cellular anatomy intact for many years. Some of the plant nutrient movement that occurs in litter is brought about by rainfall, which can leach out elements such as calcium, magnesium and potassium from plant remains lying on the surface. But only micro-organisms can remobilise the nitrogen, phosphorus and sulphur they contain. Sulphate-reducing bacteria (*Desulfovibrio* and *Desulfomaculatum*) and thiosulphate-reducing bacteria (*Thiobacillus* and others) are common in peat.

The chytrids (phylum Chytridiomycota)

Two groups of organisms that were formerly classified as fungi (and are retained in this chapter on that account) are the chytrids and slime moulds. Chytrids are mostly aquatic, microscopic organisms with uniflagellate zoospores. They show little differentiation, but are very complex and varied in spite of their apparent simplicity. They are an essential component of the mycoflora, parasitic or saprobic on algae, aquatic plants, microscropic animals etc., though a few are parasites of land plants. Apart from a few observations, mainly on this last group, very little is known about chytrids in Ireland. *Cladochytrium* is a small genus containing species that live in decaying vegetation; the bright orange globules in the sporangia of *Cladochytrium menyanthis*, which grows on bog-bean, are very distinctive. *Physoderma menyanthis* also lives on bog bean, and *Physoderma vagans* has been described on lesser water-parsnip, which frequently grows in old drainage ditches on the margins of raised bogs. *Rhizophlyctis rosea* occurs very widely in wet soils (including peat), where it plays a role in the breakdown of cellulose.

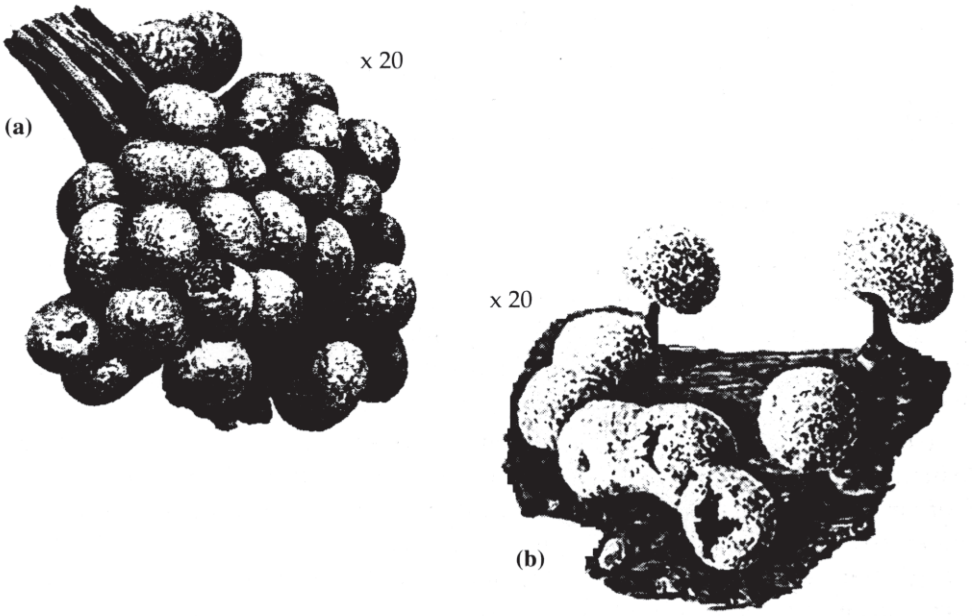


Figure 9.5: Slime moulds: the sporangia of two species associated with bogs.
(a) *Bahhamia lilacina*: whitish sporangia (c. .5mm diameter) developing from a bright yellow plasmodium.
(b) *Didymium melanospermum*: white or grey sporangia (c. .7-1.0mm diameter) developing from a colourless or grey plasmodium.

Myxomycetes: the plasmodidal slime moulds (phylum Myxomycota)

The closest relatives of slime moulds are believed to be the amoeboid protozoa, but historically they have always been bracketed with the fungi (and studied by mycologists). They are a fascinating group of scavenger organisms that feed on bacteria, yeasts and other fungi. There are two obvious stages to their life history: a slime or plasmodial stage, and the spore-producing reproductive stage. The slime stage is the feeding stage of the life cycle; the plasmodium moves slowly through the soil or surface litter in search of its chosen food, and when this is exhausted produces tiny and often very beautiful spore capsules (sporangia).

Not many species of slime moulds occur in bogs: they are at their most diverse in woodlands, including the birch woods that fringe bogs. The few that do are very characteristic, particularly *Badhamia lilacina,* which is widespread in the raised bogs of the midlands. The bright yellow plasmodium of *Badhamia* grows on sphagnum, even when it is growing underwater, and later produces lilac-grey sporangia on surface vegetation. Another species often seen on the open bog is *Didymium melanospermum,* which occurs on cladonia, heather, furze etc., but is especially characteristic of pine litter [**Figure 9.5**].

LICHENS: phylum Mycophycophyta

> *The different species of the Cup Moss (lichen v. baeomyces pyxidatus) tipped with their beautiful and conspicuous scarlet tubercles, are likewise to be seen adhering to the turfy surface; as well as the Heath Moss or Lichen (lichen ericetorum); the Ground Lichen, or Ash-coloured Ground Liverwort (lichen caninus); and many other species.*
>
> Memoir of Professor Wade on the Vegetable Matter of Bogs (1811) in the ***Fourth Report of the Commissioners on the Nature and Extent of the Bogs in Ireland***.

Bog lichens: the genus *Cladonia*

> Special means of propagation and reproduction are not necessary, since the majority of Cladoniae are endowed with almost eternal life.
>
> **Albert Schneider. *A Text-Book of General Lichenology* (1897).**

The lichens are a group of very hardy organisms whose basic way of life gives them a great head start in coping with the demands of life on the bog. A lichen is a unique partnership between two quite different life forms, a fungus and an alga: but so intimate is the association between them that they constitute together a totally different kind of organism. The role of the alga in the lichen partnership is to provide carbohydrates for the fungus, and the metabolism of the alga is controlled and restricted by the fungus to this end. Lichens such as *Peltigera,* whose algal symbiont is the nitrogen-fixing cyanophyte *Nostoc,* are able to obtain the nitrogen they require from the atmosphere, instead of having to rely on the soluble nitrate that is in such short supply on the bog. On the other hand, the fungus partner may provide the alga with protection, filtering out harmful short-wave radiation, controlling desiccation stress during the frequent periods of drought to which many lichens are subjected, and buffering the partnership against temperature extremes.

The fungus facilitates the supply of basic nutrients to the alga; the autotrophic alga provides the sugars for the metabolism of the lichen, and its metabolism is controlled and restricted by the fungus to this end. So successful is this nutrient economy that lichens can thrive in the most extreme and demanding of habitats; they are able to colonise low-nutrient situations, and able to survive environmental extremes which would kill other organisms.

In a typical lichen, the body of the plant is the *thallus,* which is made up of a flat, lobed or branched body like a miniature liverwort or seaweed. But in the bog lichens, belonging to the large genus *Cladonia,* the thallus is rather insignificant or even absent, and the main plant body is the *podetium,* which is like a miniature densely-branched tree, at the tips of which the spore-producing structures are typically produced [**Figure 9.6**]. The cladonia lichens are by far the most important group of lichens on the bog. There are over fifty species in Ireland, many of them confined to bogs, particularly the drier parts. Different species have their own ecological preferences, but not a great deal is known about this important part of the biology of lichens in their Irish habitats. Howard Fox's studies are beginning to change this, and his observations over several years are incorporated in what follows.

There are two main types of cladonias. One group, the bushy bog lichens or cladinas (*Cladonia* subgenus *Cladina*) grow as dense interwoven 'forests' of tufted and richly-branched hollow podetia that no longer have any connection with the substrate: they have no basal thallus. This makes them analogous to the bog mosses in some respects, and enables them to compete with sphagnum on its own terms as it were; indeed, they are the only lichens that are successful inhabitants of vigorously-growing raised bog. Cladinas grow vigorously in all directions when they are young, the basal parts dying away as they expand; when they are mature the two processes of expansion and decay are in equilibrium.

This mode of growth strangles seedlings: carpets of cladina expand and contract and become rigid during the wetting and drying cycle. The soft emerging cotyledons of seedlings growing up in cladina mats can be torn and damaged by this mechanical action, The cladina lichens also have a chemical strategy that helps them compete with heather. They produce a leachate which inhibits the germination of heather seedlings. Their main way of reproduction is by simple fragmentation.

The second group of bog lichens (*Cladonia* subgenus *Cladonia*) maintain their attachment to the substrate. They often have a thallus of small basal squamules as well as simple or branched hollow podetia, which form cups in some species. The podetia do not expand to form the prolific thickets of the bushy lichens. Vegetative reproduction in these lichens takes the form of *soredia* and *isidia*. Soredia are small groups of algal cells enveloped in hyphae, usually clustered together in large numbers. These originate in the medulla of the lichen, and break through to the surface. Regular eruptions of soredia, which have a characteristic form in different species, are known as *soralia.* Isidia are finger-like protuberances of the lichen cortex that incorporate algal and fungal tissues; they are easily broken off, effectively dispersing the lichen.

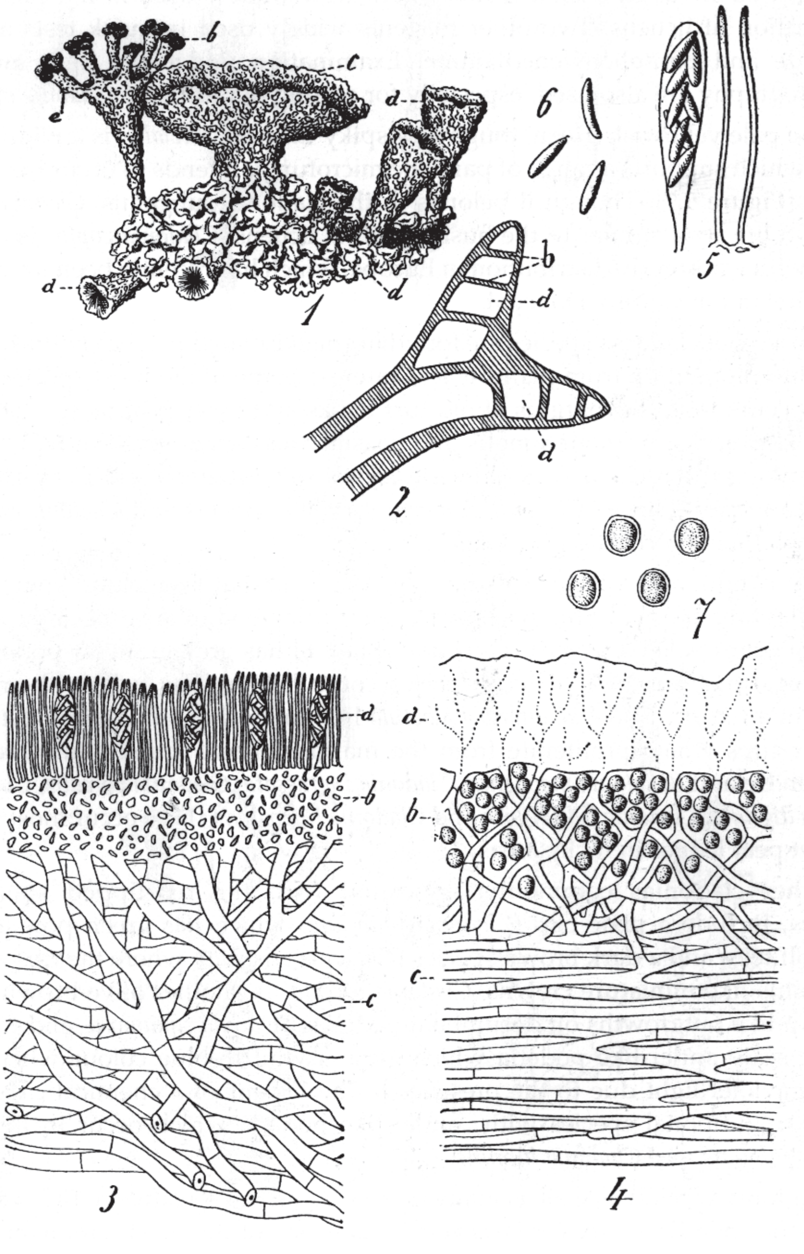


Figure 9.6: The structure of cladonia.
1. *Cladonia pyxidata*, natural size. (a,c) sterile podetia; (b) apothecia produced on apothecial branches; (d) primilry thallus,
2. Diagrammatic section of podetium cup showing mechanical struts (b) for support.
3. A section through the podetium. Notice the spore sacs (d).
4. Section through the primary thallus. Note the algal cells (b).
5. Spore-sac with spores and paraphyses (the long, thin projections).
6. Spores.
7. Algal cells.
(From Schneider).

The lichens that are most conspicuous in the vegetation of bogs nearly all belong to the subgenus *Cladina. Cladonia portentosa* [**Figure 9.7**], which forms miniature bushes, can occur as spectacular carpets on the bog, particularly where drying of the surface has impeded or stopped the growth of sphagnum. There is an odd form of *Cladonia portentosa* that has densely interwoven branches forming very regular cushions. It has a scattered distribution but is frequently seen on the uncut surface of raised bog remnants in the midlands. It is not known what causes this growth form; it may just be a patch that is re-growing after fragmentation due to trampling. *Cladonia ciliata,* which has a purplish tinge to the dichotomous apices, is often found intermixed with it. The reindeer lichen, *Cladonia rangiferina* (which can easily be confused with forms of *Cladonia ciliata*) is a rare species that grows almost exclusively on coastal turf in the north and west. This is one of the lichens that are such an important food of wintering reindeer in the arctic tundra. *Cladonia arbuscula,* with warty decumbent podetia, is also in this group. Minute fragments of podetial apices broken off by vertebrates that trample the dry lichen serve as an important dispersal aid for this group of cladonias.

Cladonia strepsilis contains a unique lichen acid, strepsilin, which turns an emerald green colour when a drop of hypochlorite bleach is applied to the base of the squamules. Unlike plants or fungi, chemical substances are routinely used in the classification and identification of lichens. Two other reagents widely used in quick tests are potassium hydroxide and paraphenylenediamine. Examination under UV light and thin layer chromatography are also used, especially for sorting out difficult *Cladonia* specimens.

The pale yellowish-green, tough and spiky *Cladonia uncialis* is a widely distributed species that supports a range of parasitic microfungi; it tends to occur in wetter parts of the bog [**Figure 9.7**]. Though it belongs in the cladonia subgenus, *Cladonia uncialis* has evolved a life style similar to the bushy cladina lichens. *Cladonia zopfii* is a very similar species with a northerly distribution in Europe, which has recently been found for the first time in Ireland in County Donegal.

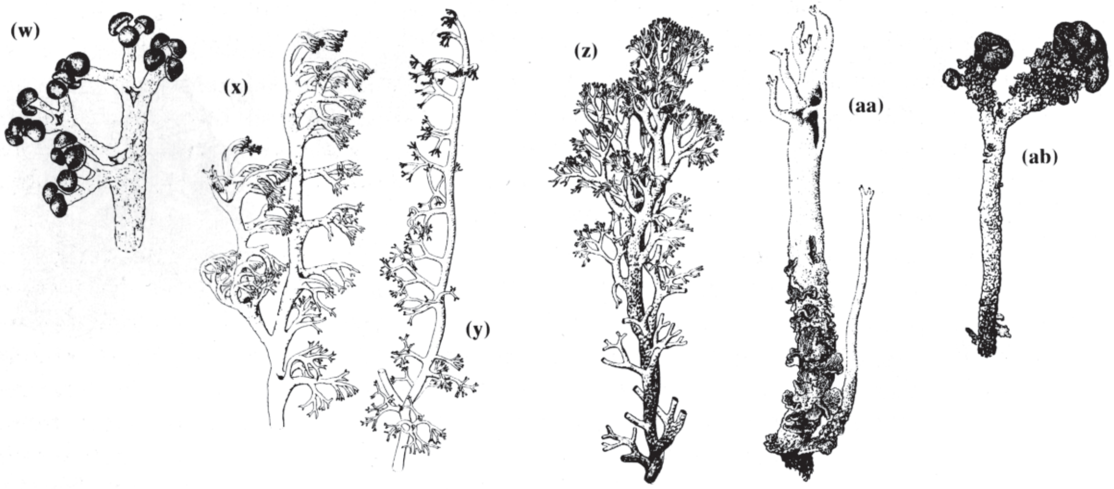
Most other cladonia species are found in small isolated patches in the bog vegetation where the competition from plants is less intense. Some of the most spectacular cladonia swards occur along the margins of old turf banks and other peat faces, or on the tops of eroded hummocks. In mountainous and coastal areas, cladonias can be found on peaty ledges among the rocks and boulders. *Cladonia subcervicornis* and *Cladonia strepsilis* are frequent in upland areas; *Cladonia coccifera, Cladonia gracilis* and *Cladonia ramulosa* occur along with them on coastal peat ledges.

The commonest species on the bog in the midlands include some of the most beautiful. Three species with vivid scarlet red fruiting bodies are especially attractive. The devil's matches lichen *Cladonia floerkeana* [**Plate 6**] has grey granular podetia and is the most gregarious. *Cladonia coccifera* (cock's comb lichen), has yellowish-green granular cups with a red rim and *Cladonia polydactyla* has antler-like powdery podetia with small irregular cups that proliferate from the margins. There are several other red-tipped species in Ireland (*Cladonia macilenta, Cladonia incrassata, Cladonia borealis, Cladonia diversa, Cladonia digitata, Cladonia bellidiflora* and *Cladonia luteoalba*); these occur most frequently on thin, wet peat ledges in rocky areas.

Other cladonias commonly associated with *Cladonia floerkeana* include *Cladonia fimbriata*, a pixie-cup lichen that has green powdery cups like small golf tees, and a dark brown species (*Cladonia crispata*) where the tips of the podetia have points like miniature crowns. *Cladonia furcata* is another olive-brown species with scaly flap-like outgrowths on decumbent podetia. *Cladonia squamosa* and *Cladonia glauca* produce scaly antler-like podetia that glow a whitish-blue colour when illuminated with ultraviolet light due to the presence in the lichens of a chemical called squamatic acid. Two additional species with antler-like podetia that occur in this habitat are *Cladonia subulata* and *Cladonia humilis.*

Cladonia species, as well as many other lichens, are sensitive to fire, and are slow to recover after bog fires. Dry *Cladonia portentosa* is one of the most flammable fuels on the

Figure 9.7: Bog cladonias.
(a) *Cladonia digitata*
(b) *C. polydactyla*
(c) *C. coccifera*
(d) *C. incrassata*
(e) *C. uncialis*
(f) *C. squamosa*
(g) *C. crispata*
(h) *C. glauca*
(i) *C. furcata var. scabriuscula*
(j-k) *C. furcata var. furcata*
(l) *C. rangiformis*
(m) *C. gracilis*
(n) *C. cornuta*
(o) *C. verticillata*
(p) *C. chlorophaea*
(q) *C. fimbriata*
(r) *C. coniocraea*
(s) *C. subulata*
(t) *C. strepsilis*
(u) *C. rangiferina*
(v) *C. arbuscula*
(w) *C. portentosa*
(x) *C. arbuscula*
(y) *C. ciliata*
(z) *C. subcervicornis*
(aa) *C. macilenta*
(ab) *C. floerkeana*
(From Hennipman, 1978).



bog. Consequently the richest floras occur in sites that manage to escape the ravages of periodic burning. In the midlands, an intact bog that has not been burnt for several decades can support many rarer species such as the bushy *Cladonia arbuscula* and *Cladonia ciliata* as well as the graceful *Cladonia cervicornis* (*verticillata*). This species has a smooth tan cortex and cups that proliferate from the centre to form tiers [**Figure 9.7**].

Cladonia lichens tend to occur in patches that can be up to ten metres apart on the intact bog, and vast quantities of spores, soredia and squamules are produced. The variety of reproductive propagules seems to suggest that a number of dispersal mechanisms may be involved. The cups of species like *Cladonia fimbriata* are likely to be adapted for rain-splash dispersal. It is also possible that the importance of ants has been underestimated in the dispersal of cladonias; ants are very active on the bog and they often appear to seek out the dry eroding hummocks which many cladonia species prefer.

Although not many large animals eat bog lichens, they are rich in carbohydrates, but poor in protein, phosphorus and calcium. In more northern countries they are a main food of caribou and reindeer, and in post-glacial time, when we had reindeer here, they may have played the same role in Ireland. However, lichens are eaten by a variety of invertebrate animals, including some moth caterpillars, molluscs, nematodes, orobatid mites and psocids.

Other bog lichens

A number of distinctive lichens from genera other than *Cladonia* also occur on the bog. Of several bushy species that grow directly on the peat *Coelocaulon aculeatum*, which has dark brown, glossy and slightly flattened branches with minute pits and short comb-like blunt spines, is probably the most elegant. Iceland Moss (*Cetraria islandica*) is a similar species with broader lobes, and can be eaten. In former times it was soaked for a few days, boiled with milk or water and eaten as a broth or jelly. It is a species of rather local occurrence, frequently found on unburnt patches in the west.

A number of interesting lichens are found on peat hags in western blanket bogs. One is *Coriscium viride*, which consists of bright green circular squamules with a raised margin. This is the basal lichenised part of the toadstool *Omphalina hudsoniana*. Several other lichenised *Omphalina* toadstools (*Omphalina pseudandrosacea, Omphalina ericetorum* and *Omphalina luteovitellina*) occur in Ireland. *Sphaerophorus globosus* is a species that is common in upland blanket bog. It forms pale grey cushions with delicate branches that sometimes have a pinkish tinge. *Sphaerophorus fragilis*, a more robust species, grows on thin peat over boulders. Another characteristic species of Atlantic and mountain boglands is *Pycnothelia papillaria* which has densely packed grey, stubby, cylindrical podetia tipped with a brownish spot, giving the lichen the appearance of a collection of miniature teats.

Several species of *Peltigera* (dog lichens) occur on bogs. *Peltigera lactucifolia* and *Peltigera membranacea* are found especially in the fringing birchwoods. *Peltigera didactyla* is an ephemeral species by lichen standards. It can complete its life-cycle from spore germination to senescence of mature fertile thallus in fifteen months. The species often colonises peaty gley soils at the margins of bogs.

A number of crustose lichens occur on the bog. Four species of the large genus *Micarea* are widely distributed on peat (*Micarea lignaria, Micarea leprosula, Micarea melanaea, Micarea peliocarpa*). They are also found on exposed sub-fossil pine stumps in the west. *Trapeliopsis granulosa*, with multicoloured fruits and a greenish-grey warted and granular thallus, is another common species. *Trapeliopsis pseudogranulosa*, with orange pigmented soralia, grows on banks and fresh soil by the roots of wind-thrown trees. Another species (*Trapeliopsis gelatinosa*) is found on vertical seepages over mosses into bogland streams. *Micarea melanaea, Placynthiella uliginosa* and *Placynthiella icmalea* are the principal brown-black crusty lichens on the bare peat of the bog. Because of their colour, they look like charred peat after a fire and are not often noticed. They can be distinguished by their tiny black apothecia, and are often abundant on otherwise bare peat.

A number of other species are really only noticed when their fruiting bodies are in evidence. One such is *Icmadophila ericetorum,* an early coloniser after fire in the west, which has a grey thallus and attractive pink sessile fruits. *Baeomyces roseus* and *Baeomyces rufus* have pinkish and red-brown stalked fruits respectively, which look like tiny mushrooms, on a tan to greyish granular thallus. They are frequent on mineral soil banks along mountain bogland tracks. *Baeomyces placophyllus* differs in having large wrinkled basal squamules and it is a rarer species occurring in the mountains in the north-east. *Baeomyces rufus* is interesting because it is host to a variety of microfungi including several parasitic lichens, one of the commonest being *Arthrorhaphis grisea.*

Mention should be made here of the most diminutive lichen in the Irish flora, *Thelocarpon.* There are several rare or overlooked species in the genus, which can be expected on wet peat banks in the west. They can be found as minute, solitary or loosely gregarious, lemon or lime green spots visible when magnified with a hand-lens. The average size is typically between 0.10 and 0.25 mm across, so it really is minuscule.

Lichens on heather

The lichen flora epiphytic on heather is surprisingly rich. At least 63 different species have been found. The most abundant species include the crusty lichens *Fuscidea lightfootii*, *Haematomma elatinum*, *Lecanora symmicta*, *Micarea lignaria*, *Micarea nitschkeana*, *Micarea peliocarpa* and the leafy and shrubby lichens *Hypogymnia physodes, Hypogymnia tubulosa, Parmelia perlata, P. revoluta, P. subaurifera, P. sulcata, Physcia tenella, Ramalina farinacea,* and *R.* cf. *pollinaria,* which are all widely distributed in the midlands. Lichen colonisation can begin as early as the first year, because the soredia and ascospores become trapped in the minute hairs that are found on young heather shoots.

Some of the more local species are often at their most common in the west of Ireland on heather. *Arthrothelium norvegicum, Byssoloma subdiscordans, Dimerella pineti, Graphis elegans* and *Porina leptalea* seem to be particularly characteristic of very old heather stems.

Lichens are too slow-growing to be able to colonise the leaves of deciduous trees, but a few species live on the leaves of evergreen shrubs and trees. *Fellanera bouteillei,* the common box-leaf lichen, is occasionally found on heather leaves on the bog. Generally foliicolous lichens tend to be very fast growing, by lichen standards, as they have to mature and reproduce within the relatively short lifespan of an evergreen leaf.

Lichens on trees

Stunted birch trees growing on bogs are often clothed in a luxuriant growth of epiphytic shrubby and leafy lichens. A relatively small number of species are involved, belonging in the following genera: *Evernia, Ramalina, Usnea, Parmelia* and *Hypogymnia.* The most conspicuous leafy lichens are *Parmelia perlata, Parmelia revoluta* and *Hypogymnia physodes.* The dominant shrubby lichens on the trees are *Ramalina farinacea, Ramalina fastigiata* and *Evernia prunastri,* and the principal crusty ones on the smallest twigs are *Fuscidea lightfootii, Lecidella elaeochroma* and *Lecanora chlarotera.* The lichen flora on the boles of larger trees is more diverse. One crustose lichen, *Pertusaria amara,* is very distinctive. It has a grey thallus with a zoned margin and white soredia, with a bitter taste that resembles the quinine flavouring in tonic water. Over 200 species have been recorded on birch trees in Scotland, and a similar number of species could be expected in Ireland.

Table 9.1: *Cladonia* species found on Irish Boglands (Compiled by Howard Fox).

***Cladonia* species**	**Frequency and distribution in Ireland**
Cladonia arbuscula	Local, on old unburnt sites, occasional in west.
Cladonia bellidiflora	Occasional, in mountains (r.f.).
Cladonia caespiticia	Very local, usually on rotting timber in woodland.
Cladonia cariosa	Rare, on disturbed mineral soil in mountains.
Cladonia cervicornis	Occasional, frequent near the coast.
Cladonia cervicornis subsp. *verticillata*	Occasional, widely distributed.
Cladonia chlorophaea	Common, on fenceposts.
Cladonia ciliata	Frequent, on raised bogs occasional elsewhere.
Cladonia coccifera	Frequent and widespread (r.f.).
Cladonia coniocraea	Common, especially on fence-posts.
Cladonia cornuta	Rare, in mountains.
Cladonia crispata var. *cetrariiformis*	Common on raised bogs.
Cladonia digitata	Occasional, on peaty soil in woodland (r.f.).
Cladonia fimbriata	Common on disturbed raised bogs.
Cladonia floerkeana	Common on raised bogs (r.f.).
Cladonia furcata	Common and widespread.
Cladonia glauca	Frequent, commonest on midland raised bogs.
Cladonia gracilis	Frequent and widespread.
Cladonia incrassata	Rare, on thin peat ledges (r.f.).
Cladonia luteoalba	Local, on thin peat ledges (r.f.).
Cladonia macilenta	Frequent, on peat banks and thin turf (r.f.).
Cladonia merochlorophaea	Frequent, chemospecies of C. *chlorophaea.*
Cladonia ochrochlora	Occasional, on wood, rare on peat.
Cladonia parasitica	Rare, more usually in oak woodland.
Cladonia polydactyla	Frequent, on vertical peat banks, widespread (r.f.).
Cladonia portentosa	Abundant and widely distributed.
Cladonia ramulosa	Frequent, common on peaty wall tops in the west.
Cladonia rangiferina	Very rare on coastal turf in north & west.
Cladonia scabriuscula	Occasional but widely distributed.
Cladonia squamosa	Common and widespread.
Cladonia squamosa var. *subsquamosa*	Common and widespread.
Cladonia strepsilis	Occasional, in mountains.
Cladonia subcervicornis	Common in west and on mountains.
Cladonia subulata	Occasional, on raised bogs.
Clac/onia uncialis subsp. *biuncialis*	Common on Atlantic and wet raised bogs.

Abbreviation: (r.f.) = red-fruited species

Many of the same leafy and shrubby lichens that are common on birch also occur on willow. The genus *Physcia* however is better represented with *Physcia aipolia, Physcia stellaris, Physcia adscendens* and *Physcia tenella.* In the west, characteristic species include *Caloplaca ferruginea,* a crusty lichen with orange apothecia, *Lecanora jamesii, Rinodina exigua* and *Japewia carrollii,* the last named after the pioneering Irish lichenologist from Aghada, County Cork, Isaac Carroll (1828-1880). Lichens on willow bark are often heavily grazed by molluscs, and sometimes the crusty lichens are so badly eaten they are impossible to identify.

ALGAE

The algae are a group of plants of enormous diversity, complexity and beauty, and no group of bog plants offers more scope for original study and observation for naturalists of all ages. Because most of them are so small and generally inconspicuous, they seldom attract the attention of the general naturalist, but their role in the ecology of bogs is much more important than is generally realised. Their small size obscures the diversity of the algae, which comprise several distinct phyla. For the algae in bogs we can still do little more than provide an incomplete list of names. But each Latin name hides a wonder, a beauty and complexity that only the microscope can unlock. Yet even this hopeless list, and the knowledge that each name here is a unique solution to the challenge of life, can add to our sense of amazement at the complexity of it all, and of how many unexplored and scarcely imagined worlds are hidden away in the bog.

On bare peat one of the first signs of life is the dull-purplish colouring produced by dense colonies of filamentous algae. These are usually described as Z *ygogonium ericetorum* [**Figure 9.8**]. However, they are always sterile and not easily identified; other genera (such as *Rhizoclonium*) may also be present. *Zygogonium* is a terrestrial representative of a family of algae most of whose members live in fresh water. It covers and binds the surface of the bare peat with a continuous web of silky threads. In dry weather these surface webs become hard and papery, but they absorb water almost immediately rain falls. This regulation of surface moisture is believed to be vital to the successful growth of sundews and other bog plants that grow on bare peat. Several other algae live on the surface of damp peat, including species of the ubiquitous genera *Chlamydomonas* and *Coccomyxa,* the filamentous green algae *Hormidium* and *Stichococcus,* and the non-filamentous conjugate green algae *Cylindrocystis* and *Mesotaenium.* One of the earliest and often most conspicuous algae here is the blue-green *Nostoc,* which occurs as wrinkled blobs of jelly. The peat contains its own distinctive algal flora, many of its members being closely related to the algae of more obvious water bodies. One of its most characteristic members is *Euglena mutabilis.*

The bases of old heather shoots are often covered with a slimy coating of algae, comprising species of *Gleocystis, Coccomyxa* and other genera. Also very common is the algal complex *Pleurococcus* (*Protococcus*) that forms a bright, pale green powdery coating on heather stems, trees etc. Other things are often mixed with this coating as well: lichen ascospores, conidia and soredia are regularly entrapped in it. *Trebouxia,* the common alga involved in lichen symbiosis, may form transient colonies derived from degenerating soredia and isidia. Fungal partners of lichen symbioses initially parasitise this species-rich film. Occasionally, when the lichen fungus encounters a suitable symbiotic algal partner, a stable lichenisation is formed. When a lichenisation is successful, the more familiar mature phase of the various lichen species can develop and after a while a recognisable thallus is formed on the heather shoots.

The water-filled tufts, cushions and carpets of sphagnum and other mosses have their own distinctive algal flora, in which free-floating diatoms (and some desmids) predominate. One of the more specialised species that occurs in the sphagnum is the green alga *Phyllobium sphagnicolum,* which grows between and into old cells of sphagnum. At intervals it produces dark green resting spores that look like little green swellings on the leaves. Many distinct communities are probably found in bryophytes, but this is yet another aspect of bog ecology that has received little attention. The epiphytic algal flora of sphagnum includes both epiphytic and endophytic nitrogen-fixing cyanophytes (blue--green 'algae' or bacteria, particularly species of *Anabaena*), which play an important and little-understood role in sphagnum nutrition. The algal flora varies between different species, and is influenced by differences in such environmental variables as microtopography and moisture. Species of *Cylindrocystis* and *Mesotaenium* often dominate the sphagnum epiflora, and are largely confined to this habitat, where they sometimes form pure masses both among the plants and on the bare peat. *Cylindrocystis brebissonii* is especially common. Other species that are particularly associated with sphagnum include the filamentous *Geminella minor* and a number of *Chroococcus* species. Many other aquatic bog plants also have their own characteristic epiflora. Bladderworts provide an even better microhabitat for desmids than sphagnum. *Chlorochytrium* includes a number of species that are endophytes of aquatic plants. *Chlorochytrium Lemnae* lives on duckweed, and *Chlorochytrium Facciolae* on the filaments of algae belonging to the family Oscillatoriaceae.

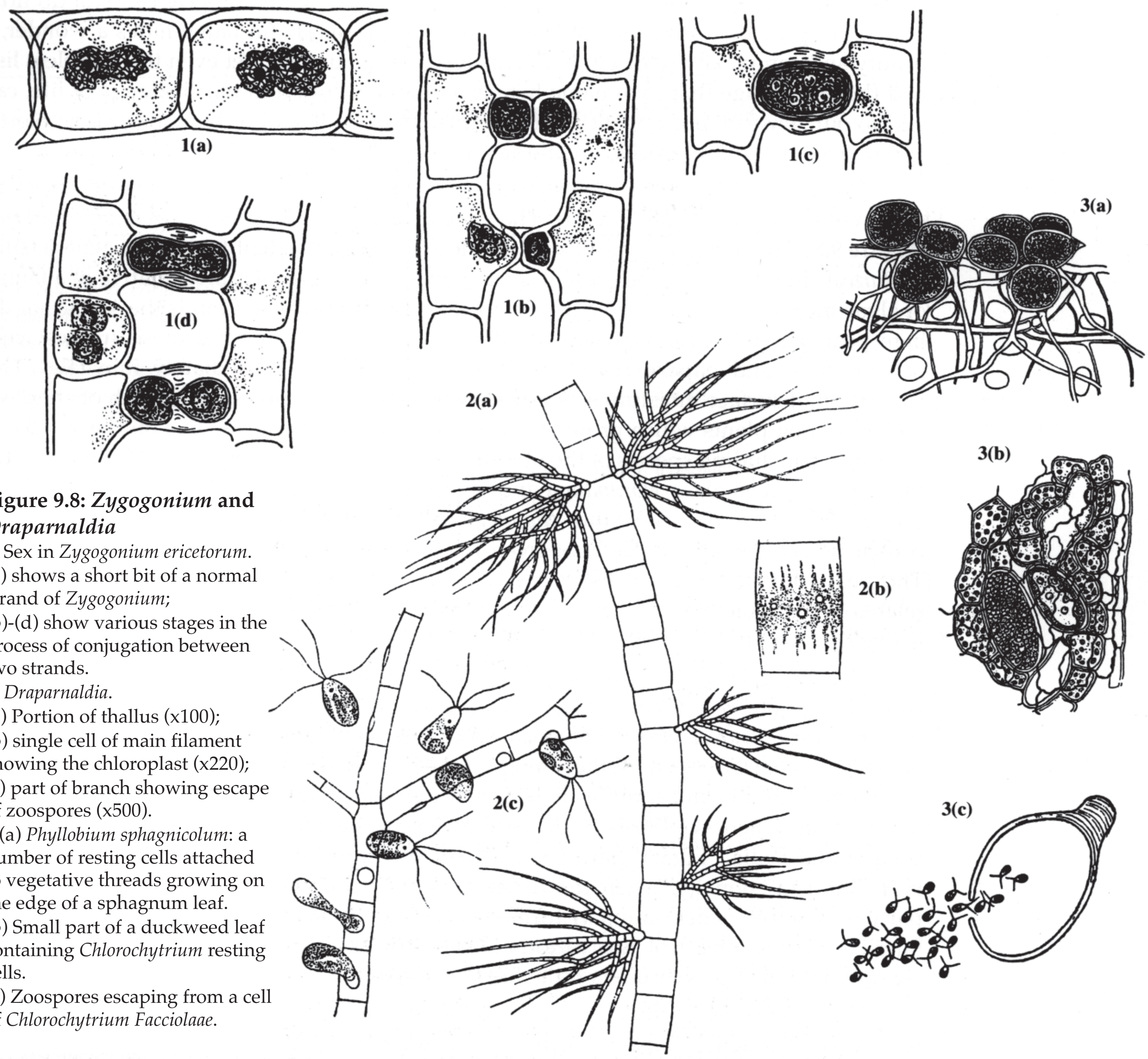


Figure 9.8: *Zygogonium* and *Draparnaldia*
1. Sex in *Zygogonium ericetorum*.
(a) shows a short bit of a normal strand of *Zygogonium*;
(b)-(d) show various stages in the process of conjugation between two strands.
2. *Draparnaldia*.
(a) Portion of thallus (x100);
(b) single cell of main filament showing the chloroplast (x220);
(c) part of branch showing escape of zoospores (x500).
3.(a) *Phyllobium sphagnicolum*: a number of resting cells attached to vegetative threads growing on the edge of a sphagnum leaf.
(b) Small part of a duckweed leaf containing *Chlorochytrium* resting cells.
(c) Zoospores escaping from a cell of *Chlorochytrium Facciolae*.

But it is in the bog pools and bog holes that the algae are at their most diverse and exciting. Two groups dominate, the filamentous green algae and the desmids, both of which are classes in the phylum Gamophyta. There is a multitude of filamentous algae such as *Spirogyra,* which occurs as free-floating masses of bright green hair, *Zygnema, Mougeotia, Microspora, Microthamnion, Draparnaldia* and others. *Draparnaldia* forms clouds of fine green thread anchored to water plants or the edges of old bog pools. When it is lifted out of the water it shrinks to a sodden, shapeless, bright green, slimy blob, but in the water it is one of the most beautiful of all bog plants. It consists of stout main filaments that are each attached by a basal disk in much the same way as seaweeds. These main filaments are branched; at close intervals along the 'stem', clusters of finer branches are produced, each branch a filament of cells end on end, becoming smaller and smaller towards the tip [**Figure 9.8**]. Reproductive structures are produced at the tips of the branches. (We have watched these being plucked like apples by grazing insect larvae. From time to time you cannot help imagining how wonderful it might be to be aquatic and very small – though of course with human awareness – swimming through the dense forests of this bright green algal wonderland!)

Table 9.2: Some algae common in bogs (From West and Fritsch 1932)

Schizochlamys delicatula	
Eremosphaeria viridis	*Zygnema anomalum*
Oocystis solitaria	*Botryococcus braunii*
Chaetosphaeridium globosum	*Chlorobotrys regularis*
Geminella mutabilis	*Melosira granulata*
Draparnaldia spp.	*Stauroneis phoenicenteron*
Chaetophora spp.	*Navicula rhomboides*
Spirotaenia spp.	*Gloenodinium uliginosum*
Cylindrosystis brebissonii	*Batrachospermum spp.*
Netrium digitus	*Gloeothece spp.*
Penium polymorphum (uplands)	*Aphanothece spp.*
Closterium spp. (esp. gracile)	*Microcystis spp.*
Cosmarium spp. (esp. cucurbita)	*Chrococcus turgidus*
Staurastrum margaritaceum (uplands)	*Hapalosiphon spp.*
Xanthidium armatum	*Stigonema ocellatum*
Gymnozyga moniliformis	*Glaucocystis nostochinearum*
Many other spp. of desmids.	

Table 9.3: Algae common in peat

CHLOROPHYTA	*CYANOBACTERIA*
Ankistrodesmus	*Anabaena*
Chlamydomonas	*Chroococcus*
Chlorella	*Lyngbya*
Chlorococcum	*Nostoc*
Closterium	*Oscillatoria*
Coccomyxa	*Pseudanabaena*
Gloeocystis	*Synechococcus*
Hormidium	
Oocystis	*CHRYSOPHYTA*
Palmella	*Navicula*
Protococcus	*Nitzschia*
Scenedesmus	*Pinnularia*
Stichococcus	*Synedra*

Filamentous blue-green algae (phylum Cyanobacteria) are not uncommon, especially *Oscillatoria,* which often forms blue-green or purplish-brown mats near the edges of bog pools; *Chroococcus* and *Merismopedia* are not uncommon in bog pools. Jelly algae frequently catch the eye in bog pools and bogholes; *Tetraspora* looks like little elongated clubs of clear jelly a few centimetres long, usually attached to stems and twigs etc., and *Palmodictyon* forms reticulate masses of jelly. Both contain cells that look like trapped *Chlamydomonas.*

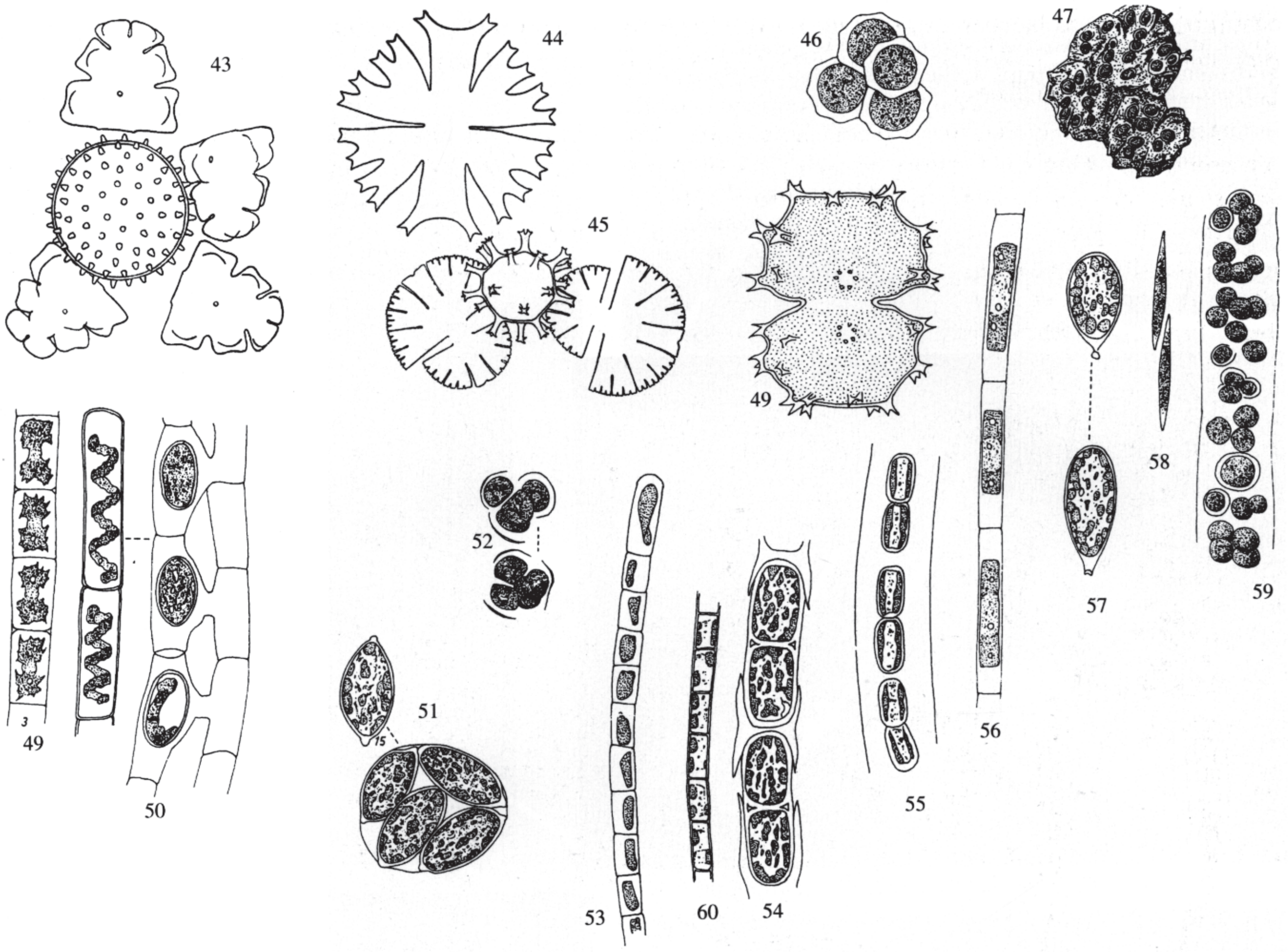
Desmids, which are specialised green algae, dominate the plankton of bog water, and are frequently enormously abundant and varied [**Figure 9.9**]. Although they colonise bog water at a very early stage, they are at their best in old pools that are little disturbed from one year to the next. Within a short time of a drainage network being laid across a bog preparatory to peat harvesting, the flowing water often becomes home to countless numbers of desmids, which anchor themselves against the current in a tenuous mucilage, so that the colonies take on the appearance of bright green, flimsy curtains waving in the water, which disintegrate under even the slightest mechanical disturbance. The absence of grazers may be a factor in this spectacular population explosion, but the colonies are often smothered in peat silt; indeed, the mucilage may play a role in trapping peat silt in these situations. Species of *Closterium, Cosmarium, Staurastrum, Micrasterias, Xanthidium* and *Euastrum* are among the most widespread. Some species of *Docidium, Gonatozygon, Pleurotaenium* and *Spirotaenium* rarely occur outside bog water. Diatoms (phylum Bacillariophyta) also occur in great abundance in the plankton, and though they are not nearly so characteristic of the bogwater habitat as desmids, they are among the most beautiful objects to be seen here [**Figure 9.10**]. Common genera include *Achnanthes, Amphora, Cocconeis, Cymbella, Fragilaria, Gomphonema, Navicula, Nitzschia, Pinnularia, Surirella, Synedra* and *Tabellaria.*

Green algae (phylum Chlorophyta) are also common in the plankton, represented by *Carteria, Chlamydomonas, Gonium, Pandorina* and others. Non-motile forms include *Ankistrodesmus, Botryococcus, Characium, Coelastrum, Crucigenia, Dicranochaete, Palmodictyon, Paulschulzia, Pediastrum, Scenedesmus, Tetraspora* and *Tetraedron.* The flagellated single-celled green algae in the phylum Euglenophyta are also well represented, with numerous genera including *Astasia, Colacium, Euglena* itself, *Lepocinclis, Menoidium, Peranema, Phacus* and *Trachelomonas.* The biflagellate

Figure 9.9: A portrait gallery of some bog algae.
1. *Gloeothece*
2,6. *Aphanothece*
3. *Chroococcus*
4. *Merismopedia*
5. *Nostoc*
7. *Stigonema*
8. *Euglena*
9. *Peridinium*
10. *Melosira*
16. *Anabaena*
17. *Gloeocystis*
15. *Hapalosiphon*
18. *Leptothrix*
19,20. *Mesotaenium*
21. *Netrium*
22. *Cylindrocystis*
23. *Spirotaenium*
46. *Coelastrum*
47. *Bothyrococcus*
49. *Zygnema*
50. *Spirogyra*
51. *Oocystis*
52. *Schizochlamys*
53. *Hormidium*
54. *Microspora*
55. *Geminella*
56. *Mougeotia*
57. *Characium*
58. *Ankistrodesmus*
59. *Palmodictyon*
60. *Tribonema*

DESMIDS:
32. *Cosmarium*
34. *Closterium*
35. *Micrasterias*
38. *Pleurotaenum*
39. *Docidium*
40. *Staurastrum*
41. *Euastrum*
42,43. Zygospores of *Euastrum* spp.
41. *Micrasterias*
45. Zygospore of *Micrasterias*
46. *Xanthidium*

DIATOMS:
11. *Fragilaria*
12. *Cocconeis*
13. *Tabellaria*
14. *Acnanthes*
24. *Synedra*
25. *Pinnularia*
26. *Cymbella*
27. *Navicula*
28. *Stauroneis*
29. *Amphora*
30. *Surirella*
31. *Gomphonema*
33. *Nitzschia*



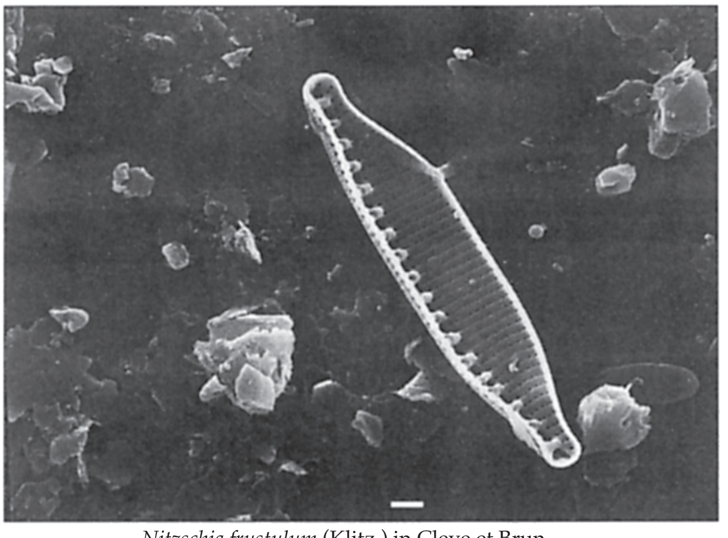
dinophyta (phylum Dinoflagellata) are represented by genera such as *Amphidinium, Gloeodinium, Gymnodinium, Hemidinium, Massartia* and *Peridinium,* the Cryptophyta by *Chroomonas* and *Cryptomonas.* Free-swimming golden-brown algae (phylum Chrysophyta) in the plankton of bog water include *Chromulina, Chrysococcus, Dinobryon, Hyalobryon, Mallomonas, Ochromonas* and *Synura.* There are relatively few yellow-green algae (phylum Xanthophyta), but *Centritractus, Chariaciopsis* and *Ophiocytium* should be found. *Tribonema* is a common filamentous species.

Algae occur widely as fossils – or more correctly, sub-fossils, since they are less than 10,000 years old – in the lacustrine clays beneath the bogs. They include *Gleotrichia, Anabaena, Cosmarium, Botryococcus braunii,* several species of *Pediastrum* (*Pediastrum boryanum, Pediastrum muticum, Pediastrum duplex, Pediastrum integrum, Pediastrum Kawraiskyi*), *Tetraedron minimum* and *Spongilla vulgaris,* along with many diatoms.

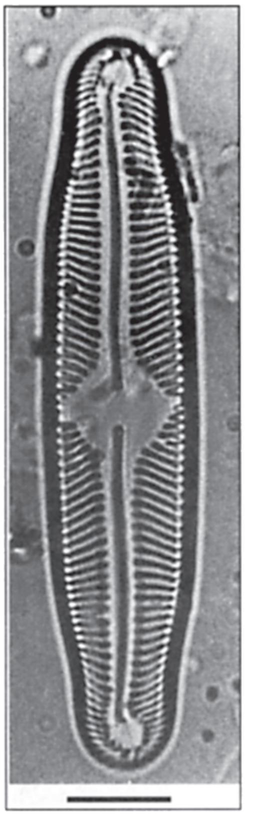
Algae in the soil

The predominant producer organisms in the peat are the algae, which can range in abundance from several thousand to many million individuals in every gram of peat. The major groups of algae which are represented are the green algae (Chlorophyta), the Chrysophyta and the blue-green 'algae' or blue-green bacteria (Cyanobacteria). Green algae tend to predominate in more acid peat, but the balance shifts somewhat on reclaimed peat, though the effect of fertiliser on the algal populations seems to wear off after a few years. The algal flora is very diverse, with representatives of perhaps sixty or more genera, many of them beautiful organisms to look at.

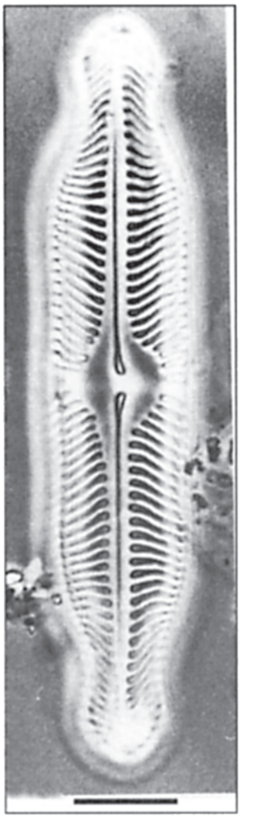
Figure 9.10:
Algae are among the most beautiful of all bog plants, but as with so many other groups in the biota of bogs their small size hides them from our everyday sight. Readers who would like instant access to their hidden world should pore over the spectacular photographs in the book by Hilda Canter-Lund and John W. G. Lund (1995). One of the modern tools which does much to capture the wonder of small lives is the scanning electron microscope. These SEM photographs were taken by Bernadette Cox and Declan Murray at the Department of Zoology, UCD.



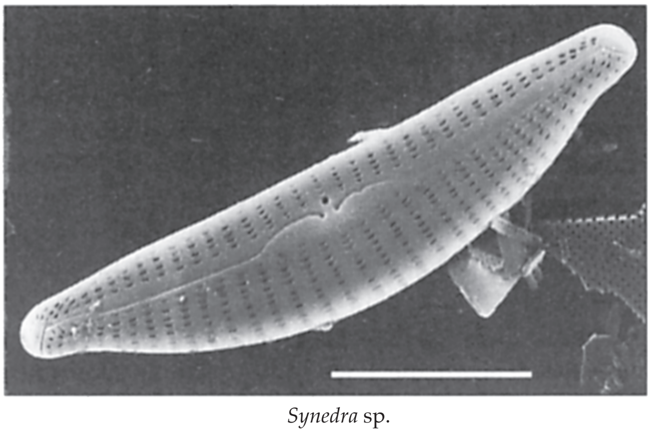
Nitzschia frustulum (Klitz.) in Cleve et Brun



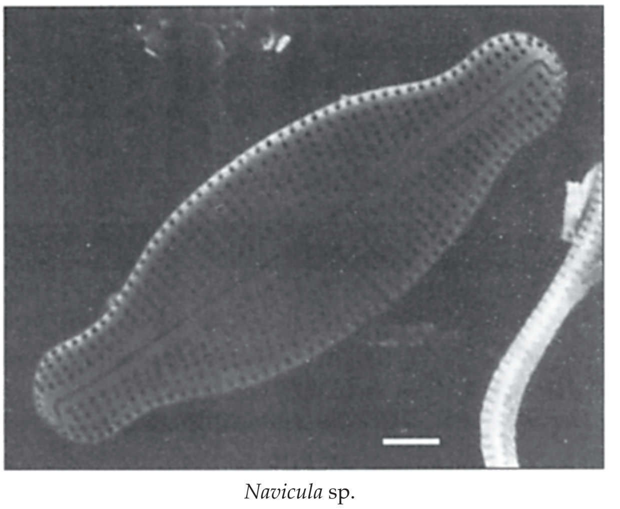
Pinnularia microstauron (Ehrenb.) Cleve



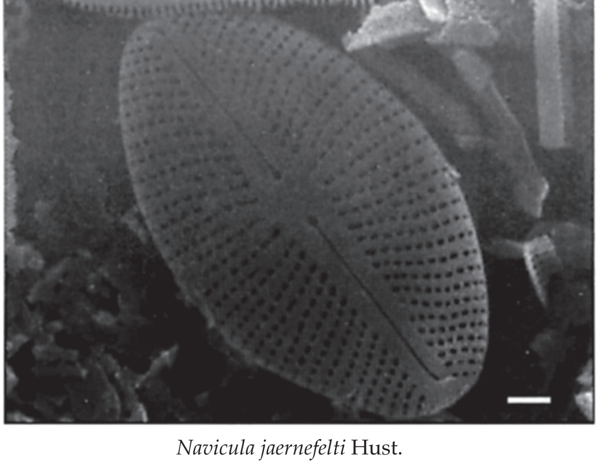
Pinnularia mesolepta (Ehrenb.) W, Smith



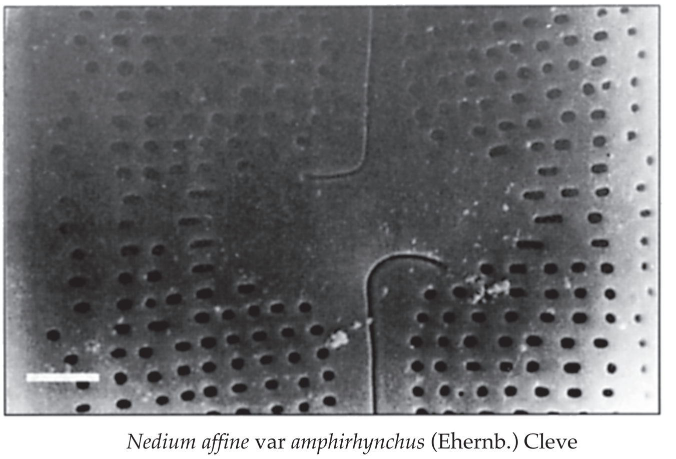
Synedra sp.



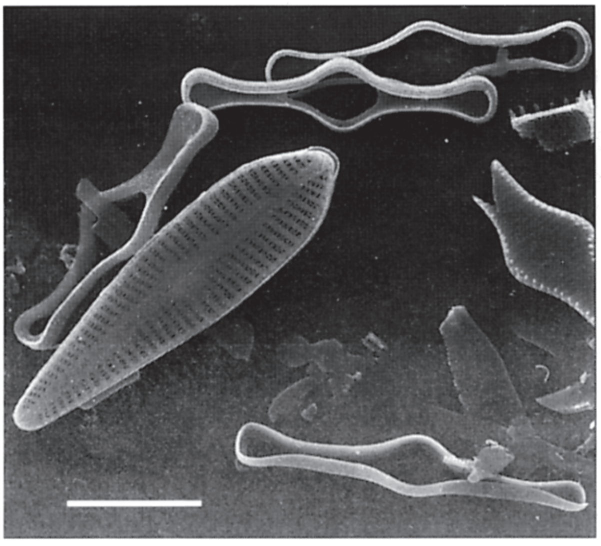
Navicula sp.



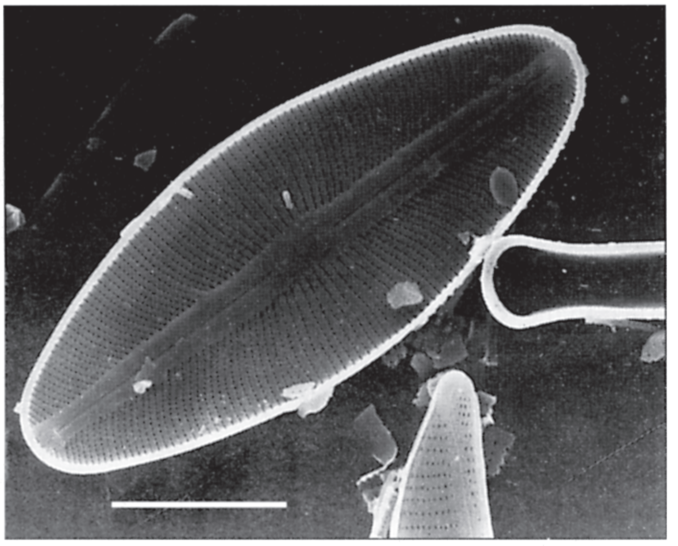
Navicula jaernefelti Hust.



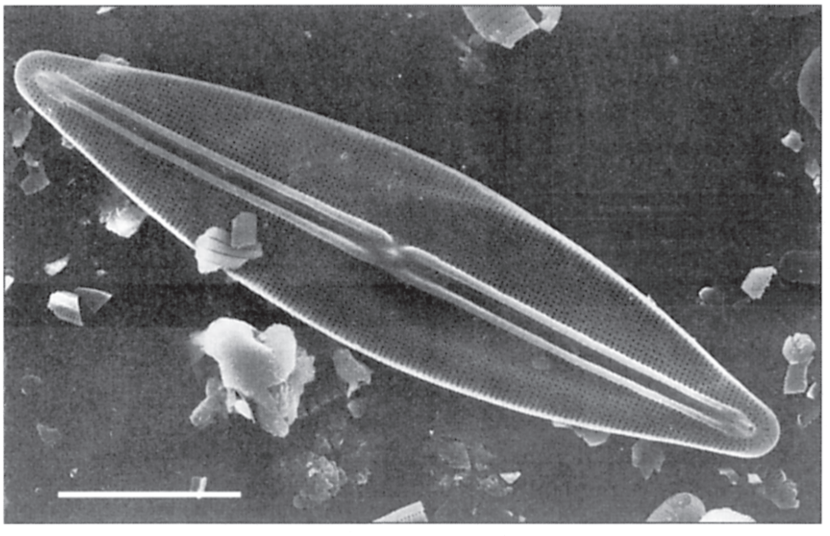
Nedium affine var *amphirhynchus* (Ehernb.) Cleve



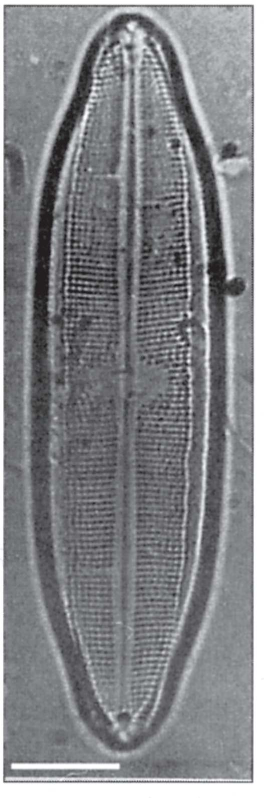
Gomphonema acuminatum var. *trigonocephala* (Ehr.) Grun



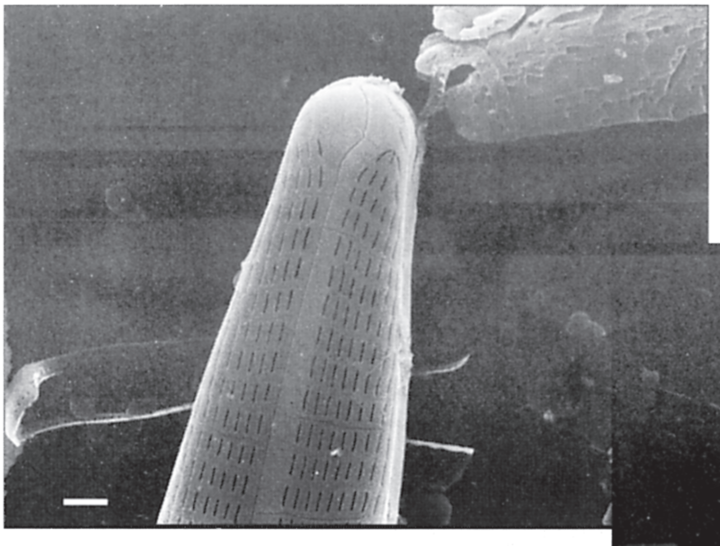
Navicula cocconiformis Gregory



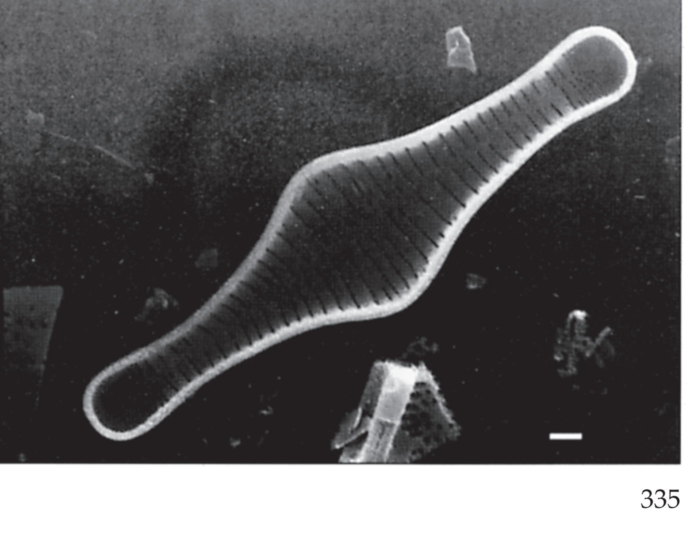
Frustulia rhomboidea (Ehr.) De Toni



Frustulia rhomboidea (Ehr.) De Toni



Navicula radiosa var. *tenella* (Bréb ex Kütz)



Tabellaria flocculosa (Roth) Kütz

Stoneworts

The stoneworts, sometimes called the water horsetails or brittleworts, are a strange group of mostly submerged aquatic algae that may be found in fens and old cutover. These remarkable algae are structurally so advanced that in the past they have been given 'higher' plant status, but they are now assigned to a separate class in the non-conjugating green algae (Chlorophyta). The plants consist of a main stem or axis from which whorled branches come off at intervals. They have an elaborate system of multicellular rhizoids that attach them to the peaty or clay substrate, and which take up nutrients.

In the course of their metabolic activity, the plants extract bicarbonate ions from the surrounding water for photosynthesis. They use the breakup products to secrete a layer of calcium carbonate around themselves. Where the plants grow in abundance, this limy material eventually forms a layer of marl, which can be several metres thick, on the bottom. Although they have a clear preference for limy water with a pH of 6-9, some species are able to tolerate slightly more acid conditions, and it is these that are found in fens and old bogholes. Several such species, which are generally considered rare in Britain, are still common in Ireland where such habitats are common. The species that occur most commonly in these situations are *Nitella tenuissima, Nitella translucens, Nitella fiexilis, Nitella gracilis, Chara pedunculata, Chara fragilis* and *Chara aspera* [**Figure 5.5**].

The stoneworts prefer still or gently flowing water as long as it is not disturbed, or enriched with nutrients (from fertiliser runoff, for instance). They are not good competitors for space and light. They are easily ousted by vascular plants, so they survive by occupying areas with deep water and low levels of light penetration that other plants find difficult or impossible to colonise. In clear still water, some species are known to occur at depths of up to eight metres. Praeger observed that just because stoneworts cannot be seen from the surface it should not be assumed that they are not present: 'it is never safe to assume that there are no stoneworts until every piece of water has been dragged over.'

Several species are good at colonising newly created water bodies. *Nitella tenuissima* seems to favour freshly-dug peat cuttings in fens. Most stoneworts are annuals, reproducing vegetatively by the formation of special outgrowths. Spores are produced through a complex process of sexual reproduction. These often lie dormant in mud or peat until some disturbance triggers them into germination; the spores are very resistant to decay, and are often preserved deep in the peat.

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Chapter Ten

Animal Life on the Bog 1:
Vertebrates 1 and invertebrates except insects

But let us be careful not to speak as if our little plummets had sounded the depths of the universe. Those who have surpassed their fellows in the improvement of natural knowledge have always been the first to admit that what they have come to know is lost in the infinitude of the unknown.

***The Natural History of Aquatic Insects* by L.C. Miall.**

Introduction

The bog is an austere world, and only those animals and plants that can meet the terms it lays down are able to live there. The most demanding of these restrictions are the high acidity and low nutrient status of peat soil, and the instability of conditions at the surface: sometimes time dry and warm, at other times wet and cold. In many ways, blanket bogs are even less hospitable places than raised bogs. There may be periodic flooding during one time of the year followed by drying of the surface at another; the vegetation is less tall, and provides less shelter from the elements.

As a result, only a limited range of plants can grow successfully here, and since green plants are at the base of the food chains that mesh together in so complex a way to spin the web of life on earth, only the animals that can feed on bog plants, and the carnivores that in turn feed on these herbivores, can find a place for themselves on the bog. As for the decomposer organisms – the tiny animals, fungi and bacteria that rely upon the dead and fallen remains of plant and animal for their livelihood – the acid conditions that are part of the very nature of the bog confine their activities to the upper few centimetres of the surface peat which are not permanently waterlogged, and where there is enough oxygen to enable them to get on with their business of decomposition and recycling. But while these conditions exclude many potential litter and peat inhabitants, there are many others – the true bog specialists – that have learned to cope with the harsh physical and biochemical demands imposed by the bog environment.

Apart from basic problems of food supply and soil chemistry, physical conditions on the surface are harsh; there are few trees to offer protection from wind and weather to larger animals, and the surface hydrology is often very unpredictable: long periods of waterlogging, alternating with times when the surface is very dry. For many of the smaller animals of the bog this is not a bigger problem than it would be anywhere else, because they either live in a very controlled micro-environment, or else their life-cycle enables them to elude the harshest affects of the weather. Many animals inhabit a much narrower world than ours, where there is not the same amplitude in such environmental variables as humidity and temperature etc. For example, the little silvery-grey weevil *Apion ulicis* spends all of its larval life inside growing furze pods, where it feeds on the developing seeds, and waits for the exploding pod to catapult it into adult freedom. Its little dark cell constitutes a *microhabitat* in which conditions are quite different from those prevailing in the great world outside. Most of the smaller animals of the bog are *oligolectic:* specialised for dealing with only a few kinds of food plants or prey organisms.

It's a different matter altogether for larger animals, which are exposed to the behaviour of the lower atmosphere and which may have to range widely in search of food. Most of these have to endure the same range of temperature, humidity and wind as we do. Their ability to move enables them to cope with these variables. Many of the larger animals that frequent bogs only spend their summers here, retreating to less harsh areas in winter.

The diversity of animal life in bogland is greatly enhanced in two ways: firstly, the many modifications of bogland brought about by man present a multiplicity of new opportunities for both plants and animals: and secondly, there is a host of animals that do not actually *live* on the bog, but only spend part of their time here, in search of food, shelter or refuge. There is more ecological opportunity and shelter in cutover areas, in bog woodland, and in the deep water of bogholes, pools and lakes. The upper part of the peat itself also has its own special fauna of tiny animals that feed on dead plant and animal debris and fungal mycelium. Springtails, small beetles and mites are the most conspicuous members of this fauna.

Few of the animals found on bogs deserve to be called *tyrphobionts* – the word for organisms found only on raised bogs. On the other hand, bogs certainly have characteristic animal assemblages and communities, and with the reduction of the area of semi-natural vegetation over the country as a whole, many organisms that once enjoyed a more widespread distribution now find their main refuges in and around bogs.

Most of the animals that are found in bogs are there because their food plants grow there, or in the case of carnivorous animals, because they eat animals that feed on bog plants. So, for example, wherever furze grows it will be accompanied by the bugs that feed on it: you can expect to find the shield bug *Piezodorus lituratus* in abundance, especially in sheltered, sunny places, and the tiny furry, pear-shaped weevil *Apion striatum.* Its close relative *Apion ulicis* feeds on the developing seeds. Another bug that is often seen on furze between the months of July and September is *Ascioderma obsoletum.* The flowers are also a powerful attraction to many insects such as the green hairstreak, and bumble bees and honey bees seeking pollen from its exploding flowers.

Worms and leeches: Annelida

There are two major groups of worms; what most people would regard as 'ordinary' worms belong to one of these major groups, the Oligochaeta. The other group is the Polychaeta, the many-bristled worms, most of which live in the sea. The Oligochaetes comprise a considerable number of families; the terrestrial members, the earthworms familiar to everybody, belong to the family Lumbricidae. There are several families of freshwater worms.

Earthworms

Like most other soil-dwelling animals, earthworms find the bog a very inhospitable place, and only the odd stray adventurer will ever be found on the uncut bog. But if conditions change, earthworms are among the many groups of animals that quickly take advantage of the new opportunities. The improved drainage that results from turf-cutting removes one of the major obstacles for earthworms, but conditions are still acid and they find the turf litter rather unpalatable and of low nutrient value. The first worms to migrate onto cutaway bog are species that live at or near the surface; they are adapted for feeding on raw humus and are more tolerant of acid conditions. Three species dominate this group: *Dendrobaena octaedra, Dendrodrilus rubidus* and *Lumbricus eiseni* [**Figure 10.1**]. *Dendrobaena* has a high tolerance of cold and periodic drying, which helps it to cope with conditions on the bog. Two other species, *Lumbricus castanelis* and *Lumbricus rubellus,* will also be among the early colonists; these are coprophage species that travel widely in search of the dung on which they feed. Other early arrivals are *Allobophora caliginosa* and *Allobophora chlorotica,* which (with *Lumbricus rubellus*) are often the most successful and abundant early colonisers.

Under natural conditions it takes about 25 years before species of more mature soils – *Lumbricus terrestris, Aporrectodea rosea, Aporrectodea longa* and *Octolasion cyaneum* – move into cutaway bog in any numbers, but in time all the species found in fertile mineral soil will colonise cutaway, and especially reclaimed cutaway, though the populations will be comparatively small. C.H. Baker recorded as many as fifteen species in grassland on long-established reclaimed fen peat soils in the Midlands, where densities of nearly 200 worms per square metre occurred. If it is well managed, reclaimed cutaway can support worm populations as high as fertile mineral soils, especially if they are deliberately introduced, an aspect which is of increasing interest to soil scientists. However, biomass is not as high, because *Lumbricus terrestris* never reaches high densities.

The earthworms of cutaway bog are extremely important from the farmer's point of view, because they are major agents for improving the structure and fertility of the soil. They mix it very efficiently, and are very effective at incorporating organic residues into the immature bogland soil. It has been calculated that worms would completely turn over the top 20cm of soil on reclaimed cutaway in about 45 years. Experiments in the Midlands have shown that worms can improve the productivity of grassland on cutaway by nearly 50% where cattle slurry is used as a fertiliser, whereas artificial fertiliser is effective only in nutrient-limited situations. In this case the worms are mineralising the organic slurry and incorporating it into the soil.

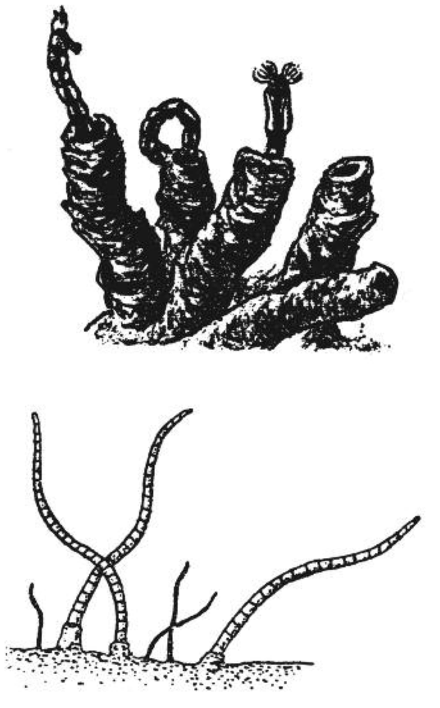


Figure 10.1: Two kinds of mud tubes can be found in waterlogged peat. The inhabitants of both have haemoglobin in their blood to help them obtain oxygen under these conditions. Above: mud tubes of chironomid midge larvae (called bloodworms because of the red colour). Below: colonies of *Tubifex* worms also live in tubes, weaving their back ends in the shallow water to obtain oxygen.

Freshwater worms

The dry-land earthworms described earlier belong to the family Lumbricidae, but there are several other families whose members are aquatic, and which occur widely in bogs. The most important of these freshwater worms are the tubificid worms (Tubificidae), the Lumbricilidae and the Enchytraeids. They are found in peaty mud at the bottom of bogholes and pools and in other situations, where they construct burrows that are often prolonged above the surface of the mud as tubes or turrets [**Figure 10.1**]. Both *Tubifex* and *Lumbriculus* are bright red because of the haemoglobin in their blood, which helps them to breathe in the poorly oxygenated peat mud. *Tubifex* often occurs in large colonies; *Lumbriculus* is a much larger worm, up to 3cm long. The long wireworms (*Haplotaxus*) are longer still – up to 30cm – and they also sometimes occur in peatlands. They belong to the family Haplotaxidae.

Enchytraeids (pot worms) are much smaller than the familiar earthworms, and they occur in every body of water, living in the bottom mud for the most part. And whereas earthworms are hardly ever seen on uncut bog, enchytraeids are very abundant, because they are much more tolerant of acid conditions, and are one of the most important components of the biomass of peaty habitats. The little enchytraeid *Marionina* almost invariably occurs in the peat of mountain bogs, where several species of *Hedodrilus* and other genera are also found. A number of species are associated with bog mosses, among them *Cognettia sphagnetorum*, which shows evidence of daily vertical migration through the sphagnum, coming closer to the surface at night when it is cooler. A number of species of *Tubifex* and *Limnodrilus* occur in peat, but virtually nothing is known of their ecology. Other species are common in bog water.

Leeches and flatworms

Another group of annelids which has few bogland representatives are the leeches (Hirudinea). There are thirteen Irish species, occurring in rivers and bogs throughout the country, but although several species occur in the larger lakes and rivers associated with peatlands, very few occur in the smaller acid water bodies found in most bogs. Those that do are mainly macrophagous predators rather than haematophagous species, feeding on creatures like worms, slugs and insect larvae. They include *Helobdella stagnalis,* which is an efficient predator of chironomid larvae. *Haemopsis sanguisuga, Glossiphonia complanata*, and *Erpobdella octoculata* are all widespread leeches that not infrequently turn up in bog waters. *Glossiphonia heteroclita* has similar food preferences, and is unusual in that it frequently overwinters inside the mantle cavities of freshwater snails.

Flatworms (Platyhelminthes) are not common bog animals, but several species do occur in bog pools and drains. One especially interesting species is *Castrada armata,* recorded in 1936 in a bog pool among weeds at Carrigahorig bog in North Tipperary – the first record of the species from Britain or Ireland.

Mollusca: snails and slugs

Slugs are seen much more frequently in bogs than snails, because they don't have the same need for shell-building calcium – in very short supply in bogs – that snails have. The most successful is the black slug *Arion ater,* which is the largest invertebrate animal of bogland, and often occurs in considerable numbers in areas of old cutover. A number of small, thin-shelled snail species are however able to tolerate the acid conditions of bogs. They include the tawny glass snail (*Euconulus fulvus*), the rayed glass snail (*Neovitrea hammonis*) and the chrysalis snail *Columella aspera*, which is believed to feed on algae and lichens on the stems of bilberry and other plants. Shortage of calcium is not always a problem. Many midland bogs developed in the hollows of a landscape dominated by lime-rich eskers and moraine, and very often the edges of the bog come right up to the ridges, which have a rich snail fauna, some of which will stray at least a short way onto the bog margins.

Nematodes

Nematodes are abundant in surface peat, though they do not attain the enormous numbers they reach in more productive soils. The dominant forms are species of *Acrobeloides* and *Plectus*, and a range of other genera are also represented: including *Wilsonema*, *Eudorylaimus*, *Tylenchus*, *Rhabdolaimus* and *Aphelenchoides.* Very little indeed is known about their ecology. In the food web of surface peat they are prominent in the diet of the numerous mites and carnivorous springtails, and microbial-feeding nematodes play an important role in mineralisation.

Rotifers

Rotifers are one of the most important groups in the microfauna of fresh waters; they are very tiny – little bigger than many protozoa – complex, and fascinating creatures. They derive their name from a rhythmically-beating crown of cilia called a wheel organ, which sets up a whirlpool effect that draws small organisms into the creature's mouth. Most rotifers find bog water too acid, but there is nevertheless a distinctive bog rotifer fauna. There are two main groups of rotifers, the ploimates and the bdelloids. Some of the ploimates are planktonic, and others live attached to vegetation. Bdelloids are abundant on sphagnum and other plants; their special niche is the surface film clinging to the plants, in which they swim or move about in a leech-like manner. Two common species of *Habdotricha* are found only in the outer retort cells of sphagnum branches.

Isopods and amphipods

The only large crustacean that occurs on bogs is the water hog-louse (*Asellus*), which is a very common scavenger in bogs and fens, especially where there is plenty of debris present [**Figure 10.2**]. It is an isopod, closely related to the land-based woodlice; indeed it looks very like a very flat woodlouse. Hog-lice are particularly interesting creatures to watch when young. They are transparent at this stage, so the rhythmic contractions of the dorsal heart are wonderfully clear, and the individual blood corpuscles can be watched as they circulate through the limbs, antennae and gill plates. The only bog amphipod is the freshwater shrimp (*Gammarus*), which often occurs in fens.

Entomostraca

Entomostraca is a collective term for several groups of small crustacea that occur, often in enormous numbers, in freshwater; they are among the most important animals at or towards the bottom of the food chain. These groups are the water fleas (Cladocera), the copopods and the ostracods [**Figure 10.2, 10.3**]. They are to be found in all wet situations on the bog, even in the peat itself, but the greatest concentrations occur in weedy pools and bogholes, and within the sphagnum carpet.

Most water fleas are between 1 and 3mm in size. Something like 35 different species occur in bog water, the distribution and abundance of the individual species being controlled to a large extent by the nature of the shore and the density of the vegetation (among other factors). Larger bodies of water, like the lakes of the western bogs, have many more species than lily pools or bogholes, because there is more variation in the character of the shore-line. Species that are truly planktonic in habit, such as *Holopedium gibberum*, *Bytotrephes longimanus* and *Leptodora kindti* (and to a certain extent *Daphnia hyalina*) are open lake species, and rarely occur in the still waters of closed lakes and lily ponds. Species like *Streblocerus serricaudatus*, *Acantholebris curvirostris*, *Alonella nana* and *Chydorus piger* on the other hand become much more abundant where there is an abundant and dense vegetation. *Sida crystallina* is another species that is common where there is abundant aquatic vegetation, which reflects its habit of attaching itself by its dorsal head gland to plant stems. *Chydorus ovalis* is a species that is found in peat, in which it can burrow to 10cm, as well as in bog water.

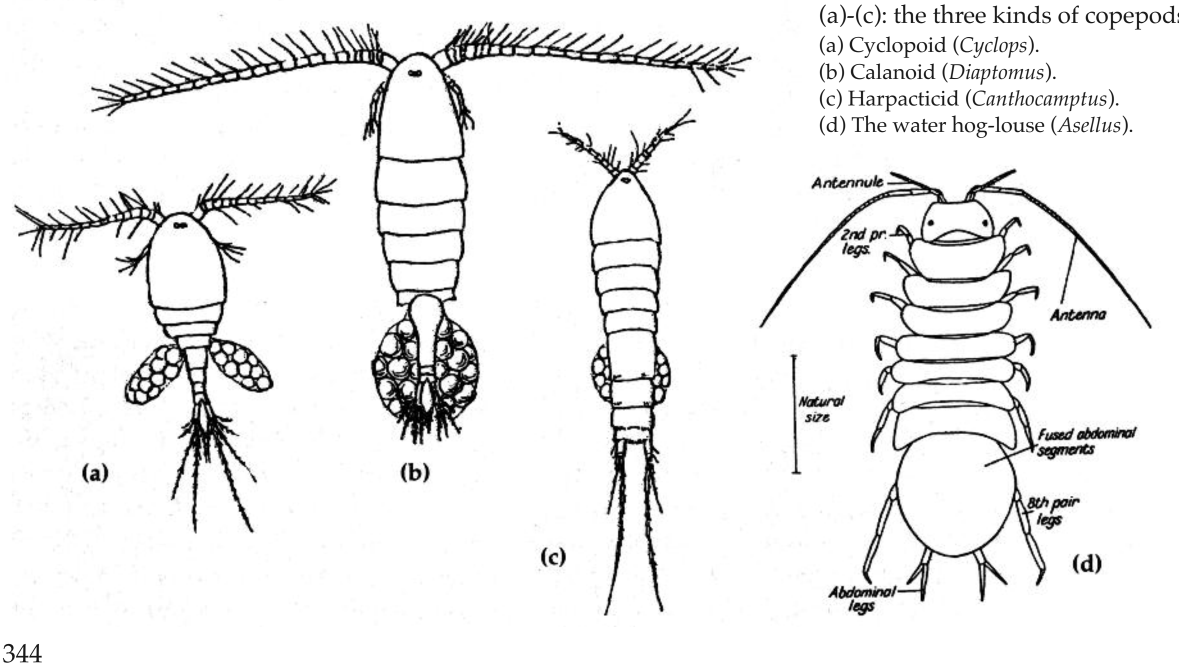


Figure 10.2: Crustaceans
(a)-(c): the three kinds of copepods.
(a) Cyclopoid (*Cyclops*).
(b) Calanoid (*Diaptomus*).
(c) Harpacticid (*Canthocamptus*).
(d) The water hog-louse (*Asellus*).

Water fleas, rotifers and other planktonic animals consume enormous numbers of the planktonic algae that are very diverse and often occur in great abundance in bog pools; *Polyphemus pediculus* is one of the most widespread and voracious predators among the cladocerans. When conditions are right – plenty of nutrients and lots of light and warmth – planktonic algae can multiply very rapidly, and their multiplication is often followed by a population explosion among the rotifers and cladocerans. But what usually happens next in cases like this is that the burgeoning population of busy little consumers overgrazes its watery pasture, and the great algal massacre is followed by a famine among the primary consumers, whose numbers in consequence decline dramatically. But in most bog pools the nutrient supply supports more stable populations of planktonic algae, and there is a balance between them and the rotifers, cladocerans and copepods which feed on them.

Copepods can occur in immense numbers in shallow water, algae and damp moss, often along with Cladocera. Among their most distinctive features are the prominent single median eye which accounts for the name of the most familiar genus (*Cyclops*), and the egg sac/s attached at the back of the female; in the Cladocera the eggs develop in a brood paunch inside the body. *Acanthocyclops venustus, Acanthocyclops nanus, Moraria brevipes* and *Moraria sphagnicola* are among the most characteristic species of copepods

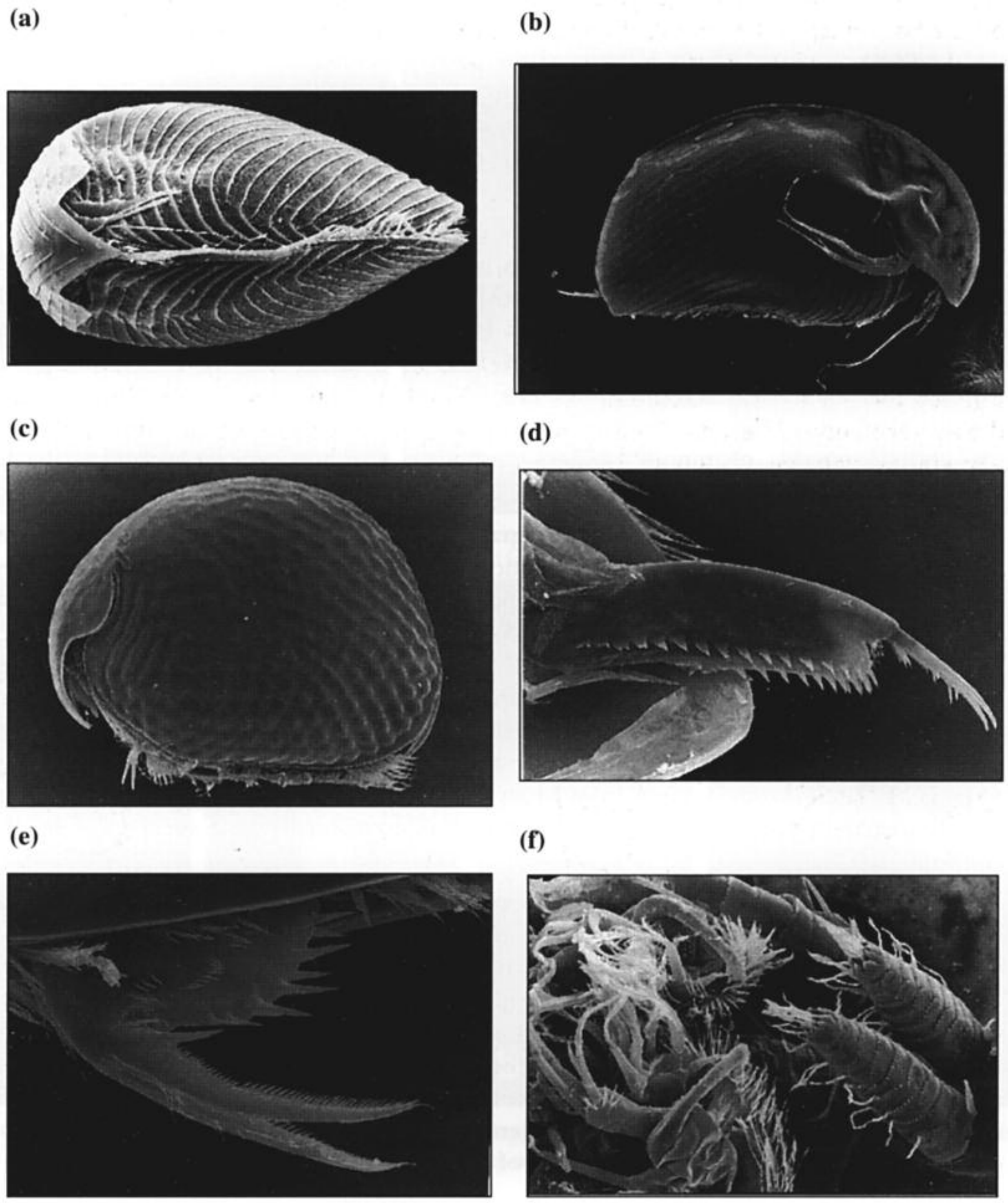


Figure 10.3: Scanning electron microscope photographs of chydorid cladocera.
(a) *Alonella nana*, one of the smallest of all cladocerans, never exceeding 0.3mm in length. It occurs widely in bog waters. This specimen is a parthenogenetic female from Lough Roe on Clara bog, seen here in ventral view under the scanning electron microscope (SEM). The little creature's mouthparts, antennae and legs are retracted within its protective head shield and shell-like external skeleton (carapace). More than any other technique SEM allows us to see the extraordinary complexity and beauty of even the tiniest animals and plants.
(b) *Acroperus* cf. *harpae* is a very common and widespread species complex, whose favourite habitats include lakes and pools associated with raised and western blanket bog.
(c) *Chydorus piger* is another common species with a preference for acid waters. It is often abundant in bog pools with sphagnum, and occurs in raised bog and both types of blanket bog.
(d) Postabdomen of ephippial female of *Alonopsis elongata* from Upper Lough Bray in the Wicklow Mountains. This is a boreal species found in unproductive waters, mainly in western counties and upland areas.
(e) *Chydorus ovalis*, parthenogenetic female, Lough Roe.
(f) Antennules and mouthparts of *Eurycercus lamellatus* from L. Dan, Co. Wicklow.
These SEM photographs were taken by Catherine Duigan and Declan Murray at the Department of Zoology, UCD.

found in bogs, often in association with sphagnum. Although they are crustaceans, ostracods look like very tiny bean-shaped shellfish. Most are only about 1.5mm long, but they are not common members of the bog fauna [See also Chapter 12].

Arthropods: arachnida: spiders

Bogs have a characteristic assemblage of spiders, although none of the individual species is confined to bogs [**Figure 10.4**]. Between 40 and 50 different species may be expected to occur on larger bogs, and they include some of the largest and most interesting of Irish spiders. But the majority are small creatures, exploiting the multiplicity of ecological niches to be found on the bog itself and in the surrounding area. Many spiders are fond of low vegetation, others like to be near water; for many of these the bog is an ideal home.

Araneus quadratus is one of the most obvious spiders on the bog, partly because of its size (the female can be over 2cm long), and partly because of its habit of spinning its web across bog tracks at just the right (or wrong!) level for passing humans. The females in particular have prominent circular abdomens with four large white spots and a white line running up the front end.

Anybody who has worked on the bog in early summer will be familiar with the activity of the wolf spiders (Lycosids), as they scurry busily across the cutover, carrying their egg sacs behind them. These active spiders belong to the genus *Pardosa.* The commonest species is usually *Pardosa nigriceps*; *Pardosa pullata* is often found in rather wetter places such as on the surface of sphagnum carpets. Another hunting spider that is often seen wandering across the spreading ground with her egg sac in June and July is *Pisaura mirabilis.* In spite of their impressive turns of speed, lycosids are very sedentary, and move little beyond a small home territory.

Common crab spiders found on bogs include *Xytiscus cristatus* and *Oxyptila trux,* species that occur among low vegetation in many other habitats as well. Three tiny spiders that can nearly always be found in heather are *Dictyna arundinacea, Clubiona trivialis* and *Scotina gracillipes. Neon reticulatus* is likely to be found in deep litter among the heather. Money spiders are tiny black spiders noted for their ballooning skills, using threads of silk as parachutes to carry them to new homes, especially in autumn. Among the various species of money spiders. found on the bog are *Bathyphantes gracilis, Leptyphantes tenuis* and *Erigone dentipalpis.*

Tibellus oblongus is a species of long grass, where it has the habit of extending itself along the blades of grass and other vegetation. *Tetragnatha extensa,* one of the commonest spiders on the bog, is often found with it, behaving in much the same fashion. *Theridion bimaculatum* can be found in the same sorts of places, and can be easily recognised by the bright yellow-white splash down its abdomen. A lovely spider occasionally seen among bog myrtle and similar low vegetation is *Hyposinga pygmaea,* which has a black abdomen with three long stripes, the middle one yellow, and the two at the side white. *Gongylidiellum latebricola* is a one of the few spider species that are more or less confined to bogs. So far it is only known from Mongan and Carbury bogs, but is probably more widely distributed. An ant-mimic spider which is occasionally seen on bogs is *Micaria pulicaria.*

A number of spiders favour damp places, among them *Pirata piraticus,* a small handsome marsh spider whose tubular webs are a frequent sight in moss and heather. It spends most of its time out of sight, hunting in the sphagnum forest. After mating the *Pisaura* mother-to-be constructs a vertical retreat tube for herself down among the sphagnum; the upper end opens to the sky through the canopy, and the bottom end is near the water level. Here the female lays her eggs and wraps them in a globular cocoon of dirty white silk. The eggs need heat to hatch, so during the warmth of the day the mothers sit head down – often in considerable numbers – each at the top of her tube, exposing their cocoons to the warm rays of the sun. When disturbed the spider retreats quickly into the tube with its cocoon, and if danger threatens it will vacate its tunnel by the lower exit and descend into the water by climbing down the submerged part of an adjacent sphagnum stem. *Pirata piraticus* is quite similar to *Pardosa pullata,* and they prey upon the same sorts of animals, but there is little competition between them because they are adapted to quite different sets of conditions, and neither can survive for long in the other's habitat. *Antistea elegans* is another handsome spider often found among wet sphagnum. It has a glossy red carapace and a very hairy abdomen.

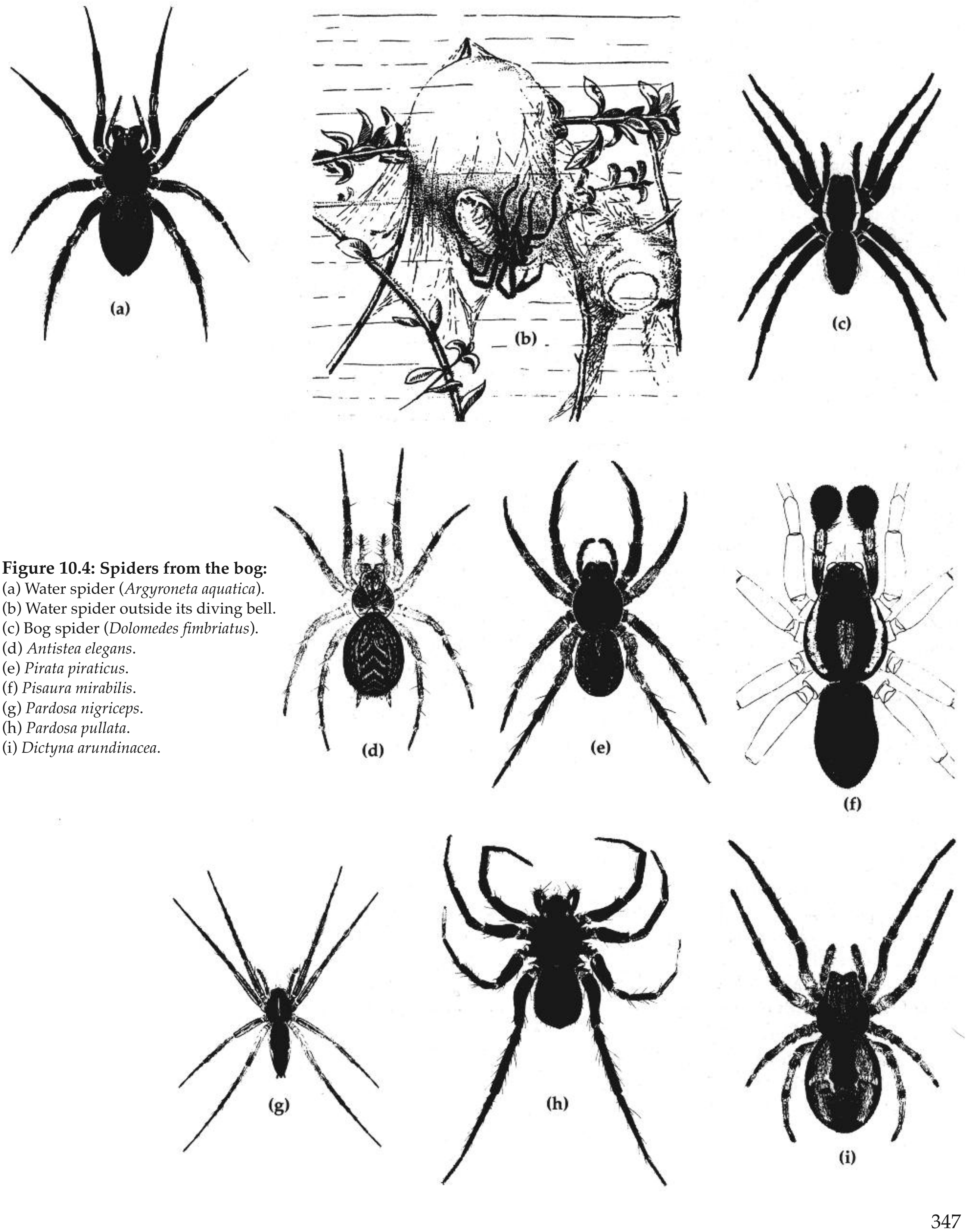


Figure 10.4: Spiders from the bog:
(a) Water spider (*Argyroneta aquatica*).
(b) Water spider outside its diving bell.
(c) Bog spider (*Dolomedes fimbriatus*).
(d) *Antistea elegans*.
(e) *Pirata piraticus*.
(f) *Pisaura mirabilis*.
(g) *Pardosa nigriceps*.
(h) *Pardosa pullata*.
(i) *Dictyna arundinacea*.

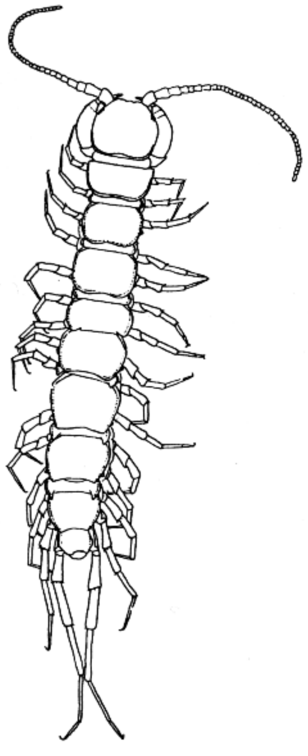
One of the most splendid of all the creatures of the bog is the bog or marsh spider, *Dolomedes fimbriatus* [**Plate 10**]. It lives in old bogholes, ditches and other watery places, where it sits patiently among the vegetation at the water's edge with its front feet resting lightly on the water, waiting for likely prey. It is over 2cm long, dark brown in colour with a yellow or whitish band down each side. Its 'web' is the water surface, and if some unfortunate creature ventures within reach, *Dolomedes* is out across the water after it like a shot. *Dolomedes* sets up surface vibrations to attract its prey – which can include things as large as damselflies and even small fishes. It will dive for safety when threatened, and can survive under water because it has a coat of water-repelling hairs that retain a silvery film of air next to the body. This *plastron* (as it is called) not only gives the spider the oxygen it needs underwater, but provides a medium into which oxygen dissolved in the water can diffuse, enabling the spider to stay submerged for quite some time. This is a solution to the problem of underwater breathing that has been adopted by many land arthropods that have taken to the water. Its ability to run across the surface is due to the dense covering of fine hairs on its legs. The bog spider is at its most active in summer, and at this time the female (which is the larger of the two sexes, as is the case in most spiders), can be seen guarding her nest; when the young emerge, they quickly disperse.

The water spider (*Argyroneta aquatica*) [**Figure 10.4**] lives a secret life down in the submerged sphagnum forest of old bogholes. Its aquatic way of life – unique among spiders – makes it seem less common than it actually is. It becomes easier to detect in August, when the females spin their silk egg cocoons just below the surface. This is to allow the baby spiders access to the open air when they are born. The prominent cocoons make it possible to make a rough estimate of the number of adult females; not infrequently, a suitable boghole may have half a dozen or more cocoons. Structurally and physiologically the water spider is very little different from other spiders. It is as dependent on atmospheric air as all its kin, but where other air-breathing aquatic insects such as water beetles and water boatmen must come to the surface every time they need to take a breath, the water spider lays in her stock of air underwater. To do this she first spins a flat web that is anchored among the water plants; she then surfaces and dives with a film of air adhering to the fine hairs on her abdomen; she strokes the air from her body with her legs under the flat web (where the bubble is trapped) and rises to the surface again and again, bringing more air down each time. The flat web rises like a balloon under the growing bubble. Once it is full this bell-shaped tent of air needs little topping up, because oxygen from the surrounding water diffuses into it. The water spider makes several diving bells: there are different ones for feeding, for courtship, for overwintering. The spider lays 50 to 100 eggs in summer; these are enclosed in a yellowish silk bag and sealed off at the top of her underwater tent. The newly-hatched spiderlings are looked after by their mother for a time, a rare example of parental care among spiders.

Arthropods: arachnida: harvestmen and false scorpions

Harvest spiders are not all that common on raised bogs, with the notable exception of *Phalangium opilio.* They are much more frequent on upland and blanket bogs. One of the most interesting is *Megabunus diadema,* which has an extraordinary eye turret or ocularium, with long spines like eyelashes around the eyes. *Opilio saxatilis* is another upland species. Harvestmen are not great hunters; they prefer to just wait until something edible comes within reach of their groping arms. The false scorpion that is perhaps most likely to be met with on the bog is *Neobisium muscorum,* a four-eyed reddish creature only 3mm long, which will be found lurking under mosses and lichens in dry places, hunting for the springtails and other small animals on which it feeds. It seizes its prey with its large pincer-like claws, crushes it, then pours digestive juices over the mangled remains and sucks up the fluids.

Arthropods: woodlice and myriapoda (centipedes and millipedes)



Woodlice occur on bogs only as occasional visitors. Centipedes are not common inhabitants either, but in certain circumstances they can be abundant. Ireland has only sixteen species of centipedes, about half the number found in Britain – partly because in general they prefer a warmer climate, and partly because they had little time to reach Ireland after the Ice Age before rising sea level cut them off. All the same, the British and Irish centipede fauna includes one very striking species that is not found at all in the rest of Europe: *Lithobius variegatus,* which often strays onto the edge of the bog [**Figure 10.5**]. The head and body of this dragon-like centipede are pale brown in colour, marbled with dark violet, but the underside is yellow, and the legs have a banded appearance. It does its hunting at night, when its colour camouflages it perfectly; by day it lies hidden and motionless. It also has the distinction of being the only centipede that climbs trees. Several other *Lithobius* species are frequent animals of bogland: that opportunist carnivore, *Lithobius forficatus,* is nearly always somewhere about, especially on spreading grounds, and *Lithobius crassipes* and *Lithobius lapidicola* sometimes occur. Several other widely-distributed centipedes are occasionally encountered on the bog, particularly *Schendyla nemorensis, Geophilus carpophagus, Geophilus insculptus, Necrophleophagus longicornis, Brachygeophilus truncorum* and *Lamyctes fulvicornis.* Millipedes are absent from uncut bog, but common on cutaway areas. One species that may be looked for is *Proteroiulus fuscus.*

Figure 10.5: A dragon among invertebrates: *Lithobius variegatus* is the most distinctive of centipedes; the upper side is pale brown marbled with dark violet, the underside yellow. Its legs are marked with alternate dark and pale bands. (From Eason, 1964).

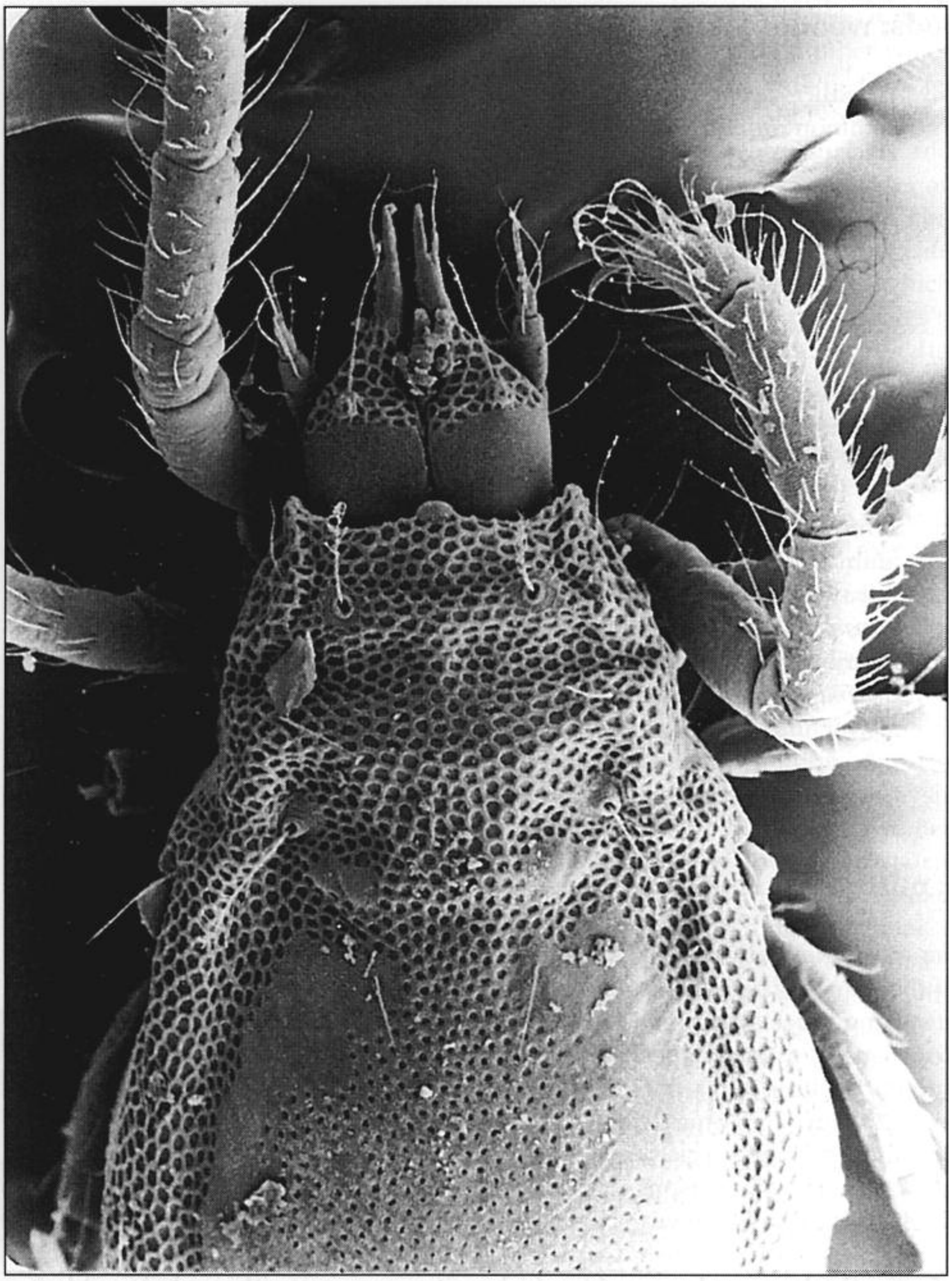
Acarina: mites and ticks

Among the most abundant yet poorly-known animals of the bog are the mites. This is because of their small size, and because as a rule they go about their important business without attracting much attention. Many live in intimate association with other animals, as parasites (usually external ones) or as harmless *commensals.* Many are crop pests in farming and horticulture and some do great damage, particularly to products in storage. A few cause economically or medically important diseases. Soil and herbage are different mite worlds, though some species are adapted for life on the borders. All have their own seasons, closely tied to the seasons in the world above, and to the cycles of plants and farmers. Each species has its own particular life cycle strategy, and numbers may vary widely from one season to the next. Our knowledge to date gives us the merest glimpse into the fascinatingly complex world that mites occupy with such bewildering diversity.

The mites that are most important on the bog are those that live in the upper few centimetres of the peat, where with the springtails and other allies of decomposition they help in the partial breakdown of plant debris. Peat is a very inhospitable medium for detritus feeders. Mites and spring tails are more or less confined to the upper few centimetres because they cannot survive in the anaerobic and waterlogged conditions that exist lower down. One order of mites, the Cryptostigmata, comprises fungivores for the most part.

There is a very complex and scarcely-investigated community of mites here, living in all sorts of ways: there are saprophagous and coprophagous forms, mycetophagous and microphagous and predaceous forms: they are probably the most diverse and abundant animals in this habitat. Some phytophagous mites make themselves more conspicuous than most by the galls they cause on their hosts, the most obvious and important culprits here being the eriophyiid mites (Eriophyidae).

Not much is know of the mites that abound in bog peat. Among the most frequent species recorded by Ruth Blackith from Glenamoy Bog were *Macrocheles submotus* and



(a)

Figure 10.6: Mites are among the most successful and abundant of bogland animals. These two SEM photographs help to give some idea of the intricate detail of these complex creatures. Note the elaborate patterning on the cuticular ridges and the pits for plumed sensory hairs. These specimens, which belong to a species that lives a semi-aquatic life in sphagnum hummocks, were collected at Clongawny bog in County Offaly. It is a small organism, just about visible as a speck to the naked eye. The pictures show it as seen from above (a) and below (b). (Photographs by Barry Cregg).

Pergamasus robustus. Nematodes are an important food of some mites, and it has been speculated that mite predation may actually stimulate nematode population growth, as does the presence of predaceous Collembola.

The numbers of species and individuals generally increases when bogland is cut away and reclaimed. More than 65 species have been recorded in reseeded grassland on cutover bog in County Kildare, but this is still less than half the number that would normally be expected to occur in permanent pasture. Two groups of mites are especially characteristic of the early stages of colonisation of newly seeded pasture: the Astigmata and the Prostigmata, and many of them are different from the species found in unreclaimed bog. These early animals include many that feed on the microfauna of plant and soil; as more abundant and varied plant debris becomes available new forms arrive and play an increasingly important role, including more of the Merostigmata that are the dominant soil mites in permanent pasture. Many of the new colonists seem to arrive mainly by air; small species are simply carried by air currents, but a number are known to hitch lifts on insects, a phenomenon known in the invertebrate world as *phoresy.* As the herbivorous community becomes more diverse, so do the predaceous mites.

(b)

Tim Longworth recorded 106 species from blanket bog at Glenamoy in the early 1970s during his research for the IBP project: 48 species from sphagnum-filled hollows on the undisturbed bog, 65 from heathery hummocks, 59 from reclaimed peat under grass and 61 from an area under coniferous trees. The greatest densities were out on the bog; the hummocks had populations of nearly 18,000 per m^2, and there were almost as many in the hollows. The lowest numbers were found in the grassland, with less than 14,000 per m^2. These numbers represent considerable biomass values. The mean biomass values calculated for the Cryptostigmata (generally the most important group of mites present; 27 of the 48 species in the hollows and 58 of the 65 hummock species were Cryptostigmata) are shown in the table below. These values are still only a fraction of the biomass of much less-well known groups such as the enchytraeids. The primary ecological role of the mites may be in making conditions more suitable for the activity of fungi, enchytraeids etc.

	Gram x 10^{-3} per m^2	
Hummocks	x= 382.138	SE ± 64.6
Hollows	x = 195.58	SE ±32.9
Grassland	x = 67.51	SE ± 14.4
Shelter belt	x = 208.4	SE ±26.73

The three dominant species in the hollows were *Limnozetes ciliatus, Nanhermannia nana* and *Muconothrus nasalis;* between them these three species accounted for 76.9% of the total acarine population. The first two are characteristic of this kind of habitat, but *Muconothrus nasalis* occurs elsewhere in its range only in cold or very cold biotopes; Glenamoy is the warmest place it lives. Because different species vary so much in size, the most abundant species are not always the most important in terms of biomass. For instance, *Limnozetes ciliatus* is the most abundant species in the hollows, but *Nanhermannia nana* makes up a much greater proportion of the biomass here.

By far the commonest and most abundant hummock mite was *Carabodes minusculus* (54% of total), but *Nanhermannia nana* is also very common on the hummocks. The grassland was dominated by populations of *Platynothrus peltifer* and *Rhizoglyphus echinopus,* while the most prominent tree-litter species were *Oppia nova,* with large populations also of *Oppia obsoleta* and *Hypochthonius rufulus.* More of the carnivorous Mesostigmata occurred in these two modified habitats: 20 species in the grassland and 23 under the trees. The acarine fauna of both habitats still has a strong bog aspect, but it is likely that with time this will gradually be lost and the mite communities in these situations will come to resemble those of woodland and grassland more closely. Each species has its own specific niche, but not a great deal is really known about the differences. Certainly they all have their own 'menu', which includes a wide range of fungal hyphae and spores, bryophytes, and assorted green plant material of other kinds. The Mesostigmata are primarily carnivorous; their menu includes nematodes, enchytraeids, collembola, tyroglyphids, the larvae of diptera and juvenile mites.

Water mites are very beautiful and vicious little creatures. Their mouth parts are beak-like and are used to suck the body fluids from their various hosts. Water mite nymphs are often parasitic on the bodies of water beetles. The ferocious *Dytiscus marginalis* is often infested with swarms of the red larvae of *Hydrarachna globosa.*

One arachnid that is all too common on bogs – especially in the west – is the grass tick or sheep tick (*Ixodes ricinus*). But troublesome though they undoubtedly are, they are also fascinating creatures. They go through three stages during the course of their life – larva, nymph and adult – and they feed once at each stage on a wide range of host mammals and birds, including ourselves, for which they lie in wait at the tips of grasses or sedges, bracken or heather. The larva feeds three to five days before dropping off to moult, and the nymphs feed for five to seven days before falling off to make preparations for their moult to the adult stage. Adult females feed for seven to thirteen days, and then drop off to lay several thousand eggs, which take eight weeks to develop. Adult ticks overwinter deep in the moss or leaf litter. Most feeding takes place during two periods of activity during the year – March-May and August-October. The sheep tick is the vector for several important diseases of farm animals: in particular looping fever and tick-borne fever in sheep that are caused by micro-organisms carried by the tick, and redwater disease of cattle. More recently, it has been causing concern as the vector of Lyme's Disease in humans. Other ticks undoubtedly stray onto the bog with the many birds and mammals they parasitise: but they are not a part of its ecology in the way the sheep tick is.

Vertebrates

The only mammal that truly belongs to the bog is the Irish hare (*Lepus timidus*) – and for the hare the bog is not just another habitat: it is its preferred habitat:

> *The hare wants the bog if it's dry. If the bog is dry the hare won't come in [to the fields] except in the winter-time if she's short of food. And if she's short of food she'll come into the very yard – and, dear God, I've seen them in the yard eating the cabbage plants. They want to be in the bog. They won't leave the bog if it's dry and getting enough of food, but if they're running short they'll come into the very yard.*
>
> William Egan, Clonfanlough, Athlone, quoted in *The Leaping Hare* by G. E. Evans and D. Thomson (p.46).

The diet of the hare consists largely of heather, cottongrass and other plants that grow on the bog, and it makes its nest or *form* in a sheltered place among the heather. The fox (*Vulpes vulpes*) is a very common bog animal, because it finds in the wilderness of the bog a sanctuary it cannot nowadays always find so easily elsewhere. Other mammals are occasionally found, especially in the fringing woodland and scrub – badgers in particular (*Meles meles*), along with wood mice (*Apodemus sylvaticus*), pygmy shrews (*Sorex minutus*), hedgehogs (*Erinaceus europaeus*), stoats (*Mustela erminea*) and rabbits (*Orcytolagus cuniculus*). Upland bog is an essential part of the territory of the once widespread native red deer (*Cervus elephus*). They are now confined to the mountains of Glenveigh in Donegal and Killarney, but only those in the Killarney area are believed to be of native stock. Fallow deer (*Dama dama*) and sika deer (*Cervus nippon*) are occasional visitors to bogs in their neighbourhood.

Blanket bogs are often richer in bird life than raised bog, because they tend to have a greater diversity of habitat: including rock outcrops, mountain streams and so on. More birds – as many as 40 species – occur in areas of cutover bog than on open, uncut bog for the same reason. However, many of the birds found on mountain bogs are only summer visitors that flee the harsh uplands long before winter; this includes resident species like meadow pipits and reed buntings, which often migrate down to more hospitable altitudes once summer is over.

The two birds which are most at home on the bog are the skylark (*Alauda arvensis*) and the meadow pipit (*Anthus pratensis*). The skylark loves open, treeless country; it is found in all bogs, but in the most extensive and wildest bogs of the west it may sometimes be the only bird in residence. The singing of the skylark fills the bog in spring and summer, especially after rain, and is the most immediately noticeable of all its sounds. Another bird that is very fond of the bogs is the reed bunting (*Emberiza schoeniclus*). It is the most characteristic bird of the lakes on the western bogs, where every island has one or two nesting pairs. In raised bogs its favourite habitat is along overgrown bog drains. Skylarks and pipits are seldom seen on the bog over winter, because they form migratory flocks in autumn and wander further afield, returning to the bog to establish breeding territories in spring. The reed bunting also moves out for the winter.

There was a time, not long ago, when the call of the nightjar (*Caprimulgus europaeus*) could be heard as evening wrapped itself round the edges of the bog. We have not heard it now for many years, although we continue to listen and hope for its return. It calls from a solitary tree, unforgettably silhouetted in our memory against the sunset sky. Its churring sound is poetically echoed in the Irish name, *túrna lín* (spinning wheel). The eggs are laid on the ground – there is no proper nest – and the sitting female looks remarkably like a rotten stick covered with lichens, dead leaves and scales of bark; both eggs and nestlings are also wonderfully camouflaged and difficult to spot. Another bird of the bogs whose booming call must have been utterly magical as it echoed across the open land is the bittern, which was common in many areas until the early part of the 19th century. The bittern has, alas, not bred in Ireland since about 1840; its disappearance is usually blamed on the extensive early 19th century drainage of the bogs and marshes, although hunting is likely to have had an increasingly severe impact as populations declined.

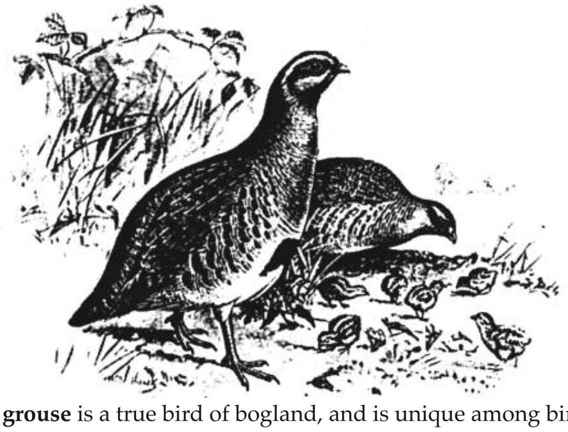
Figure 10.7: Birds of the bog

The **meadow pipit** is one of the most widely-occurring birds of the bog in summer, but after the breeding season it leaves for less exposed winter quarters.

The **skylark** is a bird of open country. It is generally abundant in grassy areas around the edge of the bog. It feeds mainly on invertebrates during summer, turning to the seeds of wild plants in the winter.

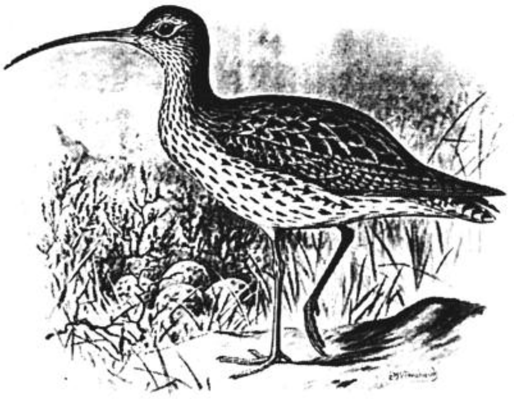
The **reed bunting** is a bird of reed marsh and fen, neglected drains radiating out from the bog, and other marshy habitats. It feeds on invertebrates during the breeding season, relying - like the skylark - mainly on seeds in winter.

The **black-headed gull** breeds widely on remote inland marshes and lakes far from the sea, though in winter it usually heads for the coast. One of the larger bog colonies was on Killeenmore bog near Tullamore. Its eggs were sought for their excellent flavour, 'almost as good as that of plovers', and (like the latter) eaten hard-boiled and cold.



Red grouse is a true bird of bogland, and is unique among birds in being confined to Great Britain and Ireland. It was formerly found on most Irish bogs, but its distribution today is much more restricted. It feeds mainly on young heather shoots.

The **partridge** is typically a bird of cultivated ground. The sheltered fringe of new wilderness between farmland and bog is now a favourite haunt.



Heathery hollows and ground with sedge or rush tussucks in blanket bog are among the nesting places of the **curlew**, one of the most alert and watchful of bogland birds. It feeds largely on insects and other invertebrate food, but is apparently also very fond of crowberry fruits.

The bill of the **snipe** has an elaborate arrangement of nerves and sensory pits which make it a very sensitive tool for probing in the soft ground of the marshes and bogs to which it is particularly well-adapted.

The **merlin** is mainly a bird of mountain bogs, but in winter it follows the small birds on which it preys to lower, less exposed ground. The meadow pipit is one of birds on which it most commonly preys, though it will also take such bigger birds as snipe and grouse. It has indeed been known to follow sportsmen shooting snipe, watching for the chance to stoop in and carry off dead or wounded birds.

The **hen harrier** nests in the heather of open bog and fen.

The **short-eared owl** is truly a bird of moor and fen, squatting on the ground during the day and hunting by night, feeding mainly on mice, supplemented by birds, bats and beetles.

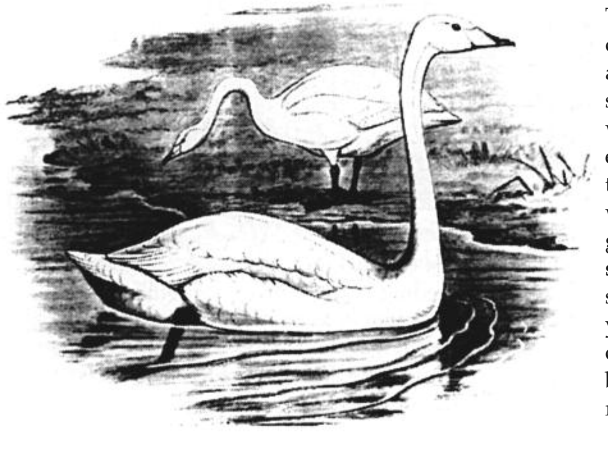
From April to August the **cuckoo** is a familiar member of the bogland avifauna, feeding on caterpillars and other small creatures. Its habit of laying in the nests of other birds is well-known; in fact, it lays on the ground and then carries the egg in its beak to deposit it in the nest of whatever foster-bird has been selected.

The **hooded crow**, the vulture of the mountains: least loved of all bog birds. It attacks birds of all kinds, is very destructive of nestlings and eggs, and will even attack hares and newborn lambs.

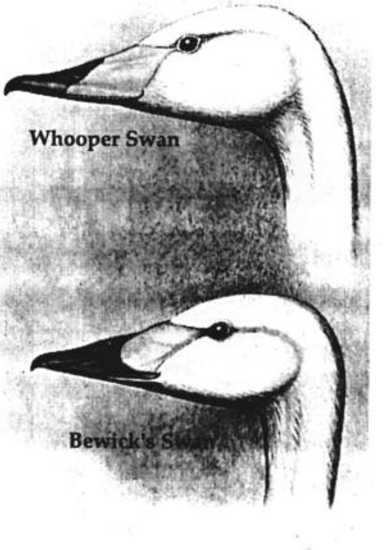
The **nightjar** is a summer visitor, at the edge of its range in Ireland, and is now very rare here. It prefers the wooded heathy fringes of the bog, and is crepuscular, and its extraordinary churring sound was once one of the most evocative of evening summer sounds around those bogs it favoured. Its song is said to resemble a spinning wheel: which explains the Irish name for the bird (*túrna lín*), which means a spinning wheel.

The reclamation of the fens, marshes and other wetlands which were its favoured haunts was responsible for the disappearance of the **bittern** from Ireland, as from much of Europe. Hunting was also a factor, because the bittern was one of that unfortunate group of birds (along with such others as the hoopoe, kingfisher and ruff) which were considered so attractive when stuffed and enclosed in a glass case. It is a nocturnal bird, spending the day quietly in reed-covered marsh difficult of access.

The **Greenland white-fronted goose** arrives in October and stays until spring. It was known locally as the tortoise-shell goose or bog goose.



The **whooper swan** carries its neck straight and erect when swimming, a feature which enables it to be easily distinguished from the resident mute swan, which has the familiar graceful curve. **Bewick's swan** is very much smaller, and the lemon yellow colour at the base of the bill does not extend below the nostrils: the rest of the bill is black.



Several predatory birds are common. Sparrowhawk and kestrel often nest in the birchwoods, and the kestrel in particular includes the open bog in its hunting territory, but the most majestic of the raptors of bogland is the hen harrier (*Circus cyaneus*). This was also a widespread bogland species before the drainage and reclamation of the early 19th century, but it declined steadily in the late 19th and early 20th centuries until by the 1950s it survived only on the Old Red Sandstone uplands of the Slieve Bloom, Comeragh and Knockmealdown mountains. Since then it has extended its range considerably. The merlin (*Falco columbarius*) is the rarest of the peatland raptors. It occurs on areas of dry heather moorland and blanket bog in areas like Wicklow, Donegal and Connemara, but it can sometimes be seen on the bogs of the Midlands in winter. It preys on such small birds as meadow pipit, skylark and linnet that share its moorland habitat.

Long-eared and barn owls often find suitable hollow trees in the woods at the edge of the bog for their daytime retreat, but the owl that is especially associated with the bog is the day-flying short-eared owl (*Asio flammeus*), which has returned to breed in some midland localities after a long absence. The commonest and most characteristic of the predatory birds of bogland is the scald crow or hooded crow (*Corvus corone cornix*). It preys on the nestlings and eggs of other birds that it seeks out in areas at the edge of and beyond the bog, but it is an extremely wary bird, and open expanses of bog give it a sense of security, especially when there is an occasional tree to perch on. A predator of a different sort is the cuckoo (*Cuculus canorus*), which has a special interest in the bog because it is the main haunt of the meadow pipit, one of the birds the parasitic cuckoo favours as foster-parent for its young.

Snipe (*Gallinago gallinago*) and curlew (*Numenius arquata*) are common species of bogs, although the snipe more especially favours the marshy rush-infested grassland that surrounds many bogs, where it feeds on worms and other invertebrates it extracts from the wet soil with its long beak. During the breeding season between March and July the bleating or drumming of the snipe – the strange un-bird-like sound it makes with its wings as it dives or swoops through the air over the bog – is unforgettable. In winter it is one of the few birds that can be found even on the most open, inhospitable bogs. Grassy and rushy oases in bogs are the principal nesting areas of the curlew in Ireland. Curlews move to the river estuaries with their new families later in the summer, and spend the rest of the year feeding there. In hard and frosty winters they will sometimes return to their summer haunts. The partridge (*Perdix perdix*) is now rare in Ireland, but its favourite habitat is the scrubby cutover fringe at the bog's edge, never far from farmland; it seldom occurs in great numbers. Mallard (*Anas platyrhynchos*) are frequent on bogs, where they will often nest in the heather, far from water.

The red grouse (*Lagopus lagopus*) is the only bird which is found *only* on peatlands, and it was once one of the most characteristic birds of both raised and upland blanket bog, although not nearly as much as in Scotland, where the moors are managed specially for grouse shooting. Before Independence, the vast areas of blanket bog controlled by the great estates were also managed for grouse, principally through controlled regular burning. 'Heather moor' was also burnt to promote the regeneration of young shoots for sheep. Grouse populations declined after 1918, and grouse shooting as a sport had virtually ceased by 1945. In 1966 a research programme to provide recommendations for increasing grouse populations was set up; one of its most significant findings was that the level of heather *productivity* was a key limiting factor was under Irish conditions. The adults feed almost entirely on the shoots, flowers and fruits of heather, although the chicks supplement this vegetarian fare with large quantities of insect food. Special winter visitors to bogs include the Greenland white-fronted goose (*Anser albifrons*).

A generation or two ago, when the large bogs were still intact, the white-fronted goose made much greater use of them for feeding and roosting. In some places it was known as the bog goose, an apt name in view of its adaptation for probing in soft substrates like peat for the underground storage organs of plants such as common cottongrass, white beak-sedge and arrowgrass. With the reduction in the large, wet bog areas favoured in the past, the goose has come to reply more extensively on the callow grasslands, but its numbers do not appear to have suffered in consequence. The goose breeds on the treeless tundra and open marshes of Greenland, migrating south to Ireland and western Scotland for the winter. Other conspicuous winter visitors to the bog include the whooper swan from the Arctic tundra and Bewick's swan from northern Russia.

The golden plover (*Pluvialis apricaria*) [**Plate 10**] was formerly widespread on the mountains and bogs of the west, and on upland bog in other parts of the country, but for reasons that are not clear it no longer breeds in many of tits old haunts; climatic deterioration is sometimes mentioned as a possible cause of its decline. The same is true of the ring ouzel (*Turdus torquatus*), a summer visitor from the Mediterranean that could once be found in every upland area of Ireland, the higher and wilder the better.

Colonies of black-headed gulls (*Larus ridibundus*) are a characteristic feature of bogs with open bodies of water, especially where there are reed-beds or other safe nesting areas. Among the largest of these colonies was one in the middle of the Seagull Bog south of Tullamore, which Praeger visited in 1894:

> It is in the central portion, where the bog is intersected by a maze of pools and dangerous quagmires, that the gulls have made their great colonies, and thither we were piloted under the skilful guidance of Mr Digby, who appeared to be acquainted with every pool and tuft of heather of the whole region. This pilotage was indeed necessary, for danger lurks in the bewildering network of water and soft moss that stretches on every hand, and ere we left, several of our party had learned, by little bits of personal experience more surprising than pleasant, the reason why this bog is feared even by the hardy and experienced cottagers around its margins.
>
> We were of course too late to see the eggs of the Black-heads, and already the majority of the young birds were able to fly [this was June 23rd]; but as we advanced into the centre of the breeding-ground, and as hundreds upon hundreds of gulls rose as we cautiously wended our way onward, we saw dozens of deserted nests, and soon came on plenty of young birds running like rats among the rushes and grass, or skulking in corners of the pools; while all the time continued the musical din caused by the cries of hundreds of gulls. To watch the myriads of graceful birds eddying overhead, and to listen to the wonderful clamour, was most interesting ...

Most of the other birds that are found on the bog occur also in many other kinds of habitat. Common resident species include many of the birds of farm, wood, hedgerow and river: robin and wren, hedge sparrow, blackbird, song thrush and mistle thrush, wood pigeon, pheasant, the four common tit species, chaffinch, greenfinch and bullfinch, tree creeper and goldfinch, linnet, starling, jay, rook, magpie, lapwing, woodcock, moorhen, coot and heron (which often fishes for frogs in bogholes and drains). Wrens are more fond of bogs than most birds; even in mid-winter they may be found right in the middle of many bogs. These residents are joined in summer by visitors: spotted flycatcher, chiff-chaff and willow warbler, whitethroat, stonechat, whinchat, sedge warbler, grasshopper warbler and cuckoo. Other resident bog birds leave during the cold months: the twite (*Carduelis flavirostris*), for instance, is a seed-eating finch which nests on open upland bogs in the north and west, but descends to lower ground for the winter. Flocks of redwings and fieldfares are often seen on bog in winter, and occasionally small groups of snow buntings (*Plectrophenax nivalis*).

The three remaining classes of vertebrates - amphibians, reptiles and fishes - have very few bogland representatives. Although it is not believed to be a true Irish native, the frog (*Rana temporaria*) is a very characteristic bogland animal, well adapted to cope with the precarious nature of its habitat. Frogs lay their eggs very early in the year in all sorts of bog pools. Vast amounts of spawn are often laid in bogholes and other temporary pools created during turf cutting; these are often disturbed before the tadpoles are ready to leave the water. Much spawn is also laid in shallow pools that dry up if the summer is warm, but by this time the tadpoles have often undergone their metamorphosis to frogs and can leave the water. But whether the pools are temporary or permanent the growing tadpoles have to cope with an abundance of predators, and very few make it to adulthood. The newt (*Triturus vulgaris*) spends most of its days in damp places away from water, emerging at night to feed. In spring it return to water to breed, and its breeding ponds include the calcareous cutover fens that fringe many bogs. Here the female lays her eggs, attaching them individually to leaves that are rolled up and glued at the edges for protection. The baby newts spend several months in the water before moving onto dry land; it will be three or four years before they return to breed for the first time. Heather is the preferred habitat of the common lizard (*Lacerta vivipara*), but it is an extremely wary animal, and is seldom seen by the casual observer. The only boghole fishes are the sticklebacks, of which there are two species: the three-spined stickleback (*Gasterosteus aculeatus*) and the nine-spined stickleback (*Pungitius pungitius*); they thrive in old bogholes, feeding on most of the smaller animals that abound there. Strangely, sticklebacks have apparently not been in Ireland for long: they are believed to have been introduced less than 1,700 years ago.

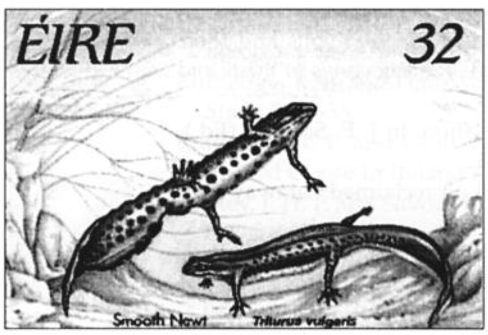


Figure 10.8: Bog vertebrates on Irish stamps.
From top: frog, newt, lizard.

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Chapter Eleven

Animal Life on the Bog 2: Insects

The museum of nature, like a palace, has an enormous number of connected chambers, filled with the stupendous contrivances and wonders of the Creator, to each of which a place is assigned according to its kind; to the greatest amphitheatres of nature the first entry is open to every one, but the smaller ones are usually shut; here there is need of skill to unclose by slow degrees the doorway of each chamber, within which a new world, as it were, displays itself before our eyes ... The chief key for unfastening the bars of this palace that has been for all the ages closed is afforded by the microscope, which gives us the same help in examining minute bodies that are close to us as astronomers get from the telescope in the investigation of distant bodies in the heavens.

Linnaeus: ***Amoenitates Academicae*** **ed.2, vol. vii, 387-88.**

Collembola: springtails

Among the most abundant of all the animals of bogland are the tiny, ancient creatures called springtails. These little wingless insects are among the most active small animals of bog litter. They are wingless not because they have discarded their wings as superfluous at some stage of their evolutionary past, like most ants and termites, but because they never sought conquest of the air at any time in their long history. It would be wrong to call them primitive for this reason: except in the sense that they retain more features of early, ancestral insects than do most other modern insects; they too are highly specialised creatures, adapted to their particular environments in ways which we are really only now beginning to understand.

Most bog springtails are creatures of litter and soil, and they live in close association with the roots of plants, different species being associated with particular plants. This is difficult to appreciate in fertile soils, where springtails appear to be everywhere, but in the poor, acid soils of bogs they tend to stay close to the roots that supply their food. It is believed that this normally takes the form of exudates from the roots, probably developed by the plant in the first place to deter herbivores.

Robert Blackith recorded 58 species of Collembola from the blanket bogs of Mayo. He discovered that different species occur in association with the root systems of specific plants. Because of the complexity of the web of microhabitats in which they live, it is not always easy to demonstrate this, but a striking example is furnished by two common species. *Tetracanthella britannica* is found in abundance in association with the roots and stem bases of purple moor-grass and black bog-rush, and rarely elsewhere, whereas *Tetracanthella wahlgreni* occurs among mosses and lichens, especially sphagnum and the black bog moss *Campylopus atrovirens,* and cushions of *Cladonia portentosa,* where *Tetracanthella britannica* is not often found. *Folsomia brevicauda* is another very common species associated with sphagnum [**Figure 11.1**], and found in enormous numbers under deer grass, but not with black bog-rush, purple moor-grass or common cottongrass. *Isotomina sphagneticola* is a species which is characteristic of sphagnum peat.

We are not so clear about the preferred rhizosphere microhabitats of many other collembolans, but Table 1 gives a list of those species that are clearly associated with the roots of common bog plants. Even though we know little of the detail as yet, it is probable that every different plant rhizosphere has an association with one or a few specific species of Collembola. Because of this intimate association, there can be a complex mosaic of springtail populations and communities even in a small area of bog. As well as the litter communities, the lichens, bryophytes and algae that encrust old heather stems also have a characteristic community of springtail species .

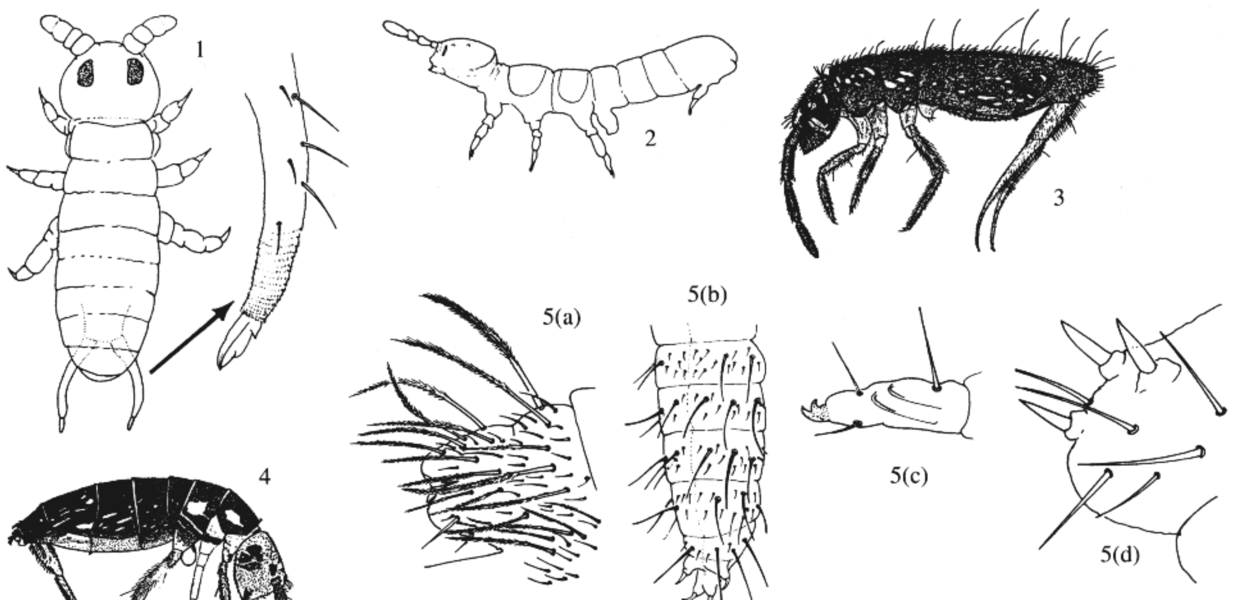


Figure 11.1: Some springtails (all highly magnified).
(1) The water springtail *Podura aquatica:* often seen in large numbers on the surface of pools and ponds.
(2) *Folsomia brevicauda.*
(3) A species of *Isotoma.*
(4) A species of *Entomobrya.*
(5) Detail of the end of the abdomen in different springtails:
(a) *Istotoma,* (b) *Tetracanthella wahlgreni,* (c) *Tetracanthella britannica,* (d) *Friesea mirabilis.*

The numbers of Collembola can be enormous; under favourable conditions there may be as many as 64,000/m^2 in the rhizosphere of purple moor-grass. When changes occur on the bog for some reason, the collembolan populations will change also, mainly because the host plants themselves have changed. When a bog is cut away and reseeded it quickly acquires a new community of springtails and other arthropods not greatly different from grassland. Among the common species are *Isotoma notabilis, Tullbergia krausbaueri* and *Hypogastrura denticulatum,* which are predominantly microbial feeders often abundant in places where there is much decaying organic detritis.

Not all bog Collembola are rhizosphere associates. Many feed on nematodes and other small animals. *Folsomia candida* and *Tomocerus vulgaris* are among the many springtails that are known to feed on nematodes, at least occasionally – but apparently this only happens when they bump into them (literally!). *Tomocerus,* in spite of its good eyes, seems unable to *see* a potential nematode meal even when it passes right in front of it – even within a few millimetres. But far from reducing the population of nematodes, predation by Collembola at times actually increases the population, possibly because the frass produced by predacious collembolans and mites produces an increased volume of substrate for the bacteria on which many of them feed, thus providing an increase in food for the nematodes.

On western blanket bogs the rising water table of winter forces springtails into the surface vegetation for as much as six months of the year. Many of the springtails that survive the winter probably fall prey to beetles in the spring. Carnivorous collembolans like *Freisia mirabilis* may also play a part in this predation.

TABLE 11.1: SPRINGTAIL SPECIES AND THEIR FOOD PLANTS

SPRINGTAIL SPECIES	PREFERRED RHIZOSPHERE
Hypogastrura scotica	Pine litter.
Xenyella boerneri	Bog myrtle, deergrass, purple moor-grass.
Friesea mirabilis	Many common plants, but especially abundant in pine litter; this is a carnivorous species.
Tullbergia krausbaueri	Many common plants, but especially abundant in pine litter.
TetracanthelIa britannica	Heather, purple moor-grass, black bog-rush, bog myrtle.
Tetracanthella wahlgreni	*Cladonia portentosa* and pine litter.
Folsomia brevicauda	Heather, bog myrtle, deergrass, sphagnum.
Isotoma sensibilis	Bog myrtle.
Isotoma notabilis	Purple moor-grass, black bog-rush and pine litter.
Entomobrya nivalis	Pine litter.

[From Blackith, 1974].

Protura

Few insect groups are more obscure than the Protura, very tiny wingless insects as ancient and mysterious as the springtails. Concentrations as high as 1,500 per m^2 have been noted in pine litter on bogs in autumn. Many species live in peat, but they are very easily overlooked, and have so far not been studied in Ireland's bogs.

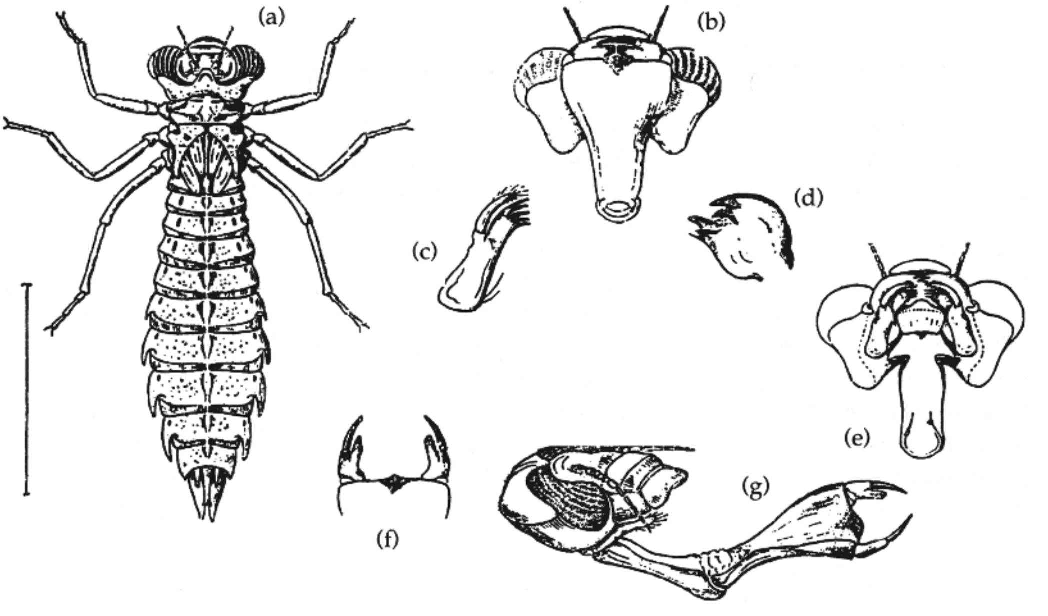
Odonata: dragonflies and damselflies

Dragonflies are among the most magnificent and fascinating of all the creatures of bogland. There are two groups of dragonflies; one comprises beautifully slender insects whose flight resembles butterflies a little, and which rest with their two pairs of similar wings folded above their backs. These are the damselflies (Zygoptera; Irish *bechiúl*). The other group (the Anisoptera; Irish *snáthaid mhór*) includes much stouter and more powerful-looking fast-flying insects, much taken to hovering – and when they come to rest they do so with their wings outstretched. These larger dragonflies have two pairs of dissimilar wings.

No other group of bog insects surpasses them for grace and beauty, and the large size of many allows the beauty of their structure to be appreciated more easily than can be done with many other insect [**Plate 10**]. Adult dragonflies are aerial predators, but they spend their nymphal lives in the water, and are among the most ferocious carnivores of the bog pools. They owe their ferocity to the extraordinary structure of their feeding apparatus, which is called a *mask.* The mask is formed from the fused third pair of jaws (the labium); it is kept folded back under the head when not in use, but is shot forward quickly to grab passing prey [**Figure 11.2**].

Dragonflies and damselflies patrolling cutover are one of the most memorable sights of a summer day on the bog. Areas of old turbary, where there are plenty of pools and bogholes of different ages and at different stages of evolution, are among the most important dragonfly habitats in Ireland, although most of the species to be found on bogs occur also in water bodies of other kinds. Here on the bog, when the time of year and the weather is right, as many as six or seven different species of these magnificent creatures can be seen on the wing at the same time and in the same place. Of course, it is the adults we see on the wing, because the young spend their lives hidden away among the aquatic vegetation and debris.

Figure 11.2:
Dragonfly nymph.
(a) Larva of *Aeschna,* with rudiments of wings on the thorax.
(b) Head, seen from beneath, the mouth covered by the mask.
(c) Mandible.
(d) Maxilla.
(e) Mouthparts after removal of the mask, except for its basal joint.
(f) Fore edge of mask with hooks extended.
(g) Head of larva seen from the side, with mask extended to sieze prey.
(From Miall, 1895).



Just because we may see so many species flying about at the same time, or because they all pass their young lives in water, it doesn't mean they have identical life styles either above or below water. Different species live in different kinds of water bodies, and when they do live in the same pool they have different food or feeding preferences, But this most important but relatively hidden aspect of their lives is also the one we know least about; it is easy enough with a bit of persistence and patience and the help of a good book to put a name on a particular kind of dragonfly. But when it comes to the really interesting questions about how a particular dragonfly differs from others in its life-style – in the details of its *life-history* – it may not be so easy to find answers. This is true of most aquatic insects (and indeed of terrestrial ones usually), but it would be so much easier to discover the answers for the dragonflies because of their large size. There is plenty of scope here for project work by patient young researchers of school-going age.

One of the first things to strike you in a face-to-face encounter with a dragonfly is its enormous eyes, which seem to take up the whole head. Each eye is made up of as many as 10,000 individual facets or lenses, each of which responds separately to light or shade. The overall result is a bit like an old-fashioned newspaper photograph, but sharp enough for a successful hunter.

Damselfly nymphs are slender insects, and are very easy to recognise because of the three prominent flat tracheal gills at the end of their tails. They usually crawl about slowly on plants, waiting for prey to come within reach of their ferocious jaws, which are shot out to impale the unfortunate victim. Anisopterous nymphs on the other hand are usually bottom dwellers, and their dull colouring makes them almost invisible against the mud or sediment. They are much stouter, and lack the prominent protruding gills of damselflies. They breathe through the anus, and there is a tracheal surface inside the body in the anal lining. The nymph takes in water from time to time through the anus, which is kept closed at other times by a series of spine-like valves; when all the oxygen has been extracted, the deoxygenated water is expelled violently; this also provides the insect with a method of jet propulsion when it wants to move quickly to a new place.

Dragonflies have a unique and fascinating way of mating. The genitals of the male are located in the second-last body segment, but prior to mating he transfers his sperm from here to the second abdominal segment from the front, which has special copulatory organs, by looping his very flexible abdomen. When mating takes place the female's head is grasped by the male, and they may fly in this position for some time. She then loops her body until her genitals, which are at the tip of the tail, come into contact with the front part of the male's abdomen. Egg-laying usually takes place straight away. Some species just hover over water and drop their eggs in, but others dip their tails in the water to lay them on or in the vegetation, while others again lay them in specially made incisions in water plants. Pairs often remain in tandem while egg-laying takes place, partly to prevent a second male taking over, because it is the most recent sperm that fertilises the eggs. In this way the male is protecting his genetic investment or chance of offspring.

Adult dragonflies have only a brief month of life. Smaller ones complete their development all in one year, but the larger kinds may take two or more years to reach full size, They have to moult about twelve times as they gradually get bigger, When the adult is ready to emerge, the nymph makes its first excursion out into the open air, crawling up along a plant until it is outside the water. Here it rests, and then the skin on the thorax splits down the middle and the adult hauls itself out of its now obsolete wet-suit. It takes an hour or two for the body to fill out and develop its full, glorious gloss. The dragonfly then takes to the air for its final month of life. Anisopterous dragonflies are usually shy and cautious about exposing their adult selves for the first time, usually emerging at night to do so, but damselflies are less so, and will emerge day or night as soon as they are ready.

TABLE 11.2: DRAGONFLIES ON BOGS: TWELVE OF THE CHARACTERISTIC SPECIES

The Common Hawker (***Aeschna juncea***) favours areas of heath species and moorland, especially in blanket bog, and is often found in heather in dull weather.

The Keeled Skimmer (***Orthetrum coerulescens***) is a very local species which breeds in sphagnum pools. In the Mourne Mountains it occurs only in small seepages and flushes with purple moor-grass/heath species.

The Four-spotted Chaser (***Libellula quadrimaculata***) is one of the commonest species, often seen hovering and circling over boggy pools and ponds. In favourable situations several males may take out territories in the same pond, each keeping to-its own patch.

The Black Darter (***Sympetrum danae***) occurs in acid sphagnum pools on both lowland and upland bogs, and is often found resting in the heather; it seems to be most abundant in Galway and Mayo.

The Emerald Damselfly (***Lestes sponsa***) occurs in many kinds of habitats, bogs included.

The very beautiful Large Red Damselfly (***Pyrrhosoma nymphula***) appears on the wing from the end of April, and is widespread along streams, canals, lakes, marshes and ~ogs.

The Ruddy Darter (***Sympetrum sanguineum***) is not often seen; it favours cutover bogs which have and purple moor-grass, and ditches and drains with plenty of emergent vegetation.

The Scarce Blue-tailed Damselfly (***Ischnura pumilio***) lives in shallow ponds, including those occuring in bogs; it has only been recorded from a small handful of localities in Ireland, mainly in the south-east and around Sligo; **the Common Blue-tailed Damselfly** (***Ischnura elegans***) is also frequently seen on bogs.

The Irish Damselfly (***Coenagrion lunulatum***) was first recorded in Ireland only in 1981, when it was seen in County Sligo by D. C. F. Cotton; the first breeding colony was discovered in Westmeath by Martin Speight in 1982. It has not been recorded from Great Britain. It favours upland lakes and cutover bogs with large pools. Most of the records are from the north, but this is probably because it has been looked for more carefully there.

The Variable Damselfly (***Coenagrion pulchellum***) is a scarce species in Britain, but here in Ireland it is one of the most abundant species of cutover bog.

Most of the recent records of **the Hairy Dragonfly** (***Brachytryon pratense***) come from areas near the coast, but there are many old records from various localities much further inland.

Ireland has 22 species of dragonflies; the two most common species are probably *Lestes sponsa* and *Libellula quadrimaculata,* whose nymphs are among the main predators in most bogholes. Thirteen species have been recorded from some northern cutaway bogs, and thirteen were also recorded from Scragh Bog – and that excludes *Aeschna juncea* and *Sympetrum danae,* which might have been expected here. The commonest included *Sympetrum striolatum, Ischnura elegans, Enallagma cyathigerum, Libellula quadrimaculata* and *Lestes sponsa.*

Orthoptera: grasshoppers

The number of grasshoppers and grasshopper relatives that make their homes on the bog is small, yet for anyone who has ever worked on the bog in summer the song of the common green grasshopper (*Omocestus viridulus*) is an essential part of the unique atmosphere of the place. The green grasshopper is very common in the long knapweed grassland that is usual around many bogs, especially in the Midlands. It appears every year in May and becomes adult in July, and it is from then to October that its characteristic and familiar song is heard. The mottled grasshopper (*Myrmeleotettix maculatus*) is a very small grasshopper that frequents grass heath, so it occasionally turns up around the edges of bogs, though it has so far been formally recorded only from a few such locations.

There is one grasshopper that is found only in bogs, and that is the large marsh grasshopper (*Stenophyma grossum*), which can be met with in August and September on very wet bogs in Kerry, Galway and Mayo, and more rarely in the Midlands, where it is associated with bog asphodel and cottongrass. It is the largest grasshopper found in these islands [**Plate 10**], and is a better flier than most – indeed, it looks rather like a locust in flight. It lays its eggs in batches of up to a dozen or more at the base of grassy tufts, covering them with a protective foam that quickly hardens.

An insect that deserves a special mention because of its *absence* is the bog bush cricket (*Metrioptera brachyptera*), which is very widely distributed all over England and Wales in wet heaths and bogs, where it is associated with cross-leaved heath – often in company with the green and large marsh grasshoppers, Yet it has not – so far – been recorded for Ireland.

Hemiptera: bugs

Water boatmen: Corixidae

Some 25 species of lesser water boatmen (Corixidae) are known from Ireland, and many of these occur in bogs. Each species has its own habitat preferences, and factors such as the density of plant growth, depth of the water, steepness of shore, amount of organic matter present and degree of stillness of the water are all important in determining what species will be present. Another habitat factor that plays an important role is the *colour* of the habitat: there is a high degree of correlation between the colour range of a particular species, and that of the habitats it frequents. Thus the dark *Callicorixa wollastoni* is confined to the dark waters of bog pools above 1,500 feet. *Hesperocorixa castanea* is a species which favours very still water, whereas *Sigara dorsalis* tends to occur in water where there is more movement, such as the open bog lakes of the north and west. *Sigara scotti* favours intermediate conditions, and is often very common in closed lakes in the west and north-west, where it finds its main Irish stations. *Glaenocorixa propinqua* is an alpine species, a survivor from colder times in Ireland, which is known from Derrycunniny near Killarney. *Hesperocorixa castanea* has been widely recorded from the west, but it occurs also in the bogs of the Midlands, Another widespread species is *Hesperocorixa sahlbergi.* Both of these species occur together in the soak on Clara Bog, which is unusual, because *castanea* is characteristic of lime-rich ponds and fens, whereas *sahlbergi* prefers the acid water of bogs. Corixids feed almost completely on freshwater algae [**Figure 11.3**].

Corixids are strong fliers, but the different species vary in their readiness to take wing. Species that favour temporary or unstable water bodies fly much more readily than those that live in permanent pools and lakes, If a pool is the wrong colour, or if it is overcrowded or too warm, adult corixids will quickly emigrate from it.

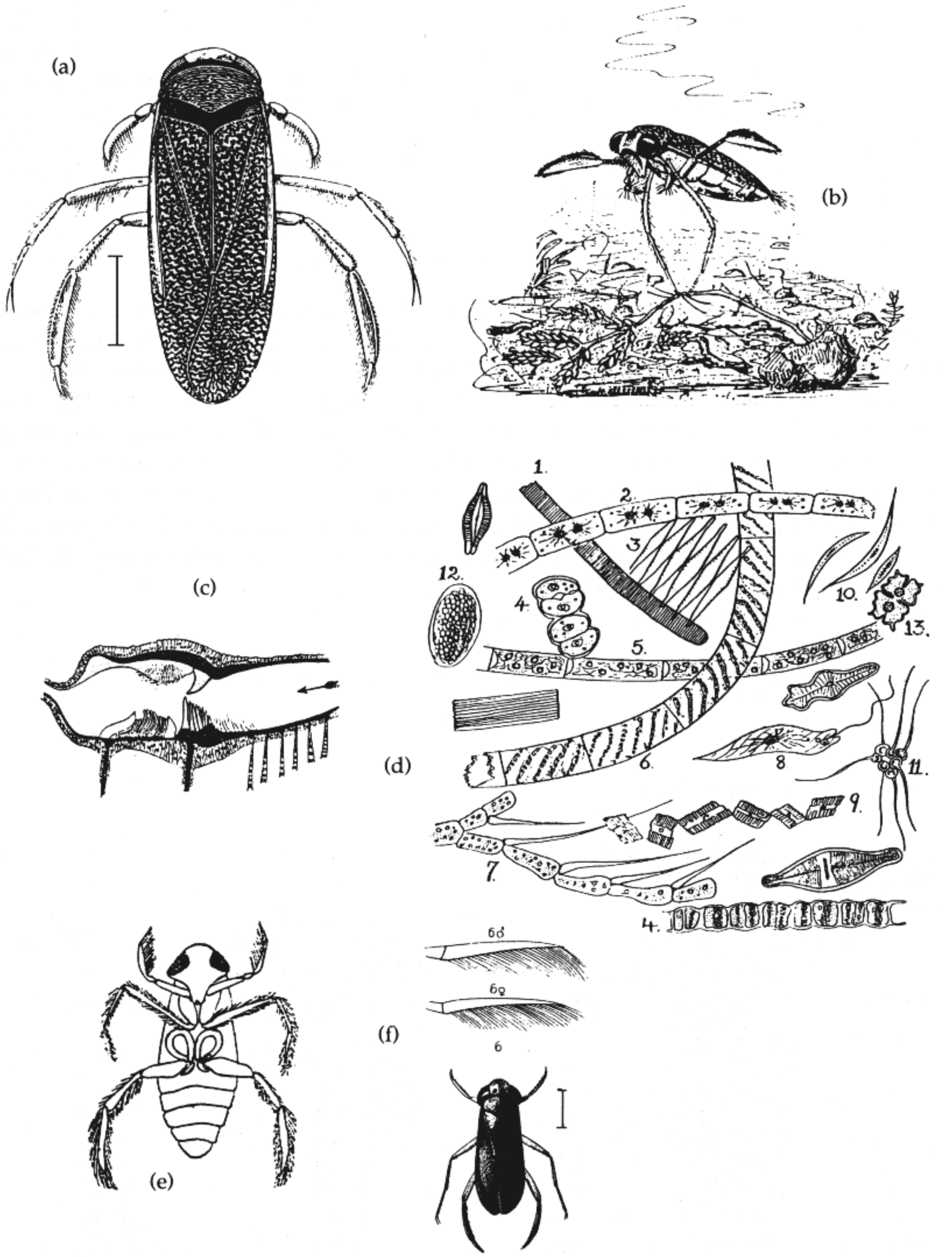


Figure 11.3: Corixids. (a) *Corixa Geoffroyi.* (b) Water boatman on the bottom - note that it has to hold on to keep itself from floating to the top. (c) A longitudinal vertical section through the centre of the pharynx of a nymph of *Glaenocorixa cavifrons* showing the complicated arrangement of the teeth for masticating and breaking up the cellulose walls of the algae which it eats (Walton, 1943). (d) Freshwater algae in the diet of *Corixa: Oscillatoria; Zygnema; Fragillaria; Scenedesmus; Mougeotia; Spirogyra; Bulbochaeta; Euglena; Diatoma; Ankistrodesmus; Gloeochaete; Enemosphera; Euastrum; Ulotrix*. (e) *Corixa* viewed from underneath. (f) *Cymatia Borsdorffii.*

TABLE 11.3: Water boatmen in bogs: species recorded at Killarney

Callicorixa praeusta
Callicorixa wollastoni
Corixa dentipes
Corixa punctata
Cymatia Borsdorffii
Glaenocorixa propinqua
Hesperocorixa linnei
Hesperocorixa sahlbergi
Sigara nigrolineata most common in small peaty pools at high altitude.
Sigara scotti in all kinds of standing water.

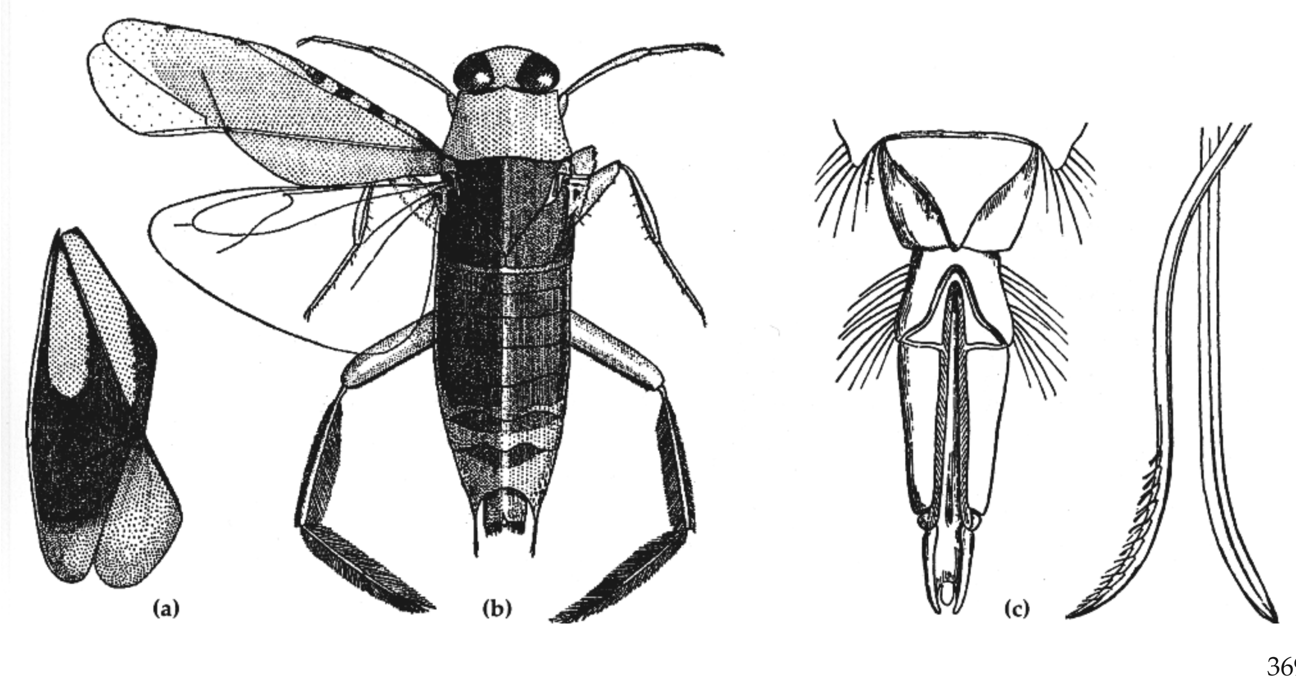
If the many open water species of the large lakes that often occur in blanket bog country were included, the list would be greatly expanded.

(O'Connor *et al.*, 1985).

Neustonic scavengers

Pond skaters, backswimmers and other predatory bugs dominate the *neuston* – a special word used to describe the surface film that separates the aquatic from the terrestrial worlds of life. Backswimmers or wherry-men belong to the family Notonectidae; they are highly-evolved predators whose toxic saliva is very painful even to humans. They are very sensitive to any disturbance on the surface of the water; they lie is wait beneath the surface film in an upside-down position, and if any small animal is so unfortunate as to fall into the pond, the ripples it generates are like a siren to the alert wherry-men. They will even tackle fully grown tadpoles and dytiscid larvae, and small fish. The commonest bog-pool species is usually *Notonecta obliqua* rather than the generally more familiar *Notonecta glauca* [**Figure 11.4**].

Figure 11.4: (a) *Notonecta glauca,* showing the fringed swimming legs, with wings outstretched on one side;
(b) wing-cover (hemielytron) of *Notonecta obliqua;*
(c) rostrum or 'beak' and setae (mandible and toothed maxilla) of *Notonecta* [(a) and (b) from Macan; (c) from Miall].



One of the commonest of the many species of the pond skater family (Gerridae) of neustonic scavengers is *Hydrometra stagnorum,* the water measurer, which takes its name from its habit of slowly walking across the surface of the water, touching the surface lightly with its tarsi, which are densely hairy on the under surface. It frequents the margins of ponds and lakes, the adults appearing in August, and feeds by spearing small creatures below the surface with its stiletto-sharp rostrum – especially water fleas, as well as ostracods, mosquito larvae and drowned insects [**Figure 11.5**]. The water measurer is absent from upland bogs, but the water cricket, *Velia caprai* is among the most characteristic insects of both raised and blanket bog. The minute water cricket *Microvelia reticulata* also occurs. *Microvelia* runs across the water, never walks, and is often seen in pools that have submerged sphagnum. *Velia* always occurs gregariously, and probably feeds mainly on drowned insects.

The common and widespread pond skater *Gerris najas* is not really a bog species, although it does sometimes occur on bogs. *Gerris thoracicus, Gerris lacustris* and *Gerris odontogaster* are all widely distributed on ponds, pools and lakes in bogland areas. *Gerris lacustris* has even been recorded in a peat pool at 2,000 feet in Kerry. Less widely distributed species include *Gerris argenteus* and the rare *Limnoporus rufoscutellata,* which has been recorded in boggy lakes in south-west Ireland, where it probably breeds. *Gerris lateralis* is an alpine species commonly found in bog pools in mountainous areas. The 'sub-alpine' form *Gerris costai* subspecies *poissoni* is best known from upland pools, but it is also found in the midland raised bogs [**Figure 11.5**]. The pond skaters play a special role in the nutrient balance of bog pools because they act as a one-way 'nutrient funnel' through which material from outside becomes incorporated in the pool ecosystem.

The water scorpion: family Nepidae

The water scorpion (*Nepa cinerea*) is an inhabitant of muddy bog pools, fens and marshes [**Figure 11.5**]. Its long tail is used as a snorkel for breathing at the surface while it goes about its submerged business. Its colour and flat form provide perfect camouflage in the bottom mud, where it lies unmoving, waiting for prey to approach. It feeds on small fish, insect larvae and other small creatures, which it embraces with its powerful prehensile front legs as they pass unsuspecting by. Although it so drably coloured superficially, the body of the water scorpion is actually scarlet, but this is only obvious on the rare occasions when it flies. *Nepa* appears to be unique among aquatic insects in being free of attached peritrichs, although it is parasitised by the water mite *Hydrachina globosa.*

Land bugs on bogs

Among the most conspicuous insects of the bog are the cuckoo-spit bugs, *Philaenus spumarius* and *Neophilaenus lineatus.* The nymphs in their bubble baths may look rather similar, but they are quite different in their food preferences: *Neophilaenus lineatus* prefers to imbibe its juices from purple moor-grass, though it will also try black bog-rush, hare's--tail cottongrass, and bog asphodel, whereas *Philaenus spumarius* almost invariably drinks the sap of bog myrtle or heather. As adults they are known as froghoppers [**Figure 11.6**].

The birchwoods are frequented by a considerable number of bug species. A common one is the birch shieldbug *Elasmostethus interstinctus,* which is an attractive green-and-brown insect. It usually hibernates as an adult under bark or in moss, and lays its eggs in May and June. Another shieldbug that can be found on birch from August to mid-October, after which it moves into hibernation in the leaf litter and elsewhere, is *Elasmucha grisea,* the parent bug. This is one of the most extraordinary of all bog insects. The mother bug lays her batch of 30-40 eggs on a suitable birch leaf, and then sits on them for the two to three weeks they take to hatch. She then looks after the young in a way that resembles nothing so closely as a hen with her chicks. They follow her about wherever she goes,

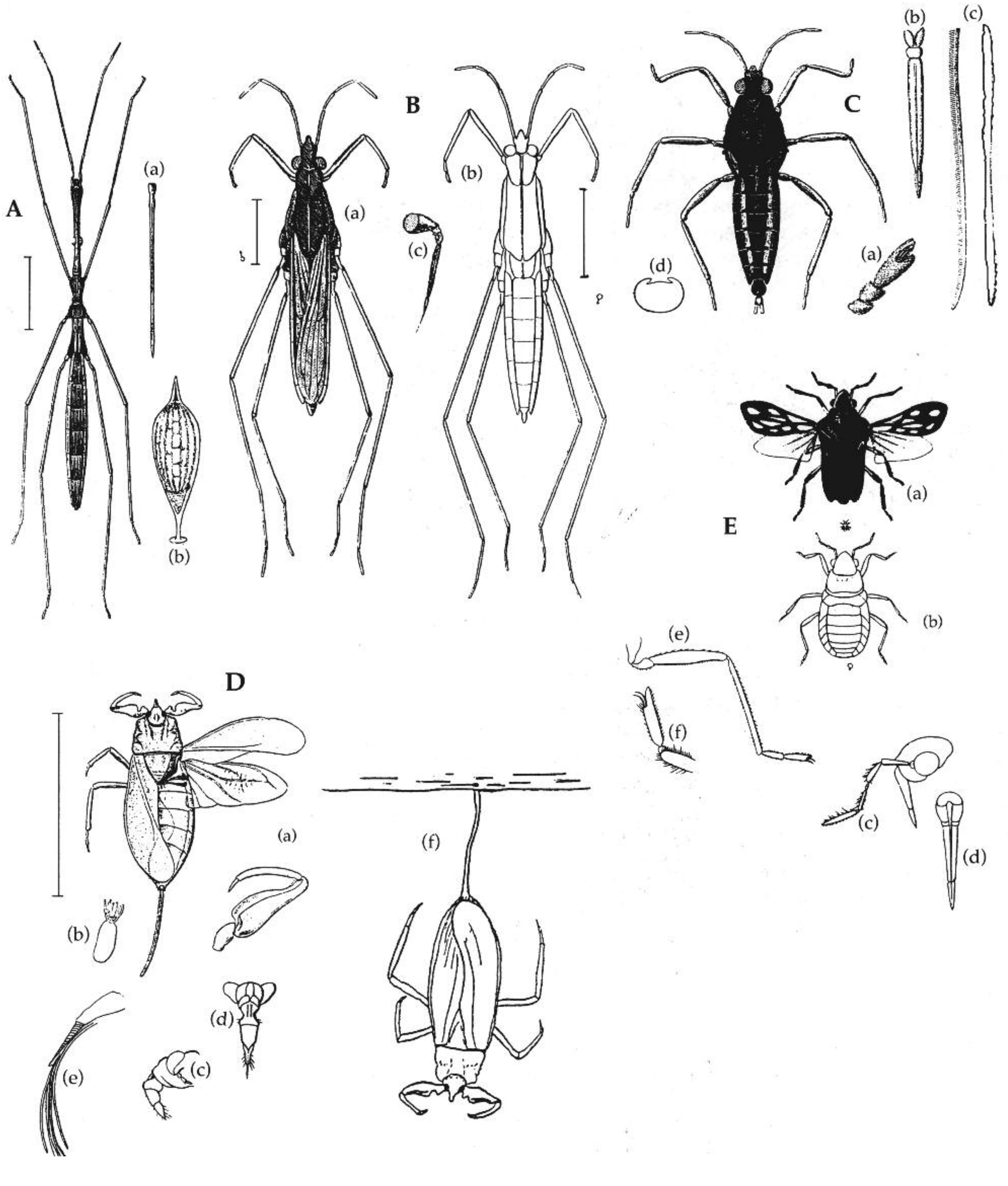


Figure 11.5: Water bugs.

A. *Hydrometra stagnorum;* (a) beak or rostrum; (b) egg [after Leuckart].

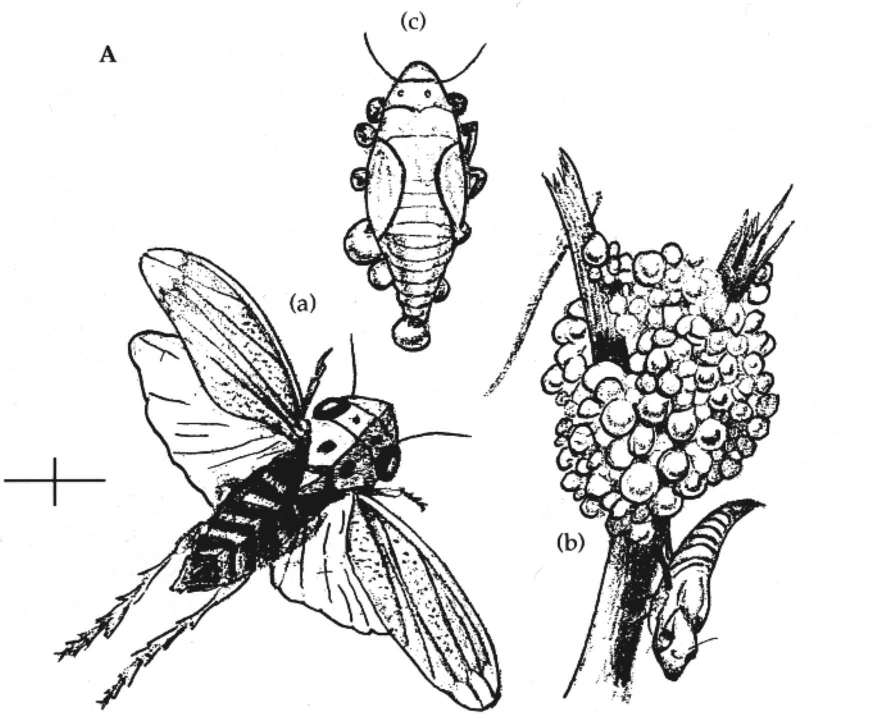
B. (a) *Gerris thoracica;* (b) wingless imago of *Gerris najas;* (c) rostrum

C. *Velia currens,* wingless form; (a) fore tarsus of fore leg; (b) rostrum; (c) lancets; (d) abdomen in transverse section.

D. *Nepa cinerea;* (a) fore leg enlarged, showing groove in femur which receives the lest of the limb (like a razor); (b) egg; (c) head in profile; (d) head and rostrum in front; (e) rostrum with the setae.exserted [(c)-(e) after Douglas and Scott]; (f) water scorpion hanging from the surface film by its respiratory tube.

E. *Microvelia pygmaea;* (a) male; (b) apterous female; (c) head in profile and .antenna; (d) rostrum; (e) hind leg; (f) fore tarsus (From Douglas and Scott).

A



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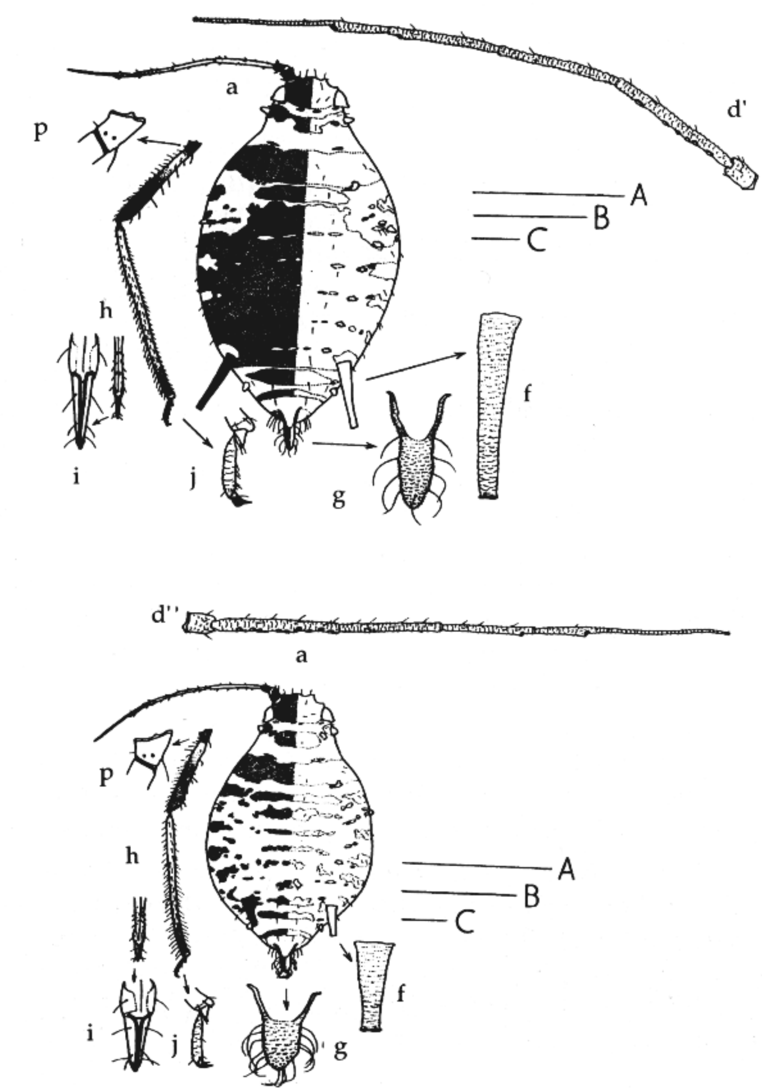


Figure 11.6:
A. Cuckoo spit bugs.
(a) Imago; note whorls of spines on legs.
(b) Pupa, with bubbles of air blown from anus.
(c) Mass of foam with larva crawling from it. (After Bucton).

B. Aphids.
(i) *Aphis ulicis* (top).
(ii) *Aphis vaccinii* (bottom).
(a,h): Scale A; (d,f,g): Scale B; (i,j,p): Scale C. The line in Scale A is 1 mm; in Scale B it is 0.25mm and in Scale C it is 0.10mm.

Aphis vaccinii lives on the shoots of bog rosemary, bilberry and several other *Vaccinium* species. It has not yet been recorded from Ireland, but may very well be one of those species which has never really been looked for. *Aphis ulicis* in contrast is common on the young shoots, flowers and green pods of furze, where it is often attended by ants. It only lives on furze, and is not known outside Britain and Ireland (Stroyan, 1984).

and she will attempt to protect them when danger threatens, and covers them with her wings at night.

Several species belonging to a large genus of small reddish bugs – *Psallus* – are common on the bog. *Psallus* and *Orthotylus* are capsid bugs (Miridae), an enormous family that accounts for over one-third of the British and Irish bug species. They are mostly delicate green or brown insects, and though they feed mainly on plant juices, many are at least partly predaceous.

Psallus betuleti is widespread on birch, laying its eggs in young wood in June and July, where they remain for some ten months, hatching out during the following April and May, *Psallus roseus* occurs widely on sallows. *Psallus falleni* is common on birch and *Psallus alnicola* on alder. *Pantilius tunicatus* also occurs commonly on birch, but it has quite a different life cycle, the eggs only being laid in late September and October, and not hatching until late the following summer. This means that the adults are only around in late September and October, both adults and larvae feeding on buds, young shoots and developing male catkins. *Lygocoris contaminatus* is another birch capsid, but it is not in competition with its relatives, because it feeds on the catkins, buds, unripe fruits and leaf stalks of its host.

Another birch bug is *Kleidokerys resedae,* an exceptionally smelly creature that frequents birch and alder catkins, among which its red colour serves to camouflage it; it passes the winter in the shelter beneath heather. Both sexes have a voice which they use for calling each other; the noise is made by drawing a special vein on the hind wing across a dorsal plectrum. This vein has a line of very fine stridular teeth, 250 of them over a distance of little more than 0.5mm.

The furze shield bug (*Piezodorus lituratus*) is a prominent insect that spends its whole life on furze; it is very common, and there is hardly an area of furze scrub where it does not occur. It feeds mainly on the juice of ripe seed pods, though it appears to need animal fluids at certain stages of its life. The drum-shaped eggs are laid in batches of a dozen or so, usually on the unopened flower-buds; these have neat little hinged lids, which are lifted off by means of an elaborate topping process, a characteristic of pentatomid bugs. One interesting aspect of its biology is its remarkable camouflage; the adults are often almost impossible to spot against the furze, and the colours of the different larval stages or instars closely match those of the background at any particular time. The larvae become adult late in summer. At first they are pink and green, but when they emerge from their hibernation among the furze litter on the ground, or in old seed-pods, they are dark green, and on warm days even in January they can be found feeding on the bushes. Like many pentatomids, they are frequently parasitised by other insects, especially tachinid flies, while the eggs are parasitised by tiny hymenopteran egg parasites called scelionids.

Another bug that is very common on furze is *Dictyonota strichnocera,* the furze lacebug, which feeds on the juices of its host plant Although they are very small, lacebugs (Tingidae) are beautiful insects, taking their name from the lace-like appearance of the forewings and thoracic region (the pronotum). The larvae are also remarkable-looking creatures covered with star-shaped hairs.

A bug that is common on furze is *Asciodema obsoletum.* It is a small pale green insect (which can however easily be mistaken for *Orthotylus concolor*). The larvae, like the adults, are pale green, well-camouflaged among the furze needles. Adults can be found from June to September wherever furze is common. It overwinters in the egg stage.

Several bugs are common on heather and species of heath, One of the most abundant is the heath damsel bug (*Nabis ericetorum*) [**Figure 11.7**], which rarely occurs outside bogs and heaths. Adults are usually found between August and October, when the heather is in flower, but it does not feed on the plants themselves: it preys on other insects that frequent heather and heaths. These include other bugs such as *Orthotylus ericetorum* and *Scoloposthetus decoratus,* and probably moth larvae that feed in the heather, such as *Anarta*

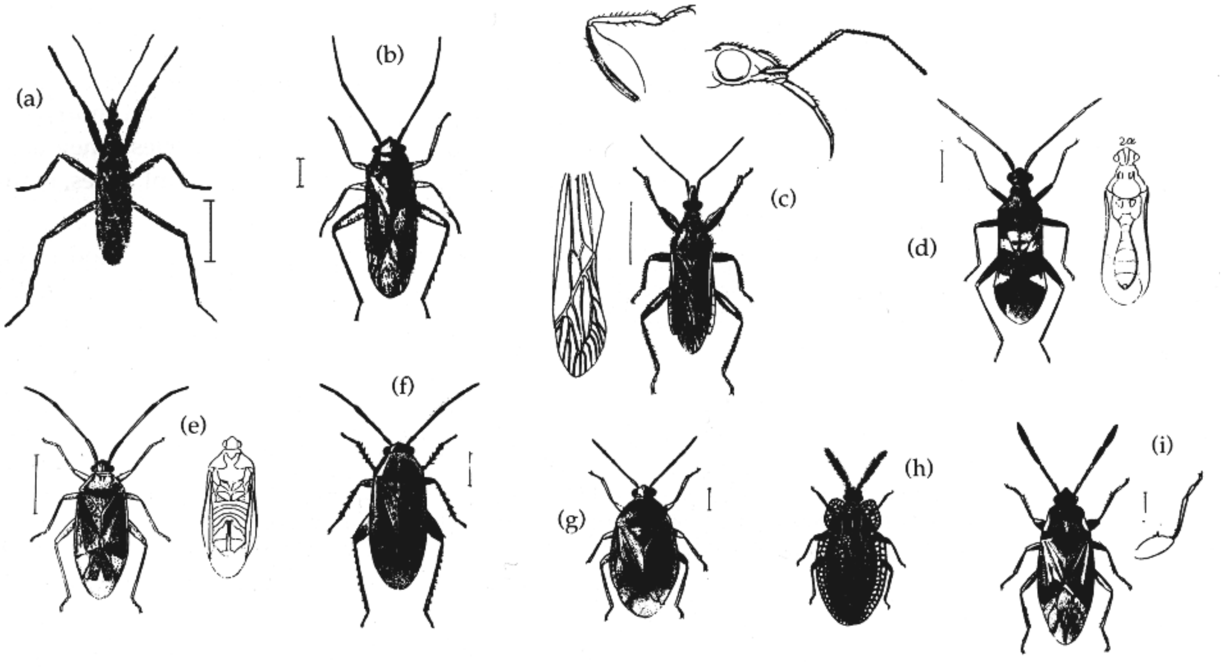


Figure 11.7: Land bugs.
(a) *Nabis ericetorum;*
(b) *Orthotylus ericetorum;*
(c) *Nabis* sp.;
(d) *Systellonotus triguttatus;*
(e) *Pantilius tunicatus;*
(f) *Psallus* sp.;
(g) *Monalocoris filicis;*
(h) *Dictyonota* sp.;
(i) *Scoloposthetus* sp.

myrtilli and various small geometrid caterpillars (such as the grass wave moth *Perconia strigillaria,* which often occurs in great numbers on bogs), as well as the beetle *Lochmaea suturalis. Orthotylus ericetorum* [**Figure 11.7**] lays its eggs in young heather shoots, and when the larvae hatch they feed on the flowers and leaves; young larvae are said to be especially partial to heather petals. *Scoloposthetus decoratus* is an attractive little bug that is very common on heather and heath species, and is seldom found anywhere else; its numbers sometimes run into several hundred thousand per acre. It lays its eggs on dead heather shoots in summer, and the adults are found from July onwards, feeding right through winter. Their feeding habits are obscure, but their diet is known to include other bugs, including *Orthotylus ericetorum*, *Orthotylus* has other enemies, because it is also preyed upon by fossorial Hymenoptera.

Another capsid species is *Systellonotus triguttatus*, which is sometimes found in cutover areas of dry fen peat colonised by creeping willow. It feeds on both plant and animal food, its favourite plants including tormentil, heather and creeping willow. One of the most interesting things about the species is that the female and larval bugs are ant mimics, and are often found in the company of ants. They never attack the ants, although they will eat ant pupae and honeydew. Their favourite animal food appears to be aphids, especially the species that feeds on the sap of creeping willow (*Chaitophorus salicivorus*); unlike the female, the male is fully winged, and is less predaceous. The eggs are laid in cracks in creeping willow bark, where they overwinter. *Stenodema holsatum* is a capsid whose yellow-green larvae can be found feeding on purple moor-grass and other grasses late in summer and in the early autumn.

Some bugs that we would expect to be common here in Ireland because they occur in bogs in Britain and elsewhere are rare: such as *Lamproplax picea,* which is widely distributed – though never abundant – over much of Britain, but has so far only been recorded in this country from North Kerry. *Chartoscirta elegantula,* a species of river estuaries, callows, fens and bogs, has only been found in Ireland in North Kerry and along the River Slaney, and *Chartoscirta cocksi* is absent altogether from Ireland, although it occurs in bogs in much of Britain.

Ferns and mosses also have their bugs. *Monalocoris filicis,* the bracken bug, eats the sporangia of its host, and indeed often lays its green eggs under the indusia (the little umbrellas on the underside of the leaves that shelter the spores) [**Figure 11.7**]. The sphagnum bug (*Hebrus ruficeps*) is a very tiny amphibious bug that lives among sphagnum cushions around the margins of bog pools, where it is often abundant. It seems to feed on other small arthropods that inhabit the mossy cushions. The species overwinters in the adult stage; egg-laying is spread over a two month period beginning in mid-May, and it takes about two months to develop through the five larval instars to maturity. It is easy to find this little bug at nearly any time of the year in spite of its size by squeezing a handful of sphagnum and then leaving it on a sheet of paper; as it dries out the insects will move downwards and can be collected on the surface of the paper.

The dark-green apple-capsid (*Orthotylus marginalis*) is often abundant on sallow. It lays its eggs in young wood, near the buds on which the larvae will feed when they hatch in late spring and early summer, and in this stage it overwinters; adults are found from June to August. The apple capsid (*Plesiocoris rugicollis*) is only too well known to fruit growers; it is a widespread pest of apples and other fruit trees, being responsible for the corky scabs often seen on apples in old orchards, but more critically it feeds on flower buds and developing young fruit. In the wild its main hosts are bog myrtle and willows, and it can easily be confused with *Orthotylus marginalis.*

Aphids are among the most widespread and successful of the Hemiptera; they are predominantly insects of north temperate regions, and over 4,400 species are known. They have complex life histories; a 'typical' aphid life cycle consists of one sexual generation and several generations in which only parthenogenetic females are produced. More complex life cycles involve host alternation. Most species of plants have their own specific aphids: *Cehuraphis eriophori* is specific to cottongrass, *Aphis callunae* occurs on heather, and *Aphis vaccinii* and *Wahlgreniella vacinii* are found on bilberry [**Figure 11.6**]. No fewer than thirteen kinds feed on downy birch, and most of these are confined to birches. Their sonorous names are at least worth placing on record in this volume on the bogs that are their main habitat in Ireland!

DOWNY BIRCH APHIDS

Betulaphis quadrituberculata	*Clethrobius comes*	*Monaphis antennata*
Calaphis betulicola	*Euceraphis punctipennis*	*Stomaphis quercus*
Calaphis flava	*Glyphina betulae*	*Symydobius oblongus*
Callipterinella calliptera	*Glyphina pseudoschrankinna*	
CalIipterinelIa minutissima	*Hammamelistes betulinus*	

Scale bugs are also represented on the bog. A species of *Eriococcus* attacks cross-leaved heath, causing galls that make the stems twist into spirals.

Trichoptera: caddis flies

Caddis flies are rather unfamiliar insects to most people, because they are seldom seen on the wing by day, and because they are rather drab-coloured grey or brown insects as adults. The larvae (caddis worms) are aquatic, and there are two quite different types: those that build cases in which they live during their larval life, and those that do not. Cased or *eruciform* larvae are mainly vegetarian, and occur both in still and running water, and the many different species can generally be distinguished by the structure and building materials which go into the making of their distinctive cases, Case-making bog species include *Agrypnia varia, Limnephilus luridus* and the very local *Limnephilus elegans*.

Uncased or *campodeiform* caddis larvae usually live under stones in running water, where they build nets to catch animal prey brought in by the current; when the time comes to pupate, these caddis worms build little houses out of small stones which they cement onto a large stone at the bottom of the stream. The commonest species of uncased caddis is *Plectrocnemia conspersa,* which occurs in both upland and raised bog pools, and in boggy streams.

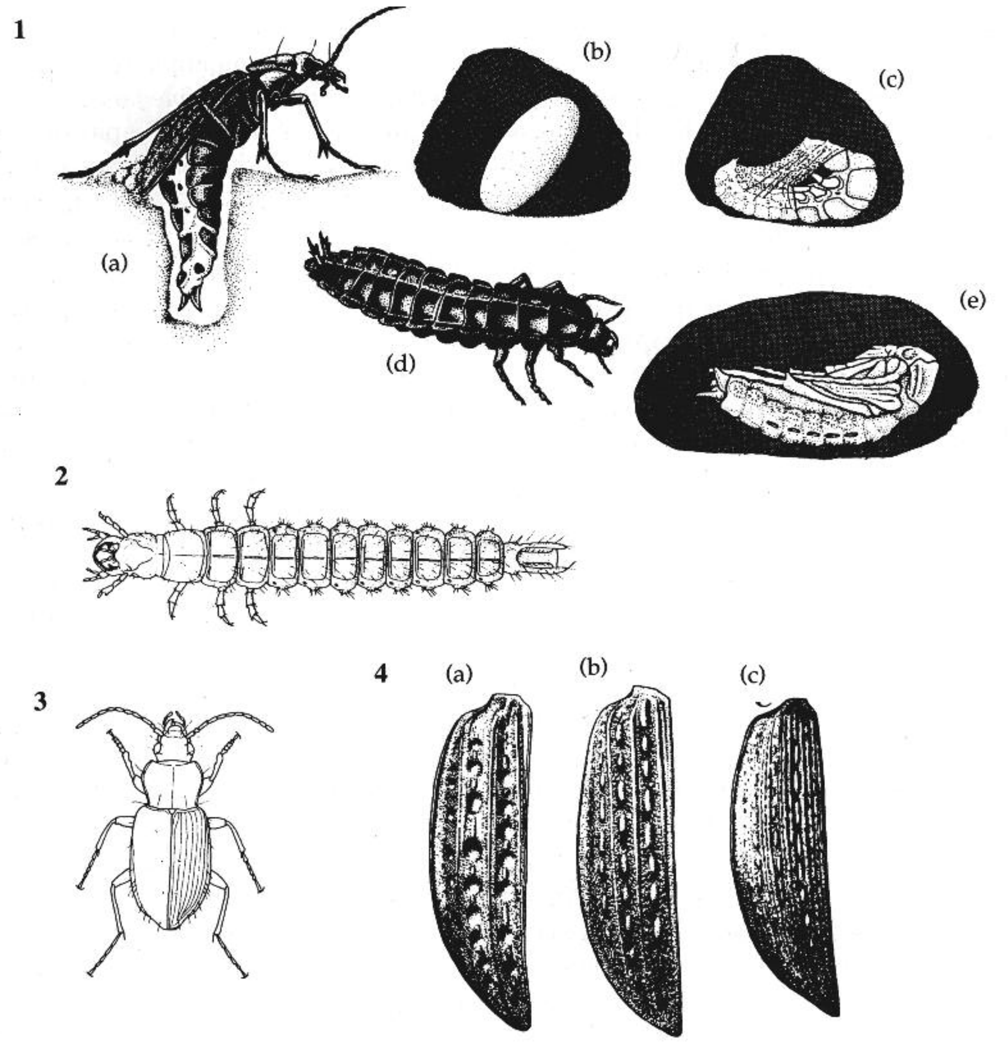


Figure 11.7: Ground beetles.
(1) The life cycle of a *Carabus* beetle (Trautner and Geigenmüller, after Sturani).
(a,b) 40-60 eggs are laid over a period of weeks, each in a specially dug hollow.
(c,d) The larva hatches after one to two weeks and digs its way to the surface. It moults three times in its first two months.
(e) The larva pupates underground, and on emerging as an adult, remains here until its skin has hardened.
(2) A typical carabid larva. Note the powerful jaws.
(3) A species of *Pterostichus.* Some of the carabids in this sub-family care for their young, the females remaining on the eggs until they hatch.
(4) Patterns on the elytra of three species of *Carabus* common on bogs.
(a) *Carabus clathratus:* copper-coloured.
(b) *Carabus granulatus:* dark copper in colour.
(c) *Carabus problematicus:* black with bluish lustre.

Coleoptera: beetles

Land beetles

Beetles are among the most diverse of all bog insects, both on dry land and in the water, and a complex mosaic of beetle communities occurs on bogs. From Laurence Swan's work at Glenamoy as part of the IBP programme we have a very good idea of the range of species that occurs on bogland and in adjacent peaty habitats, but we still have very little understanding of the adaptations and preferences of the individual species (of course this is still true of most groups of bog invertebrates).

The ground beetles (Carabidae) include some of the largest and most abundant of bog insects. Well over thirty species occur on bogs, some of them among the most conspicuous predators here. They are especially common on cutover and otherwise disturbed bogland, although most of their hunting is done out of sight of casual human observers. They feed on whatever they can catch, mainly detrivores, but their heavy armour is not enough to save them from being themselves eaten by frogs, in whose diet they figure prominently – indeed, in some bogs ground beetles are the main item on the frog menu.

Perhaps the commonest is *Carabus granulatus,* a very characteristic insect of the spreading grounds, where it hunts and hides under the drying turf sods [**Figure 11.8**]. It is a beautiful copper-coloured to black beetle, often over 20mm long, with three rows of oblong elevations separated by simple ridges running down each side of its back. Its 'back' is its wing cases or upper wings (elytra); underneath is a pair of rudimentary wings; in many ground beetles these have been dispensed with entirely, and the elytra are fused. Another common species about the same size (but more associated with woods than open areas) is *Carabus nemoralis,* which varies in colour from purplish black to bronze or reddish; it has three rows of longitudinal pores running down each elytron. A much smaller (5mm long) and very speedy cousin that is often seen in similar situations is the brassy-coloured *Notiophilus aquaticus. Carabus clathratus* is a flightless ground beetle with long legs adapted for life in the heathery vegetation.

The rather dull (though often irridiscent) ground beetles belong to the sub-family Carabinae. The 'Cinderella' of the family belongs to a closely-related sub-family, the Cicindelinae or tiger beetles – though Cinderella is perhaps not an appropriate name for such ferocious insects. Tiger beetles are members of a group of beautifully-coloured beetles that are mainly tropical in distribution. They are wonderful-looking insects, very fast-moving, but able to fly when they want to. The elytra are usually a brilliant green, with coppery-red margins and legs. Although their most typical haunts are sandy places like eskers, two species are often met with in cutover areas between early spring and mid-summer, just around the time the turf is being cut; these are the green tiger beetle (*Cicindela campestris*) and the bronze-coloured wood tiger beetle (*Cicindela sylvatica*) [**Figure 11.9**].

The tiger beetle has large, prominent eyes and overlapping mandibles like scimitars. The larvae live in long, vertical burrows that open as circular holes to the surface. Just inside the entrance to its burrow the larva waits, using the front of its specially-modified head and thorax as a living manhole, with mandibles no less ferocious than those of the adult at the ready; when likely prey passes within striking distance the startled and doomed victim is catapulted into the burrow.

The third and by far the largest sub-family of the Carabidae – there are over 10,000 species worldwide, nearly 300 of them in these islands – are the Harpalinae. Some of the commonest beetles of bogland, and especially of the many fringe habitats including fens, are small harpalinids belonging to the genera *Feronia, Agonum* and *Pterostichus.* These little ground beetles are among the most important predators and scavengers around, and they will eat anything that comes their way. *Pterostichus nigrita* is one of the most widespread of peatland carabids, here in Ireland as throughout northern Europe.

One of the most successful of all beetle families is the Curculionidae, the weevils, a family better known to the human species than most other families of beetles because

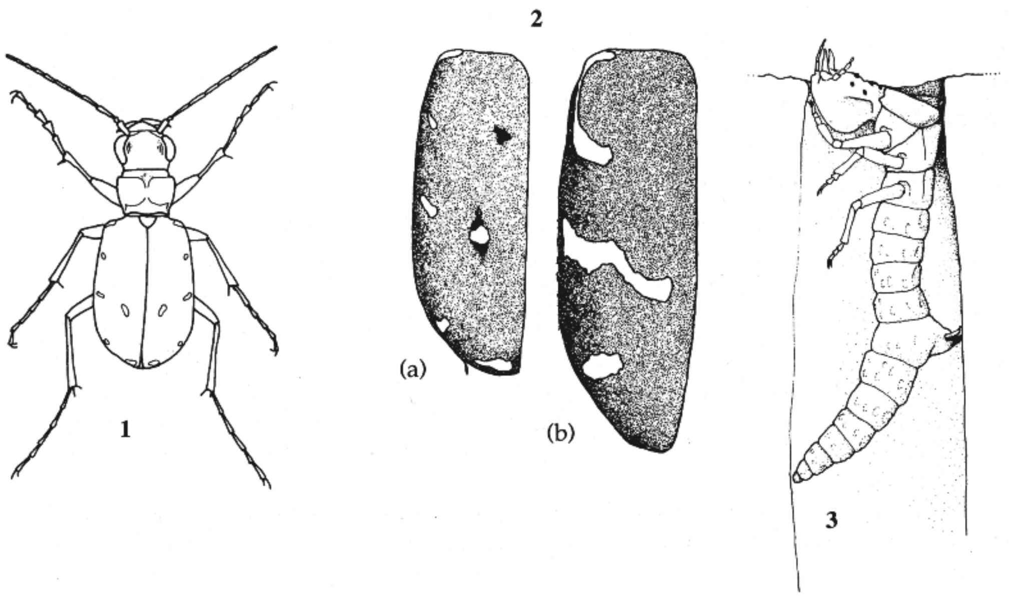


Figure 11.9: Tiger beetles.
(1) *Cicindela campestris.*
(2) Patterns on the elytra:
(a) *Cicindela campestris,*
(b) *Cicindela silvatica.*
(3) Tiger beetle larva lying in wait for prey at the entrance of its burrow (Trautner and Geigenmüller, after Peterson).

of the destruction some few of them cause to crops and stored products. The most distinctive feature of weevils is their beak-like mouthparts. They make up the largest family in the animal kingdom, with well over 500 species in these islands alone. Few plants are immune from the attacks of one or more weevils, and those that occur on the bog are here because this is where their host plants are. Among the most widespread and distinctive therefore are the furze weevils *Apion ulicis* and *Apion striatum* [**Figure 11.10**] and the very tiny heather weevil *Micrelus ericae* that is found nearly everywhere on heather and species of heath; it has the ability to mine heather stems. Another weevil that mines heather and heaths is the shiny black *Strophosomus sus,* a representative of a genus renowned for its prominent eyes. *Ceuthorhynchus ericae* is a small weevil found exclusively on heath species, and very characteristic of most bogs. Birch attracts the attention of several weevils, *Polydrusus cervinus, Anoplus plantaris* and *Coeliodes rubicundus* in particular; the first two are small black weevils, while *Coeliodes* is red in colour.

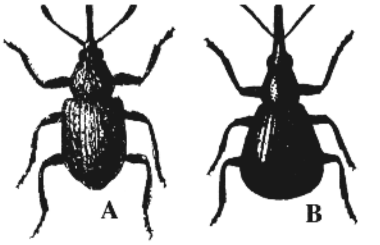


Figure 11.10: Furze weevils.
(a) *Apion ulicis;*
(b) *Apion striatum.*

The fascinating beetles belonging to the family Sylphidae (burying and carrion beetles) are represented on bogs, as they are in most habitats where animal carcasses occur. *Necrophorus humator* is the largest; it is very appropriately named, because the Latin name of the beetle means 'dead-eating burier of the dead.' Equally appropriately for a full-time undertaker, it is entirely black in colour, whereas other species in the genus have two orange bands across the black elytra. They include *Necrophorus investigator*, *Necrophorus vespillo* and *Necrophorus vespilloides.* These beetles have one of the most extraordinary life histories found in the insect world. They are attracted to carrion by scent, males and females alike. If more than one pair of beetles arrives, they will fight for possession of the carcass, the winner taking up residence. Mating takes place here, and the beetle then begins to excavate a burrow under the dead animal, into which it is hauled and manipulated into a neat ball shape. The depth of this burial vault varies between different species. In *Necrophorus vespilloides* it is shallow, whereas in *Necrophorus humator* it is up to 7.5 cm. The female then excavates a side-gallery above the mortuary chamber and it lays eggs in alcoves which open off this – about fifteen in *Necrophorus vespillo.* When she has finished all this work the female returns to the mortuary chamber, makes a feeding crater on the top of the carrion, and has her first meal since she started work. After five days or so she is joined in the crater by the newly-hatched larvae, which receive their first meal in the form of a droplet of brown liquid exuded from the mother's mouth before they start on their solid diet of rotting flesh. As the larvae grow they go through three stages or *instars,* each one quite different from the others in appearance. When they are fully grown and the time comes to pupate, they burrow into the chamber wall and each constructs a pupal chamber in which it spends a fortnight before emerging as an adult. Adult *Necrophorus* beetles feed on other things as well, however, being particularly fond of the blow-fly larvae that are ubiquitous in rotting animal carcasses, a habit they share with the related *Necrodes littoralis,* a black sexton beetle.

Burying beetles are one family in the large super-family known as the Staphylinoidea, all of whose members have short elytra under which the back of the abdomen protrudes, making many of them them look a bit like small earwigs. Another big group in this superfamily are the rove beetles, which comprise several different families, most of which are placed in the family Staphylinidae. This is a huge family, with 15,000 species worldwide, about 1,000 of which are found in Britain and Ireland. Among the most familiar, because of its large size, is the devil's coach-horse (*Ocypus olens*), but very few species are as big as this. *Tachyporus hypnorum* is a moss-loving species common on bogs, and *Tachyporus obtusus* is often seen in bog woodlands. Several members of the genus *Stenus* occur on bogs. *Stenus geniculatus* is a fast-moving species found sometimes on heathery hummocks; it feeds mainly on springtails that it captures with its sticky tongue. Another rare, but characteristic bog species, is *Stenus brevipennis*.

Two other groups of beetles that are commonly encountered on the bog, though they are not in any real sense bog beetles, are the plant feeders (Chrysomelidae) and the ladybirds (Coccinellidae). Most of the plant feeders are visitors, following food plants more common outside the bog. The commonest leaf beetle, seen on bog willows, is the metallic blue or shiny green or copper coloured *Phratora vulgatissima,* which is especially fond of rusty willow (*Salix cinerea*), although it will also eat goat willow (*S. caprea*), eared willow (*S. aurita*) and osier (*S. viminalis*) if they are present. Other species are rarely attacked, a difference that is attributed to their chemical defence, which makes them unpalatable: they have higher levels of phenolic glycosides than other willow species. The amount of damage the beetles do depends on the population in any particular year. In years of heavy infestation they may consume the entire leaf biomass of the tree, but although the depredations of the beetle may appear devastating in late July or August, the tree will have been in leaf for several months before the insects begin munching seriously. The affect on trees growing under stressed conditions appears much greater. The trees show little outward sign of permanent damage, coming to green life again every spring, but the attacks are often very severe, and are a serious drain on the plants' resources; if the various species of willows favoured by the beetles were of significant economic importance, the brassy willow beetle would be a much better-known creature than it is. The adults spend the winter hibernating under old bark or in litter, waiting to renew their onslaught the following April. The larvae are about from June on into the autumn; they feed for nearly two weeks before they pupate in the litter. The pupal stage lasts about a week, and the newly-emerged adults feed for a month or so before going into hibernation.

Phratora vitellinae (which is bluish, but more usually coppery or brassy), *Galerucella lineola* and *Crepidodera hexines* are three other species of willow beetles that are met with from time to time, but are never as abundant as their voracious cousin. One of the commonest beetles on Midland bogs is the little heather beetle *Lochmaea suturalis,* which is dark brown in colour and only 0.5cm long. In some years it occurs in phenomenal numbers, causing enormous damage on heather moors, stripping the stems completely of leaves and bark. The beetle lays its eggs on the ground among sphagnum.

Only the weevils comprise a bigger family of beetles than the chrysomelids, brightly-coloured, metallic-looking beetles, different species of which are specialised to feed on specific plants or groups of plants. *Plagiodera versicolora* is occasionally seen on bog willows. Flea beetles (Halticidae) are one group of plant beetles, many crop pests among them. A very small yellow species of flea beetle found here and there on bogs, where its food plants (meadowsweet and marsh cinquefoil) occur, is *Aphthona lutescens.*

A typical ladybird of bogs is the very tiny but colourful *Scymus testaceus,* which is no bigger than 1.5cm and is fond of marshy places generally. *Coccinella septempunctata,* the ubiquitous seven-spot ladybird, is found on the bog from time to time; its small relative, *Coccinella hieroglyphica,* is a very variable ladybird fond of heathery places. It is yellow or reddish-yellow with black markings. *Chilocorus bipustulatus* is also a common bog species.

Other common bog beetles include *Microcara testacea,* a species fond of wet places generally, and *Cyphon padi.* A little beetle that often occurs under the bark of decaying fir and oak around bogs is *Rhizophagus depressus.* A tiny fungivore species is *Proteinus ovalis.* Two very tiny beetles that are common are *Atomaria fuscipes* and *Ephistemus gyrinoides,* which frequents moss. The cottongrass beetle *Plateumaris discolor* is a handsome, metallic insect, but its larva is of greater interest because of its breathing system: it lives inside the plant, where it breathes by plugging into the air spaces of the stem by two special syringes attached to its backside.

Water beetles

Bog pools and bog holes are home for an incredible variety of creatures; many of these will be found in bodies of standing or stagnant water in other situations, but some are rather more particularly characteristic of the very distinctive environment of dark and peaty acid water. Among the commonest and most interesting of these are the water beetles. Water beetles are descended from the carnivorous ground beetles we are all very familiar with, and they are – with some exceptions – among the easiest of insects to keep in an aquarium. In basic structure they are still terrestrial beetles, and will drown if they do not come to the surface periodically for air, but their external anatomy is beautifully adapted to life in water. They are streamlined in the way other aquatic animals such as dolphins or fishes are, and so they can move smoothly and swiftly through the water, without setting up ripples or disturbance. Their legs are flattened so that they can be used as swimming paddles, and in many species are fringed with hairs. They are still able to fly, which is extremely useful, because if the pools they inhabit dry out in a warm summer, they can quickly find a substitute.

Most water beetles are dytiscids (Irish *doirb* [*doirbeacha*]; family Dytiscidae). There are many species, and they all look very much alike except in size. Many are very small, but some are large, and one of the commonest, *Dytiscus marginalis,* is about 3cm long. Many species occur in bog pools, but nobody has studied them all that closely, so very little is known about the detail of their ways of life. The larger dytiscids are ferocious and voracious creatures. The biggest and most notorious of the lot is the great diving beetle *Dytiscus marginalis* (Irish *tumadóir mór*), which probably occurs in every bog in the country. The larva is an even more murderous creature than the adult, and if it put into an aquarium it will kill everything else, including small fish [**Figure 11.11**, **Plate 9**].

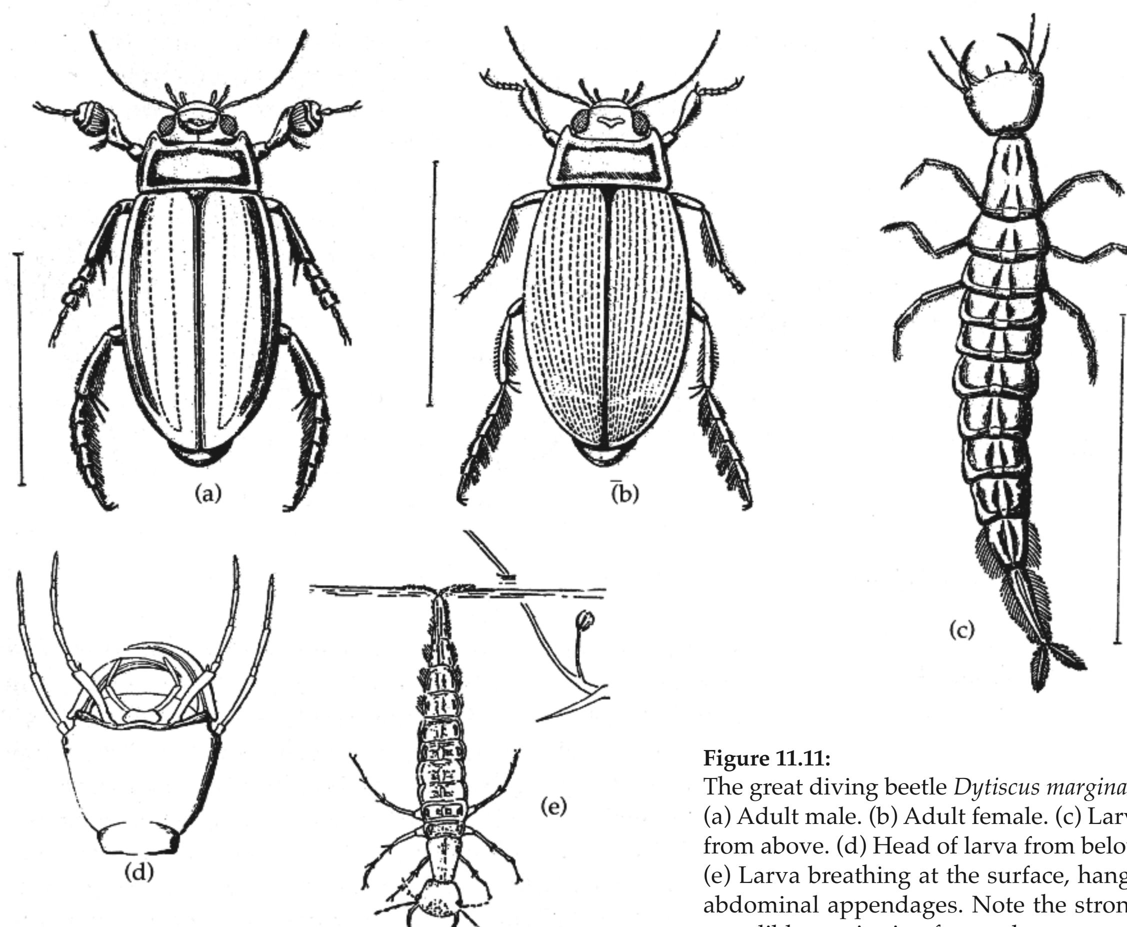


Figure 11.11:
The great diving beetle *Dytiscus marginalis.*
(a) Adult male. (b) Adult female. (c) Larva seen from above. (d) Head of larva from below.
(e) Larva breathing at the surface, hanging by its abdominal appendages. Note the strong, curved mandibles projecting forwards.
(a)-(d) from Miall; (e) from Charpentier.

One of the most fascinating things about dytiscids is the form of the anterior tarsi of the males. An insect's leg is divided into five parts: coxa (haunch), trochanter, femur (thigh), tibia (shin) and tarsus (foot); the tarsus is divided into five segments. In *Dytiscus* the first three segments are modified to form a flattened disc that has suckers for holding onto the female during mating. These extraordinary structures are quite different in different species [**Figure 11.12**].

Underwater beetles like *Dytiscus* must come to the surface from time to time to breathe. Dry-land insects breathe through pairs of special openings called spiracles that are situated along their sides. *Dytiscus* has eight pairs of these, but seven pairs have lost their original function, whereas the eighth pair has become greatly enlarged. When the beetle surfaces it sticks this pair of spiracles out into the air, and at the same time raises its wing cases slightly, so that air is trapped by the dense coating of hairs on the body surface. *Dytiscus* lays its eggs individually in incisions that it makes in water plants. The larvae breathe in the same way as the adults, but in order to pupate they have to leave the water. So in many ways these beetles are still conditioned by the upbringing of their terrestrial ancestors.

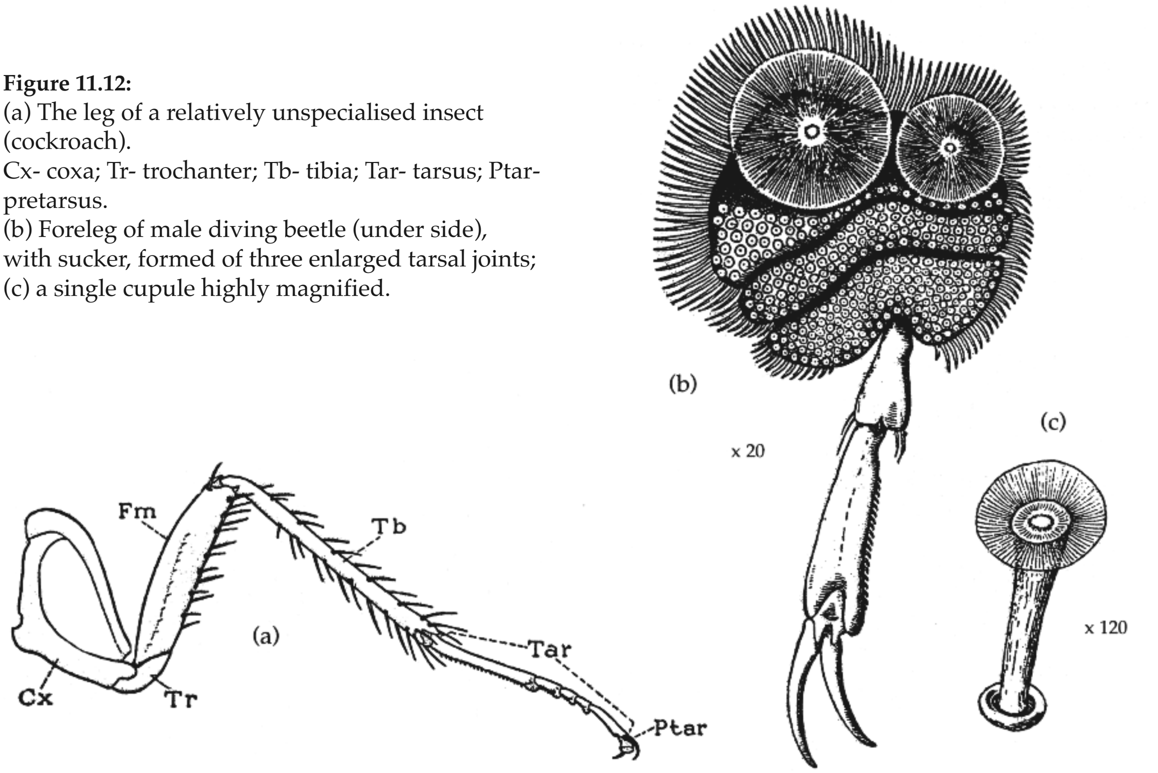


Figure 11.12:
(a) The leg of a relatively unspecialised insect (cockroach).
Cx- coxa; Tr- trochanter; Tb- tibia; Tar- tarsus; Ptar- pretarsus.
(b) Foreleg of male diving beetle (under side), with sucker, formed of three enlarged tarsal joints;
(c) a single cupule highly magnified.

Whirligigs

Another common family of water beetles is that of the aptly-named whirligigs (Irish *táilliúir:* family Gyrinidae), which patrol the open water of ponds and pools in most bogs, looking like schools of animated miniature fairground bumper-cars. They are extraordinary little beetles, superbly designed for their chosen way of life. Their middle and hind legs are modified as oars, while their front legs are used for grabbing and holding their food, and are adapted for mating in the male. One of the most amazing thing about them is their eyes, each of which is divided into two: an upper part for seeing in the air, and a lower part for seeing under water [**Figure 11.15**]. Whirligigs lay their eggs in groups on water plants; when the larvae hatch, they skulk among the vegetation in wait for smaller water creatures. They breathe by means of tracheal gills, but when the time comes to pupate they leave the water and construct cocoons from bits of plant debris, in which they pupate. One of the most marvellous adaptive features of whirligigs is their hind legs, which are specially modified for swimming: but not in the rather simple way of other water beetles. They are broad and flattened and fringed with stiff hairs, but what is most peculiar is that they have a structure like a fan made of separate lobes pinned together at one end. When the fan segments are extended the beetle can exert an extremely powerful stroke against the water; when it brings back the leg for the next stroke the segments are compact and collapsed, so that they offer the minimum resistance to the water; then they are expanded for the next stroke and so on. But this is done extremely rapidly – the legs whir like tiny motors, powering the little beetle around the surface with superb ease and control.

Several species of whirligig beetles are likely to be encountered, but they are notoriously difficult to distinguish. Much the commonest species is *Gyrinus natator. Gyrinus minutus* occurs mainly in the north and down the west. Half a dozen or so species occur on the Connemara lakes, the commonest being *Gyrinus natator*, *Gyrinus aeratus* and *Gyrinus minutus. Gyrinus minutus* is especially characteristic of bogholes and the water-lily pools so characteristic of the western bogs. *Gyrinus colymbus* and *Orectochilus villosus* are species found on larger and more open lakes.

Most of the smaller water beetles belong to the family Haliplidae, tiny creatures only a few millimetres in length. Many of them have extraordinary-looking larvae which look anything but beetle-like. They feed on algae, and are not very good swimmers – unlike their bigger carnivorous relatives they don't really need to be – and keep very much to themselves.

Other beetles characteristic of bog pools include *Hydroporus melanarius*, which occurs mainly in upland bogs. *Hydroporus gyllenhall*, *Hydroporus obscurus* and *Hydroporus pubescens* are common species in raised bogs. Others include various species of *Agabus*, and *Rantrus bistriatus.*

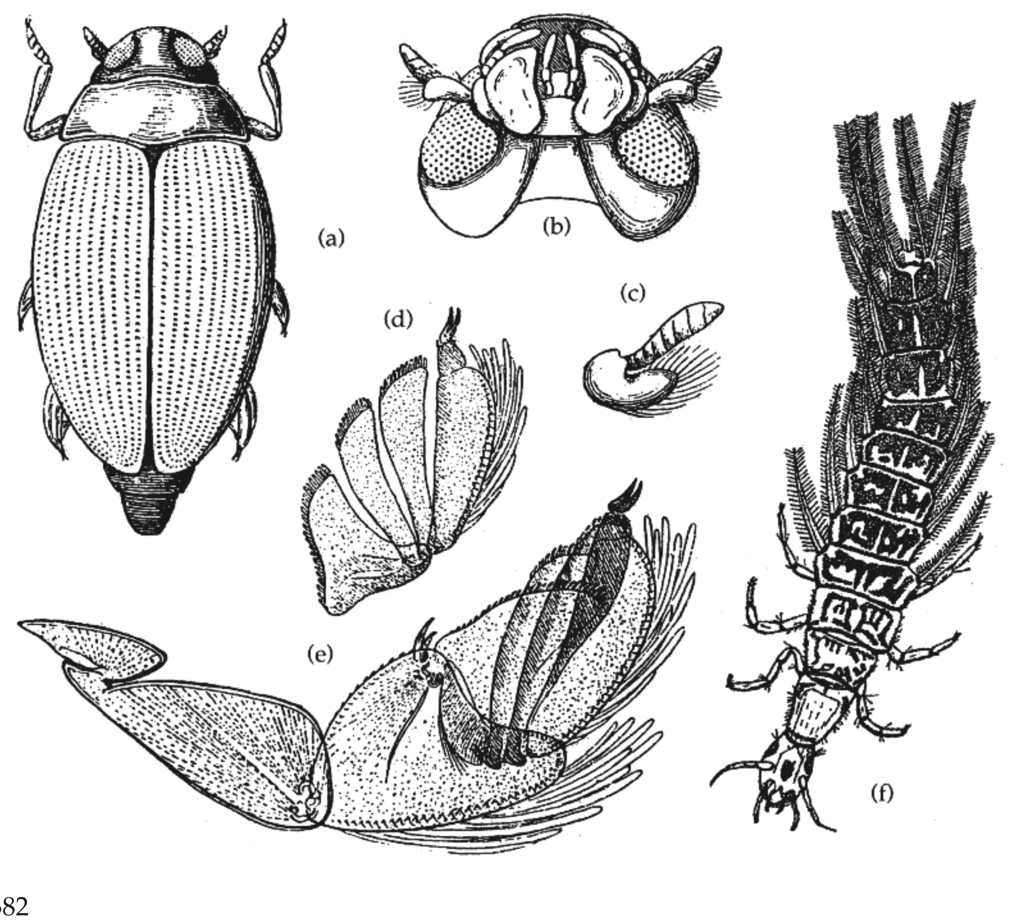


Figure 11.13: Adult and young whirligigs.
(a) *Gyrinus marinus; Gyrinus natator* is almost identical. Notice the upper pair of eyes.
(b) Head seen from beneath, showing the mouthparts and the lower pair of eyes.
(c) Antenna.
(d) The third leg.
(e) The tarsal joints of the third leg separated and extended, showing how marvellously it is adapted to function as an oar.
(f) Larva of *Gyrinus marinus* [From Miall, (e) after Schiödte].

Table 11.4: Beetles recorded as common on virgin bog at Glenamoy (Swan, 1973)

CARABIDAE	**GYRINIDAE**	**PSELAPHIDAE**
Carabus graulatus *	*Gyrinus minutus* ++	*Bibloplectus ambiguus* *
Carabus clathratus *	**HYDROPHILIDAE**	*Pselaphus heisei* *
Carabus problematicus *	*Helophorus flavipes* ++	**CANTHARIDAE**
Pterostichus niger *	*Paracymus scutellaris* **	*Cantharis pallida* ∞
Pterostichus nigrita *	*Anacaena globulus* **	*Rhagonycha fulva* ∞
Pterostichus diligens *	*Enochrus quadripunctatus* ++	**ELATERIDAE**
DYTISCIDAE	*Enochrus affinis* ++	*Dolophius marginatus* ∞
Hydroporus tristis +	*Necrophorus vespilloides* *	**HELODIDAE**
Hydroporus gyllenhalii +	**PTILIIDAE**	*Cyphon hilaris* ∞
Hydroporus palustris ++	*Acrotrichis grandicollis* ∞	**CRYPTOPHAGIDAE**
Hydroporus melanarius +	**STAPHYLINIDAE**	*Cryptophagus pseudodentatus* ∞
Hydroporlls obscurus +	*Olophrum piceum* *	**LATHRIDIIDAE**
Hydroporus pubescens +	*Staphylinus aenocephalus* *	*Lathridius nodifer*
Agabus paludosus ++	*Quedius boops* *	**CHRYSOMELIDAE**
Agabus chalconatus +	*Tachinus rufipes* *	*Plateumaris discolor* ∞
Agabus bipustulatus ++	*Myllaena gracilis* **	*Crepidodera transversa* ∞
Ilybius aenescens +	*Drusilla canaliculata* *	**CURCULIONIDAE**
Dytiscus semisulcatus ++	*Meotica exilis* *	*Micrelus ericae* ∞
Acilius sulcatus ++		*Rhamphus pulicarius* ∞
Acilius canaliculatus ++		

* Mainly in drier areas
+ Temporary pools as well as streams
++ Streams and permanent pools
** Semi-aquatic
∞ In taller vegetation

Table 11.4 gives an indication of the diversity of the beetle fauna of bogs. However, when bog is reclaimed and converted to grassland the level of diversity rises steeply. Several times as many species may occur in grassland as in bogs (staphylinids being particularly prominent among them), reflecting the much greater productivity of the grassland. When bogland is afforested, the beetle fauna disappears slowly; eight years after planting at Glenamoy, nearly nine out of every ten species in the young plantation turned up at one time or another on the bog, Woodland beetles eventually take over, as species that are at home on the bog find themselves in increasingly alien surroundings.

Lepidoptera: butterflies and moths

No two animals occupy exactly the same niche in their ecosystem; even two animals which seem to be very similar will have different habitats, exploiting slightly different sets of opportunities. We really know very little about the hidden lives of the many tiny animals which live on the bog, but we can get some idea of how diverse they are from the fact that more than 150 different kinds of moths and butterflies live here, each one of them exploiting a different niche – and there are much bigger numbers of species for several other groups of animals. The great majority of Lepidoptera are small creatures, and as the adults of most are out and about mainly by night – which is one reason there is little reason for them to be attractively coloured by our standards – they are very seldom noticed. But there they are just the same, equally unmindful of us, living out their little lives, which often show the most astonishing and beautiful adaptations to the demands and opportunities of life on the bog.

Butterflies

Butterflies (Rhopalocera) are the most conspicuous bogland Lepidoptera, because they fly by day and are often attractively coloured. They are more abundant at the edge of the bog than anywhere else, because of the mosaic of ecosystems that occurs here, and because it is largely unaffected by the activities of modern farming. Most butterflies live in areas of semi-natural grassland and woodland, where the food plants of their caterpillars grow, and as suitable habitats have diminished, so too have the butterflies that depend on them become increasingly scarce. Most of the butterflies that add so much to the beauty of the bog in May and June are not bog insects exclusively, but some are found here more commonly than in most other places. As many as eighteen species live in and around the bog, especially on the fringes. Because their caterpillars feed on plants and cannot move very fast, some of these butterflies can be seriously affected by the burning of bogs.

The larvae of the family Satyridae feed mainly on grasses, and several species are common along the grassy edges of the bog. The large heath (*fraochán mór*) however is a true bog butterfly [**Plate 7**], and feeds on plants that are largely confined to the bog: white beak-sedge and purple moor-grass. The female lays her eggs singly in late June or July on the leaves and stems of the larval food plant. The caterpillar eats away for all it is worth, and is fully developed after its fourth moult, when it has grown to about 25mm and is grass-green in colour, with horizontal white stripes: most satyrid caterpillars have this kind of green camouflage for feeding on grasses. In late September the fully-grown caterpillar goes into its winter quarters down among the leafy bases of grasses and related plants, and here it stays for five or six months, emerging to pupate when the weather gets warm again.

The pupa is a beautiful emerald-green in colour, and this stage lasts 23 days. The adult (imago) has fulvous-brown wings with a ringed black spot near the tip, and darker hind wings, usually with three ringed spots near the edge; the underside of the wings is also brown, and the eye spots are larger here, with white pupils, three on the front and six on the hind wings. It only lives for fifteen to twenty days, and seldom feeds on flowers during that brief period, moving restlessly over the grassland with the slow, fluttering flight characteristic of many members of its family.

Another butterfly that is largely confined to the bog is the green hairstreak (*stiallach uaine*) [**Plate 7**]. For a brief few weeks in May and June, when the furze is in full bloom, this lovely little butterfly can often be seen darting about among the blossoms, sometimes in considerable numbers. It flies rapidly, but never very far, and when it comes to rest is very difficult to spot, because the under side of the wings is green, in marked contrast to the rich bronze colour of the upper side. The adult lives for up to six weeks. The caterpillar is a brilliant green, with a lemon-yellow line down the sides and similarly coloured markings on each segment. The usual food plant is furze, but the caterpillars can feed on a number of other plants, including bramble, heather, bilberry, bird's-foot trefoil and broom, but its colouring renders it especially inconspicuous on furze and bird's-foot trefoil.

The green hairstreak spends the winter as a pupa among the moss and other ground vegetation around its larval food plant; it stays in its pupal stage from around the middle of July to the middle of the following May - about ten months. The little green eggs are laid singly on flower buds or young leaf shoots, and they hatch after eight days. The larvae feed for 25 days or so, and then wander away to pupate on the ground; they are often cannibalistic.

A third butterfly which is very particularly at home on bog is the marsh fritillary (*fritileán eanaigh*), whose larval food plant is devil's-bit scabious [**Plate 7**]. The Irish populations of this beautifully-patterned little butterfly constitute a distinct subspecies with a colour pattern somewhat different from other races. It hibernates as a caterpillar, and only pupates when it comes out of hibernation in spring. The pupal stage lasts about fifteen days, and the adults are on the wing late in May and through June, their adult life span being about a month. The eggs are laid on the undersides of the leaves of devil's-bit scabious in large batches of as many as four to five hundred at a time. When these hatch after twenty days or so the tiny caterpillars spin themselves a web, and they live under this is very close quarters indeed, feeding at first on the skins of the scabious leaf. After a few days their first tent has become too small for them all, so they move out and spin themselves a new and larger home. Here they feed and grow, and when September comes – by which time they have moulted three times – they spin a dense web in among the leaves, and in this they all gather for the winter. This winter nest has one or more exit holes, and for the first few days the caterpillars tend to come out in groups around the middle of the day, remaining out for a few hours at a time. They begin to move about again as soon as the weather gets warmer in spring. After their fifth moult, by which time they are nearly 300 days old, the caterpillars pupate. By now they are attractive-looking little creatures around 25-30mm long, velvety black on top and brownish beneath. There are seven rows of shiny black hairy tubercles down the back, and a pattern of white flecks along the sides, each spiracle being at the centre of a white floral pattern.

The common blue butterfly (*gormán coiteann*) will nearly always be found around the edge of the bog wherever its larval food-plant, bird's-foot trefoil, is abundant. The butterflies appear in May and in June, flying rapidly in short bursts of flight across the flowering grassland. The sexes are quite different in colour. The upper side of the male's wings is a glossy blue-violet colour, whereas those of the female are fuscous brown, suffused by violet-blue in the lower half of each wing. There is a series of orange crescents near the wing margins. The underside, though, is almost identical in both sexes, a beautiful pattern of orange, black and white crescents and dots and eye spots. In dull weather and at night the butterflies rest with closed wings on grasses and other plants. They sometimes assemble in small groups for the night; rather intriguingly, they cling to the stems head downwards until it gets dark, and then they turn around and rest head upwards for the night. No doubt there is a reason, but nobody yet knows what it is!

The butterflies spend the winter as tiny caterpillars at the base of the food plant or on other vegetation, and do the rest of their growing the following spring and summer. Bird's-foot trefoil is their main food plant, but they can feed also on black medick, clovers and related plants. The eggs are laid singly and hatch after nine days into minute larvae, When fully grown the caterpillars are brilliant green in colour, and around 12-13mm long.

TABLE 11.5
Common butterflies at the edge of the bog, and their larval food-plants

Name	Food plant	Larva feeding/ adult on the wing	Overwinters as
FAMILY HESPERIIDAE			
Subfamily PYRGINAE			
Dingy skipper	Bird's-foot trefoils	5-8	L
Erynnis tages			
FAMILY PIERIDAE			
Subfamily DISMORPHIINAE			
Wood white			
Leptidea sinapis	Meadow vetchling etc.	5-7	L
Subfamily COLIADINAE			
Brimstone	Buckthorn	4-9	P,A
Gonepteryx rhamni			
Subfamily PIERINAE			
Green-veined white	Cruciferae*	3-8	P
Pieris napi			
Orange tip	Cruciferae*	5-7	P
Anthocharis cardamines			I

TABLE 11.5 - continued

FAMILY LYCAENIDAE			
Subfamily THECLINAE			
Green hairstreak *Callophrys rubi*	Furze, buckthorn, bird's-foot trefoil, bilberry etc.	5-6	P
Subfamily LYCAENINAE			
Small copper *Lycaena phlaeas*	Common/ sheep's sorrel	5-10	L
Subfamily POLYOMMATINAE			
Small blue *Cupido minimus*	Kidney vetch	5-9	L
Common blue *Polyommatlls icarus*	Bird's-foot trefoil	5-8	L
FAMILY NYMPHALIDAE			
Subfamily NYMPHALINAE			
Red admiral *Vanessa atalanta*	Nettle	6-9	M
Painted lady *Cynthia cardui*	Thistles	5-10	M
Small tortoiseshell *Aglais urticae*	Nettle	3-11	P,A
Peacock *lnachis io*	Nettle	7-10	A
Subfamily ARGYNNINAE			
Silver- washed fritillary *Argynnis paphia*	Dog violet	7-9	L
Subfamily MELITAEINAE			
Marsh fritillary *Eurodryas aurinia*	Devil's-bit scabious	5-6	L
Subfamily SATYRINAE			
Speckled wood *Pararge aegeria*	Various grasses	4-10	L&P
Wall *Lasiommata megera*	Grasses	5-10	L&P
Grayling *Hipparchia semele*	Grasses	7-9	L
Meadow brown *Maniola jurtina*	Grasses	6-10	L
Ringlet *Aphantopus hyperantus*	Grasses	6-8	L
Large heath (marsh ringlet) *Coenonympha tullia*	Hare's-tail cottongrass	6-8	L
Small heath *Coenonympha pamphilus*	Grasses	5-10	L

* Frequently hedge and garlic mustards, water-cress, cuckooflower.
A: adult; L: larva; P: pupa; M: migratory.

Moths

Although no butterflies do so, many kinds of moth caterpillars feed on heather, and several of them are large and conspicuous. The most splendid is certainly the emperor moth (*Saturnia pavonia*; Irish *impire*). The adult is a glorious insect, but perhaps the most fascinating stage of its life history is the caterpillar. It can feed on a variety of other plants, including bramble, but in Ireland it feeds mainly on heather, The eggs are laid in early summer; the young caterpillar is black at first, and is remarkably hard to spot against the heather. As it grows, it becomes green, with a black band on each segment; the green areas between have seven pink or yellow tubercles with tufts of short black bristles. The spiracles through which the caterpillar breathes are bright orange in colour. It is fully grown as the heather begins to flower, and this wonderful display of colour, which would make the insect so conspicuous against a uniform background, enables it to disappear against the green and pink and black of the flowering heather [**Plate 8**]. In autumn the caterpillar spins a silken sarcophagus – it is in fact the only Irish silkmoth – inside which its body dissolves in the amazing transformation of metamorphosis. The pupal case has a trapdoor at one end that enables the adult moth to emerge. The forewings of the female have prominent eye spots consisting of a black pupil rimmed by alternating brown and black rings and with a bluish or reddish crescent on the inner side; the hind wings have a similar eye spot standing out against a broad white band [**Plate 8**]. The female is on the wing only in darkness, but the somewhat less conspicuous male frequently flies by day. They have a most remarkable sense of smell, and can locate a female in the darkness from miles away. Like many other moths and butterflies, the caterpillar is often parasitised by ichneumon wasps.

Between June and September the caterpillar of the puss moth (*Cerula vinula*) can found on most bogs where rusty willow, its favourite food-plant, grows, It is one of the most fascinating of larger insects, and for this reason was the subject of detailed study by many of the great 18th century naturalists, including de Geer, Réaumur, Lyonet and von Rosenhof. It is a fat, juicy-looking green caterpillar when fully grown, with a purplish-red band down its back and sides (rather like a saddle), and with a hump on the third body segment [**Figure 11.14**]. The eggs of the puss moth are laid singly or in groups of two or three on the upper surface of the leaf; they look just like little galls, and as such are unlikely to attract the attention of prowling egg eaters. When they emerge, the little caterpillars are black; they also rest on the upper surface of the leaf, where they look rather like the dark blotches that are often found here. As it grows, the caterpillar develops a green ground colour that

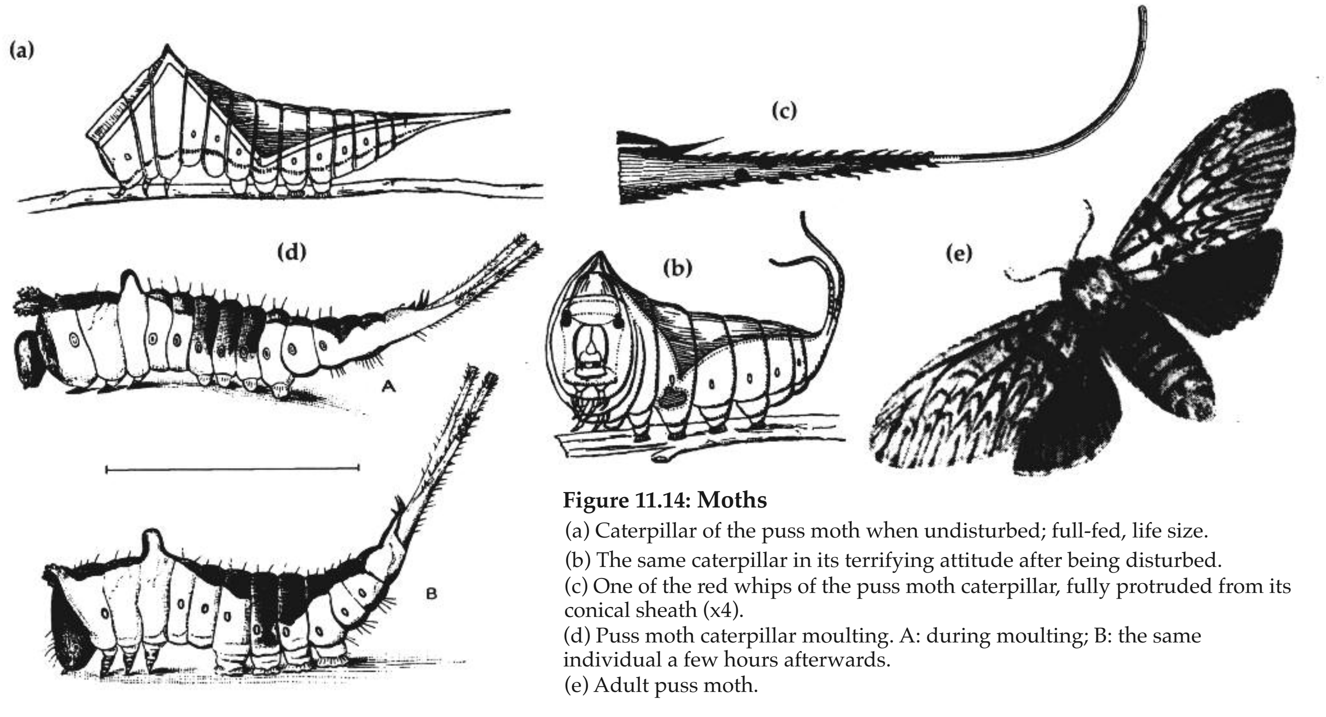


Figure 11.14: Moths

(a) Caterpillar of the puss moth when undisturbed; full-fed, life size.
(b) The same caterpillar in its terrifying attitude after being disturbed.
(c) One of the red whips of the puss moth caterpillar, fully protruded from its conical sheath (x4).
(d) Puss moth caterpillar moulting. A: during moulting; B: the same individual a few hours afterwards.
(e) Adult puss moth.

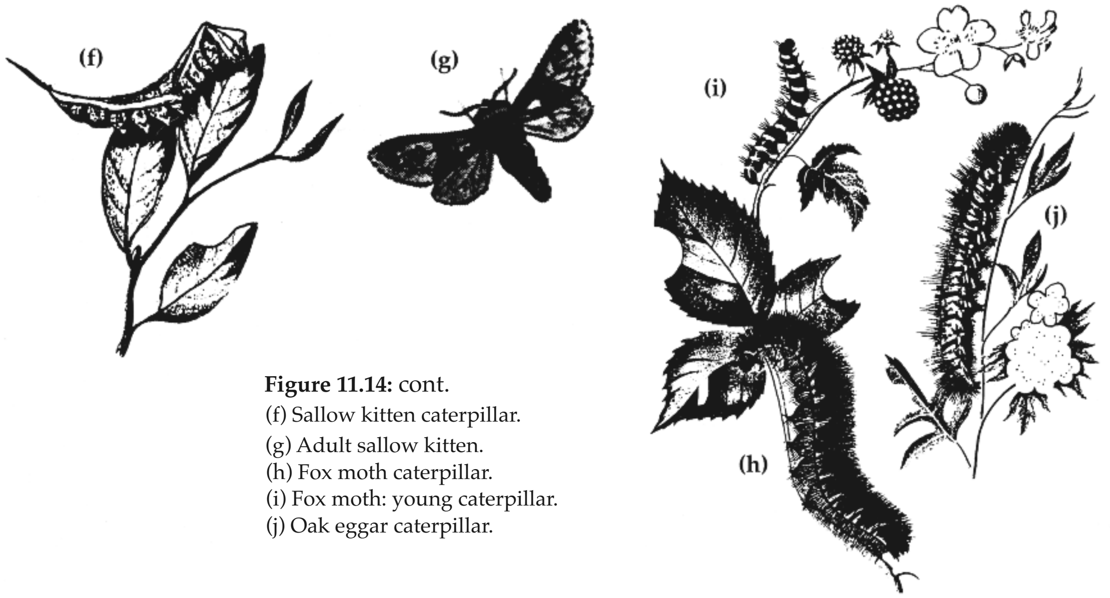


Figure 11.14: cont.
(f) Sallow kitten caterpillar.
(g) Adult sallow kitten.
(h) Fox moth caterpillar.
(i) Fox moth: young caterpillar.
(j) Oak eggar caterpillar.

harmonises with the leaf, and the back develops its red-purple tone, The result makes it extraordinarily difficult to spot – in spite of its size – and even though you suspect it might be present on a particular bush from the stripped skeletons of its leaves and abundant droppings on the ground beneath. Although the colour and pattern of its skin makes the caterpillar so difficult to see as it goes about its business of feeding on the edge of a sallow leaf, the puss moth has two further lines of defence if a predator should see through this camouflage. When threatened it adopts a decidedly menacing posture. It draws itself up, exaggerating the hump, and rears its front end to confront the would-be assailant. Its head is withdrawn into the first body ring, inflating its bright red margin. On this margin there are two intensely black spots just where eyes would be in a vertebrate face, and the appearance of these two staring black 'eyes' at the corners of a red-hooded 'face' in a fat caterpillar must be quite startling to a vertebrate predator.

If the threat persists the caterpillar extrudes two dangerous-looking red filaments from prongs at the back end of its body, curving the end of the body forward over the back as it does so, so that the whips are brandished above the head. These prongs are highly modified abdominal claspers. The whips can be directed to any part of the body that may be touched, and it has been postulated that they are used to repel parasitic ichneumons. But it has more than these wasp-whisks with which to attack these dreaded visitors. The caterpillar directs its 'face' in whatever direction it has been touched. This is important, because just below the mouth is an opening from a gland that secretes a reservoir of irritant fluid, which is ejected with great force if the threat continues. It causes acute pain if it gets into the eyes, because it contains formic acid – as much as 40%.

Although birds and other small vertebrates will eat puss moth caterpillars with relish, their greatest enemy is the ichneumon *Paniscus cephalotes.* This little wasp swoops down on the caterpillar and seizes it just behind the head, holding on with its sharp claws so that it cannot be dislodged while it lays its shiny black eggs on the caterpillar's skin. This is the one place the caterpillar cannot get at the eggs with its powerful jaws – or at the dreadful little maggots that hatch from them – and where the caterpillar is unable to direct its jet of formic acid. The maggots begin sucking the body juices of their fat host as soon as they hatch, but while they are sucking they keep their tail ends firmly inside their egg-shells and never stray from this safe zone until the caterpillar is almost dead. The maggots leave enough life in their host for it to become fully grown and spin a futile cocoon. In this way they obtain the maximum of nourishment and a safe haven for themselves when they in turn come to pupate and spin their own little cocoons. At least six other parasites are also known to attack the caterpillar of the puss moth.

The cocoon spun by those caterpillars that safely reach pupation is a very hard sarcophagus-like container made of twigs. The cocoon is itself a masterpiece of camouflage, melting into the background of twigs and leaves where it is situated. In this prison the creature remains for nine or ten months. When the moth is ready to emerge it softens its wooden box with an alkaline saliva containing caustic potash, and pushes its way out with the help of a special shield formed of part of the pupa shell, The adult puss moth is much more reserved in appearance, with greyish-white or ashy wings with various waves and streaks.

The puss moth has a smaller relative that is also common, and can frequently be found feeding on the same bushes. This is the sallow kitten (*Cerula furcula*), which looks like a dimunitive version of the puss moth [**Figure 11.14**]. Both species of *Cerula* spend two years in their chrysalis. The only hawk-moth frequently seen on bogs is the eyed hawk (*Smerinthus ocellatus*), which also feeds on willow. The dark tussock moth (*Dasychira fascelina*) feeds on other plants as well as willow; the caterpillar has five very distinctive tufts of black-and-white hair down its back, and pencils of black hair on its head and tail.

Two other large moths that live on most bogs are the fox moth (*Macrothylacia rubi*) and the oak eggar (*Lasiocampa quercus*). The large, black caterpillar of the fox moth is covered when fully grown in long, golden-brown hairs that cause skin rash if handled, and can be very dangerous if they get into the eyes. It has a series of transverse orange streaks across its back, and it feeds mainly on heather [**Figure 11.14**]; its name comes from the reddish-brown colour of the adult moth. The males are often noticed on a bright day as they fly wildly over the bog. The caterpillar of the oak eggar is a large black insect, with long brown hair; it feeds on heather and various other plants (including oak, as the name suggests). The adult male is a deep reddish-brown colour with a broad ochre-coloured band at the margins of the wings and a prominent white spot on each forewing. The larger female is somewhat paler in colour.

Heather and heaths are the main or only food plant for several other species of moths also. Some of these are true *tyrphobionts,* meaning that they are seldom found away from bogs. Among them are the beautiful yellow underwing (*Anarta myrtilli*) [**Plate 8**], which is on the wing between April and August; the caterpillars will be found on heather from July to October. The caterpillar is green with broken white bands, and is extremely hard to detect as it feeds in the heather. The colouring of the adult provides even better camouflage. The forewings are purplish-brown in colour, and melt into the hues of the heather when the moth is at rest. The hind wings are covered by the front wings when the moth is not flying, and so are suddenly exposed when it takes wing. These underwings are yellow with black borders, and this sudden 'flash' of the underwings briefly distracts would-be predators – and then, just as suddenly as it came, as the momentarily distracted predator is gathering its wits, it is gone – and the insect has disappeared, hidden away again among the heather a short distance away. The same defensive mechanism of cryptic colouration is also adopted by several other common bog species: the common heath moth (*Ematurga atomaria*), the narrow-winged or heath pug (*Eupithecia nanata*), the true lover's-knot (*Lycophotia porphyrea*) and the heath rustic (*Amathes agathina*). Camouflage is important to animals in any habitat, but it is especially so on bogs and heaths, because they are such open and well-lit areas, devoid of trees, which makes it much easier for a sharp-eyed carnivore to spot potential prey.

Another common bog moth is the grey scalloped bar (*Dyscia fagaria*), which adopts a different approach to camouflage. The caterpillar feeds on heather shoots mainly at night, and the adults rest not on the heather but on bare peat, where their grey or white colour merges into the background. The oddly-named neglected moth (*Amathes castanea*) also feeds on heaths; it does not appear to be all that common in Ireland, but it is a very secretive moth, and is not easily noticed since both larva and adult confine their activities to night time. Because of this, neither needs to be particularly well camouflaged.

One of the commonest of the geometrid moths found on bogs is the grass wave (*Perconia strigillaria*) which feeds on heather, bell heather, broom and furze flowers, The geometrids comprise the largest family of small moths. The caterpillars are known as 'loopers' from their characteristic way of moving. They have two pairs of claspers at the tail end of the body; they move forward by stretching out to their full length, then wave their bodies from side to side in the air before taking hold with their true legs. The claspers are then brought forward to a position just behind the legs, so that the body is 'looped', before the legs are again stretched forward. Other heath and heather-feeding geometrids include the netted mountain moth (*Semiothisa carbonaria*), smoky wave (*Scopula ternata*), common heath (*Ematurga atomaria*), grey mountain carpet (*Entephria caesiata*) and the heath or narrow-winged pug (*Eupithecia nanata*). Several geometrid moths feed on bilberry, including the northern spinach moth (*Lygris populata*), the dark marbled carpet (*Dysstroma citrata*), the July highflyer (*Hydriomena furcacta*) and the argent and sable (*Rheumaptera hastata*).

Another family with many bog representatives is the underwing or owlet moth family (Noctuidae), some of which we have already met. Heath rustic (*Xestia agathina*) feeds on heath and heather, small wainscot (*Photedes pygmina*) is a sedge miner, northern dart (*Xestia alpicola*) feeds on crowberry and bilberry. Caterpillars of the widespread noctuid moth Haworth's minor (*Celaena haworthii*) feed on the stems of hare's-tail cottongrass, and the adults sip nectar from heather and devil's-bit scabious.

There are two rare species which feed on eyebright, which (is a very common plant on many bog fringes: the pretty pinion (*Perizoma blandiata*) is known only in the southwest and north-west of the country, though it may well be more widespread, but the heath rivulet (*Perizoma minorata*) has so far only been recorded from the Mountains of Mourne. A very rare bog species is the silver-barred moth (*Eustrotia olivana*), which is known only from a few bogs in Kerry, and in Britain only from one or two fens, though its food plant is the widespread purple moor-grass, The broom moth (*Melanchra pisi*) is often seen on bogs, where it feeds on a variety of common plants, including bracken, birch and sorrel.

Many small moths belonging to the family Pyralidae are very much at home on the bogs. Among the most characteristic are various members of the sub-families Crambinae (grass moths) and Nymphalinae (China-marks). Grass moths frequent the fringing grasslands in great abundance; they are the little moths that rest among the long grass, and when disturbed fly rapidly for a couple of metres before settling on a grass-stem head down, wings tightly wrapped around the body. Bog fringe species include *Crambus pascuella*, *Crambus silvella*, *Crambus lathionellus*, *Crambus perlella*, *Catoptria pinella* and *Catoptria margaritella*. All of these feed on various grasses and sedges. *Donacaula forficella*, a species in the related sub-family Schoenobiinae, lives in rolled shoots of common reed, sweet-grass or sedges, while the widespread species *Eudonia pallida* is believed to feed on mosses and lichens. A heath and heather-feeding pyralid is *Oncocera palumbella*. The China-mark moths feed as larvae on the leaves of water plants. *Elophia nymphaeata* is the brown China-mark moth, which feeds on pondweeds and bur-reeds, at first as a leaf miner, and later in a floating case made of leaf fragments. *Nymphula stagnata* (beautiful China-mark) lives inside the stems of bur-reeds and some other plants; *Paraponyx stratiotata* spins pond weed leaves together and lives underwater in an open web; *Cataclysta lemnata* (small China-mark) lives in a case made of overlapping leaves of duckweed.

Most of the moths mentioned above are relatively large. But there are few groups of insects that bring home the complexities of ecology better than the small moths, the microlepidoptera. Because the great majority of them are so small, and because they are so secretive, many being on the wing only after dark, we are hardly aware of the existence of this highly successful and complex group of insects. Some twenty species of microlepidoptera are recorded from heather and heath in Great Britain, and most of these occur in Ireland. Very little is known about the private lives and habits of these tiny moths, each of which exploits its food plant in a slightly different way, avoiding direct competition with the many other creatures that also feed on it. A very brief look at a few of these moths may convey some hint of their diversity.

Argyrotaenia pulchellana is a tortricid moth (family Tortricidae) that is often abroad late in the afternoon; it feeds on bog myrtle and bilberry as well as heather and heaths. It lays its eggs in batches of 40 or 50, and the young caterpillars feed together at first on the underside of the leaves, reducing them to skeletons. Later on each caterpillar goes it alone, foraging from a protective silken tent that it constructs from a leaf of the food plant. Another heath, heather and bilberry-feeding tortricid is *Expate congellata;* the female in this species has vestigial wings. *Xenolechia aethiops,* whose larvae live and feed in silken galleries among shoots of heath occurs on the raised bogs of the Midlands, and perhaps elsewhere. One of the commonest bog tortricids is *Ancylis geminana,* which lives on willows; it seems to be particularly fond of rusty sallow. The caterpillar spins the leaves into 'pods', binding the edges with silk, and feeds in safety within, leaving only the upper epidermis [**Figure 11.15**], The hollowed-out 'pods' are especially prominent in early autumn. Other small heather-feeders include *Olethreutes schulziana,* which is often abundant on raised bogs (and will also feed on bilberry) and *Neofaculta ericetella.*

Figure 11.15: *Ancylis geminana* pods on sallow.

The commonest species of plume moth (family Pterophoridae) on bogs is *Stenoptila bipunctidactyla,* which lives on devil's-bit scabious: on the flowers during summer and when these have faded in a silk tent spun in a partly-folded leaf. After hibernation they will be found among the young shoots and leaves. A little-recorded small plume moth of special interest is *Buckleria paludum,* whose caterpillars feed on the leaves of common sundew, though it wisely avoids the upper surface of the leaf where the glue-tipped tentacles would reverse the arrow on the food chain. Two other little moths that seem to be confined to bogs are *Aristotelia ericinella* which lives in a silk tube among the heather shoots on which it feeds, and *Biselachista serricornis*, which is a sedge leaf-miner; so far these have only been recorded for a few midland bogs.

Several species of the large genus *Coleophora* live on bogs. The larvae of these tiny moths make little portable cases from silk and bits of heather and other plants on which they feed. *Coleophora tamesis* feeds on the seeds of jointed rush, *Juncus articulatus*. *Coleophora juncicolella* feeds on heather, and its case looks for all the world like a broken bit of a heather shoot. But of all the moths of the bog, the one which (for us at any rate) best epitomises the complexity, intricacy and fascination of its ecology is the heather case-carrier moth *Coleophora pyrrhulipennella,* whose life-history was elucidated in Jane Feehan's meticulous study for the Aer Lingus and European Young Scientist Contests during 1992-94. The adult moths emerge from their cocoons around the end of July or early in August. The female lays her eggs singly on the undersides of the leaves of heather, each egg directly above the leaf seam. The emerging larva hatches out from the underside of the egg, going directly into the space enclosed by the folded leaf [**Plate 7**], where it begins to feed. As it gets bigger it finds the little enclosure too small, and its tail protrudes from the seam with potentially disastrous conspicuousness. By way of camouflage it covers its behind with a makeshift coat of frass bound loosely with silk. When the caterpillar reaches a certain size it spins what at first looks like a cone or tent of dark silk above the entrance. When this is finished it emerges and wraps the cone around its body, enlarging it as it continues to eat and grow, until finally the cone takes on the appearance of a cigar-shaped twig. When the caterpillar feeds it attaches its case to a leaf seam and grazes from the shelter of the leaf cavity. It is beautifully camouflaged by its dark-coloured case, which looks most un-insect like and stands out at a steep angle from the leaf. The larvae pupate in an inverted position on a woody stem, still holding their cases at a steep angle, and pass four weeks in the pupal stage before emerging [**Plate** 7], *Coleophora pyrrhulipennella* has been formally recorded from very few bogs, but is probably widespread if nowhere abundant. The same is likely to be true of two other species: *Coleophora lusciniaepennella* (*viminitella*), which feeds on bog willows, birch and bog myrtle, and *Coleophora milvipennis* (recorded for the first time in Ireland at Killaun bog near Birr), which feeds on birch [**Figure 11.16**].

Microlepidoptera feed on many other bog plants as well. Nearly two dozen species occur on bog myrtle, and something like fifteen are known to feed on bilberry, though few feed on it exclusively. *Stigmella myrtillella* makes irregular blotch mines on the leaves of cranberry. *Acleris maccana* feeds on *Vaccinium* species and on bog myrtle, making a tube for

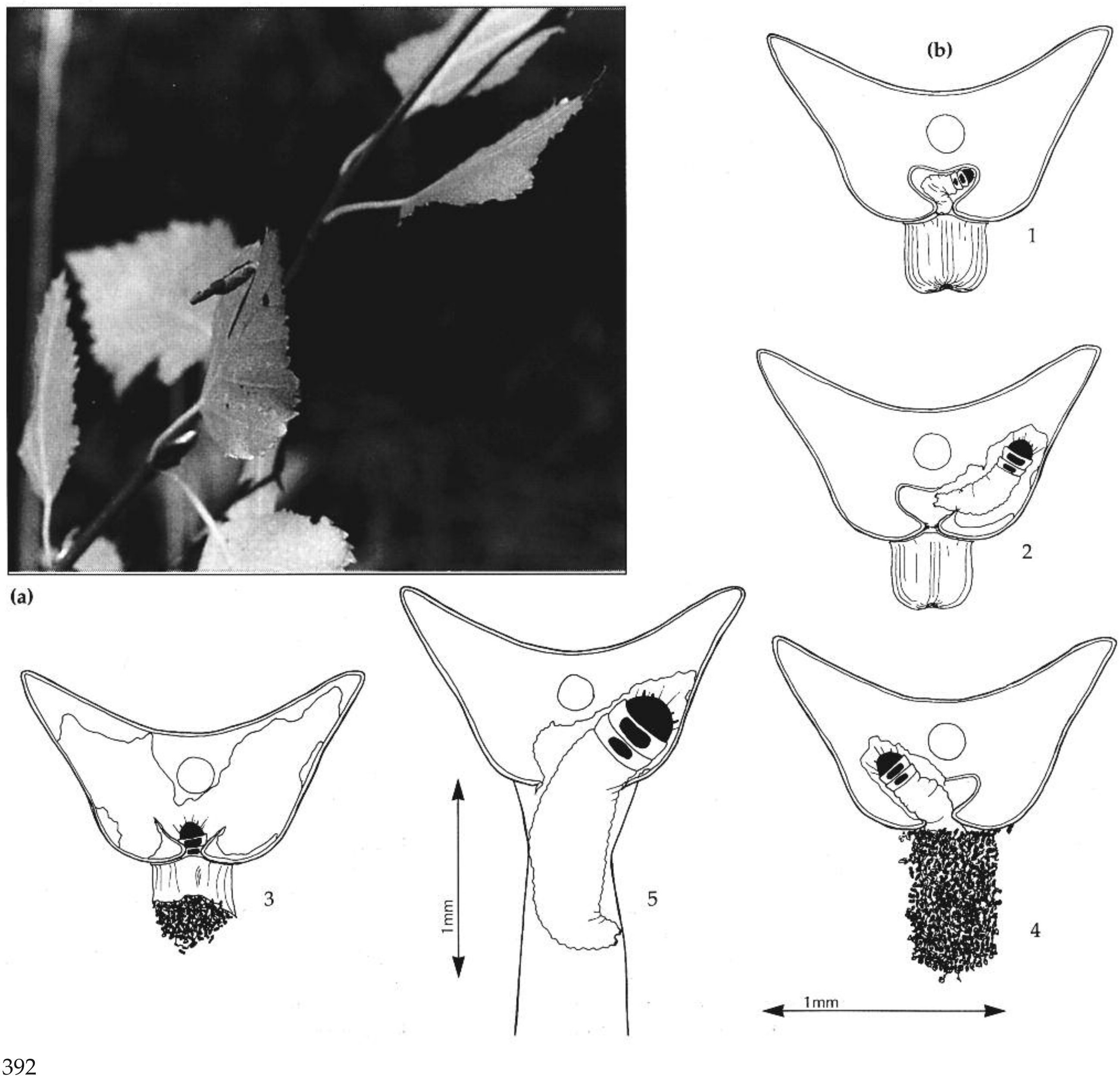


Figure 11.16: (a) Birch case-carrier, (b) Different stages in the development of the heather case carrier moth. (1) shows the larva just after hatching, making its way into the leaf cavity; (2) young larva feeding on heather leaf tissue; (3-4) later stages showing frass being deposited externally; (5) larva about a month after hatching. (Drawings by Jane Feehan).

itself out of leaves spun together in a rather haphazard way. *Griselda myrtillana* is found only on bilberry. The caterpillar lives between two leaves that are spun flat against each other, and in this spacious tent it overwinters before pupating late the following spring in leaf litter. A dozen or so species of micro-moths feed on furze, including the interesting little leaf-miner *Phyllonorycter ulicicolella.*

There are however some bog plants that offer so little in the way of nourishment that few small moths – or indeed other creatures – bother with them. Among these are purple moor-grass, black bog-rush and bog rosemary, bog asphodel and the orchids. Five or so species feed on the different species of cottongrasses. At the other end of the scale is birch, on which at least 74 small moths are known to feed in Great Britain. One particularly common species is *Swammerdammia calsiella* which folds a leaf over and spins the edges together, then grazes its enclosed leaf pasture in (comparative) safety. Willows are nearly as popular, some moths restricting themselves to particular species. *Stigmella salicis* for instance confines itself to the three common bog species (goat willow, rusty sallow and eared willow), feeding in small galleries on the undersides of the leaves. Several *Phyllonorycter* species are willow leaf-miners, such as *Phyllonorycter dubitella* on goat willow.

Non-flowering plants are not immune from the attentions of these ubiquitous little creatures either. Quite an assemblage feeds on mosses, including *Catoptria margaritella*, which seems to be more or less confined to bogs. Others feed on lichens, and about twenty are fungus-eaters, including five or so on birch bracket fungus. One of the few moths which has developed an appetite for the prolific food supply offered by the rhizomes of bracken is the map-winged swift moth (*Hepialus fusconebulosa*).

TABLE 11.6: Some moths which feed on heather and its relatives

Aderis hyemana	Heather or heath species
Adais maccana	Bilberry etc., bog myrtle
Amathes castanea (neglected)	Heather, heaths, rusty sallow etc.
Anarta myrtilli (beautiful yellow underwing)	Heather, bell heather
Ancylis uncella	Heath species, birch
Aphelia viburnana	Bilberry, heaths, bog myrtle
Argyrotaenia pulchellana	Heather and heaths, bog myrtle and bilberry
Aristotelia ericinella	Heather
Callophrys rubi	Heather, bilberry, furze, broom etc.
Carsia paludata (Manchester treble-bar)	Cranberry and cowberry
Coleophora pyrrhulipennella (heather case-carrier)	Heather, cross-leaved heath
Dyscia fagaria (grey scalloped bar)	Heather, heaths, white willow
Dysstroma citrata (dark marbled carpet)	Bilberry etc.
Ematurga atomaria (common heath)	Heather and heaths
Entephria caesiata (grey mountain carpet)	Heather, heaths, bilberry
Eupithecia nanata (heath or narrow-winged pug)	Heather flowers
Expate congellata	Heather, heaths and bilberry
Griselda myrtillana	Bilberry only
Lasiocampa quercus (oak eggar)	Heather mainly
Lycophotia varia (true lover's knot)	Heather, bell heather, cross-leaved heath
Lygris populata (northern spinach)	Bilberry, cowberry, willow
Macrothylacia rubi (fox moth)	Heather mainly
Neofaculta ericetella	Heather, heath species
Olethreutes sculziana	Cranberry, heather, bilberry
Oncocera palumbella	Heather and heaths
Oporinia filigrammaria (small autumnal carpet)	Heather, heaths, bilberry, sallow
Perconia strigillaria (grass wave)	Heather, bell heather, broom and furze flowers
Plusia interrogationis (scarce silver Y)	Heather, bilberry and nettle
Pyla fusca	Heath species, bilberry, cranberry etc.
Satumia pavonia (emperor moth)	Heather, bramble etc.
Scopula ternata (smoky wave)	Heather and heaths, bilberry, sallow
Semiothisa carbonaria (netted mountain moth)	Heather and heaths
Stigmella myrtillella	Cranberry
Xenolechia aethiops	Heaths
Xestia (*Amathes*) *agathina* (heath rustic)	Heather and heaths
Xestia (*Amathes*) *alpicola* (northern dart)	Bilberry and crowberry

Glacial survivors

Several moths that feed on various members of the heather family are glacial survivors, widespread during the cold millennia after the Ice Age but now confined to a few last mountain refuges. The grey mountain carpet (*Entephria caesiata*) is an Arctic-Alpine moth that feeds on heathers and bilberry. The adults are often found in late June and July at rest on old stone walls, against which background they are almost impossible to see. Two rare Arctic-Alpine species are the Manchester treble-bar (*Cassia sororiata*), a rare blanket bog insect that feeds on cranberry and cowberry, and the yellow-ringed carpet (*Entephria flavicinctata*), which feeds on mountain saxifrages; both have so far been seen only in the north of Ireland. Other Arctic-Alpine bog moths include the small autumnal carpet (*Oporinia filigrammaria*), and the scarce silver Y (*Plusia interrogationis*), whose food plants are heather and bilberry.

Hymenoptera: ants, bees and wasps

A considerable number of different species of bees and wasps live on bogs, and many others are regular visitors. Hives of honey bees are often put out on the bog in August to forage on heather blossoms. Heather honey has a jelly-like consistency and is strongly scented, and greatly prized; honey made from species of heath has a 'normal' honey consistency. Heather also attract a variety of other bees, including several bumble bee species. Of the half dozen or so species that regularly visit bogs, the commonest are *Bombus pascuorum, Bombus lucorum, Bonibus muscorum* and *Bombus lapidarius,* The yellow-and-white heath bumble bee *Bombus jonellus,* which feeds on the flowers of bilberry, heaths etc. is also sometimes seen. There are also numerous species of parasitic Hymenoptera that attack the caterpillars and eggs of such insects as moths and butterflies. The main groups are ichneumenoid and braconid wasps, which play an important (if little appreciated) role in biological control in natural communities. Some groups include hyperparasites that in turn parasitise the larvae of parasitic Hymenoptera. Other wasps cause galls in plants, a common example being *Xestophanes brevitarsis*, which can develop only in tormentil; this was quaintly described, as long ago as 1729 by William Maple in his pamphlet on the use of tormentil for tanning:

> It is observable, that from the Bark of the Stalk of this Plant, at its breaking forth from the Root, excrementitious Tubercles or Knots, resembling Oak-Galls have been often discovered, and like them are subservient to the Propagation of Insects; which, considering the extream nice, and distinguishing Taste of those Animalculas, may well be allowed as a Proof, that their Juices are similar.

Solitary bees frequently venture into the bog in search of their preferred nectar and pollen plants. In early spring *Andrena jacobi* is often found on willow catkins, and the girdled colletes or plasterer bee *Colletes succinctus* is one of the commonest visitors to heather in August; this is a small, tunnel-making bee that confines its attentions to heather. *Andrena cinerea,* the grey-haired mining bee, is also fond of heather. The brightly-coloured, wasp-like homeless bee *Nomada lathburiana* always makes its home near the grey-haired mining bee; it is a parasite that hangs around the nests of its host, waiting for an opportunity to lay eggs in its cells. Several species of the large family Tenthredinidae (sawflies), whose larvae feed on plants and look very like small moth caterpillars, are met with on bogs. One of these is *Brachythops flavens.* A very abundant sawfly is *Pontania,* several species of which cause the conspicuous reddish bean-shaped galls that are often very abundant on willow leaves. Crack willow, which is occasionally found growing along bog drains, appears to be particularly susceptible to attack by the sawfly *Pontania proxima*.

Several species of ants belonging to the genera *Myrmica*, *Formica* and *Lasius* forage extensively on the bog: they will be found even in the centre of the most extensive bogs.

The most characteristic species are probably *Myrmica ruginodis*, *Myrmica scabrinodis* and the black ant *Formica lemani.* They seem to be in search of pollen and whatever other fodder may be available, but their main quarry is insect prey for the larvae back home, and honeydew secreted by aphids for themselves, *Seangán* – the Irish word for ant – is occasionally found as an element in townland names. This is surprising in view of their unobtrusive life style: unobtrusive until a sultry day in August that is, when the winged forms take to the air in unbelievable numbers, and we are reminded of just how numerous the earthbound workers must be, going about their endless labour on and below the ground, and that the role they play in bogland ecology – little though we know about it must be a very significant one.

Diptera: true flies

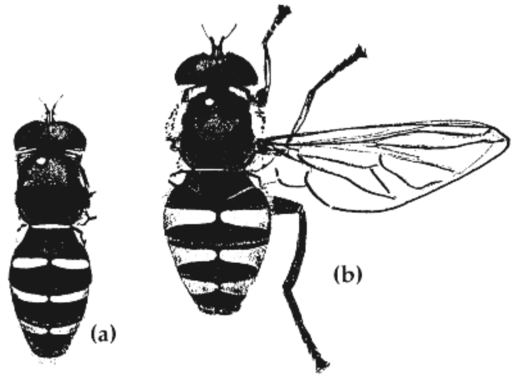
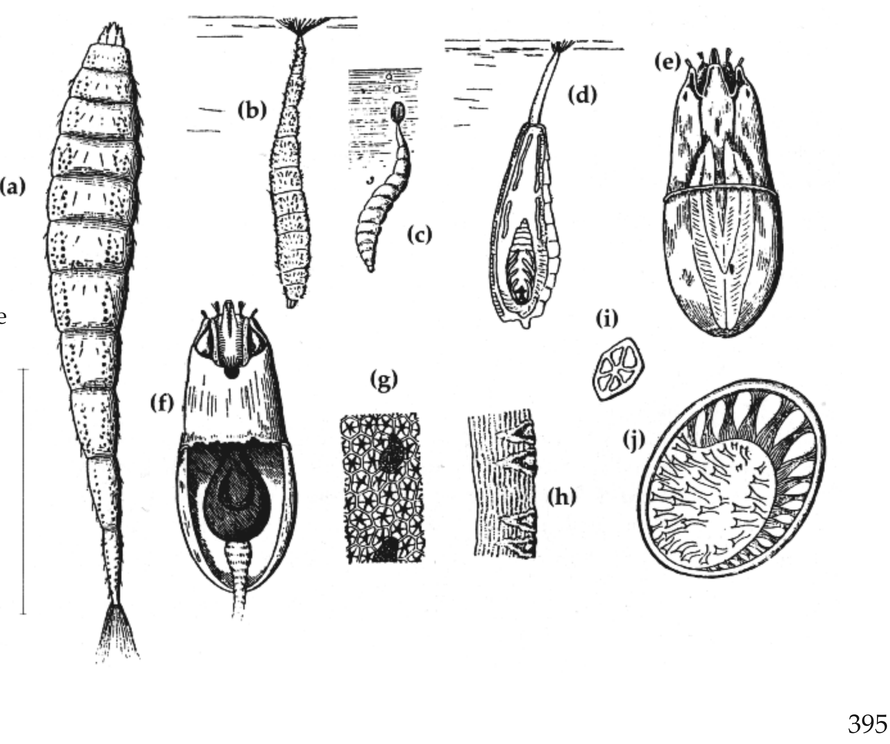


Figure 11.17:
(a) *Sericomyia lappona.*
(b) *Sericomyia silentis.*

Flies abound on the bog, although few can be regarded as real tyrphobionts. Many are inhabitants of the fringing birchwoods, where wild angelica is often abundant, and its flowers are a good place to see a cross-section of the resident larger flies. Hoverflies are always well represented, including species of the genus *Sericomyia*, elegant wasp-like flies whose larvae inhabit soggy peat and peaty pools, where they feed on whatever bits of organic matter they can find. The commonest species is *S. silentis*, which is often seen on devil's-bit scabious in late summer; *S. lappona* is widespread but not very common. The larvae are known as rat-tailed maggots because of their long tails – telescopic breathing tubes in fact, which they use as snorkels to enable them to take in atmospheric air while remaining submerged. Most of the other hover flies attracted to wild angelica are more in the nature of blow-ins.

The maggots of soldier flies (Stratiomyidae) are sometimes found in old bogholes and stagnant ditches. They are irridiscent and attractive flies as adults, but the larvae are especially interesting. The body segments overlap each other, enabling the larva to expand in a telescopic fashion. This helps it to keep the tip of its tail - through which it breathes air - at the surface. The tail opening is surrounded by a beautiful coronet of branched

Figure 11.18:
Stratiomys. (a) Larva.
(b) Larva floating at the surface of the water.
(c) Larva descending.
(d) Pupa inside the larval skin.
(e) Dorsal view of the head.
(f) Ventral view of the head; wall incomplete behind, to show pharynx and gullet.
(g) A small piece of the leathery skin.
(h) Leathery skin in section, showing the conical calcareous nails.
(i) A single nail, seen from above.
(j) The spiracle, which lies in the centre of the tail-coronet.
(From Miall, 1895).



filaments; when expanded these form a basin which is impervious to water. They are folded up at the first hint of danger, allowing the larva to submerge with streamlined efficiency **[Figure 11.18]**.

Crane flies are among the most conspicuous insects, on cutover bog especially, where they often occur in great numbers. The larvae are big, greyish-brown thick-skinned cylindrical maggots, the leatherjackets familiar to anybody turning turf, because they are often very common under sods left to dry on the spreading ground [**Figure 11.19**]. The larvae hatch from the eggs around August, and spend the nine months between September and July underground, feeding on the roots of various plants, including those of agricultural crops if they are available. There are several species, the most abundant by far being *Tipula paludosa,* the marsh crane fly, and *Tipula subnodicornis*, but in any bog there may be as many as a dozen other species, each occurring in a different habitat, occuping its own specific niche. Some species are confined to areas of sphagnum, others to peat mud; *T. subnodicornis* seems to be especially fond of peat dominated by hare's-tail cottongrass and heath rush. On Irish blanket bogs there may be as many as fifty species altogether, and a considerable number of these are confined to peaty habitats. Meadow pipits take large numbers of crane flies, especially when they have young to feed. A species worthy of special mention is *Dictenidia bimaculata,* which occurs in the birch woods at Clara and All Saints' bogs, where its larvae live in rotting wood. It is more colourful than most crane flies, with a shiny black body, the female with orange legs. This particular fly is a representative of the ancient European woodland fauna that was once much more widespread than it is today. Its survival in Europe generally is now threatened because of extensive habitat loss.

Horseflies (tabanids) are certainly among the most conspicuous of bog insects in summer, for the very good reason that they pay great attention to moving reservoirs of warm mammalian blood – at least the females do, for it is only the females that possess the efficient little dagger-like syringes for drawing blood. They need this blood to give them the nutrients they require to produce eggs. These dreaded flies are very beautiful creatures, with iridescent eyes and patterned wings. Nine species are known for Ireland,

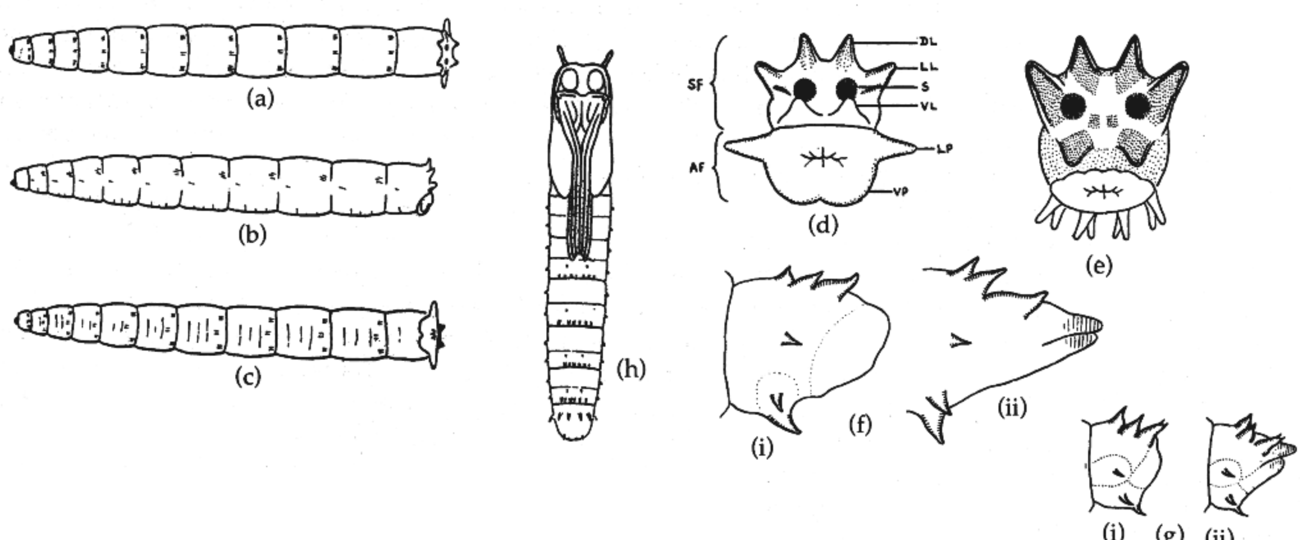


Figure 11.19: Leatherjackets.
The details of anal anatomy are important in distinguishing the many species of leatherjackets. The contrasting anal details of *Tipula paludosa* and *Tipula subnodicornis* are shown here (Brindle, 1960).
(a)-(c) *Tipula paludosa* larva in dorsal, lateral and ventral view respectively.
(d) The anal segment of *Tipula paludosa* viewed from the rear. SF: spiracular field; AF: anal field. VL, DL, LL: ventral, dorsal and lateral lobes respectively. LP, VP: lateral and ventral anal papillae. S: spiracle.
(e) The anal segment of *Tipula subnoricornis* viewed from the real.
(f) The anal segment of *Tipula paludosa* viewed from the side; (i) male, (ii) female.
(g) The anal segment of *Tipula subnordicornis* viewed from the side; (i) male, (ii) female.
(h) Pupa of *Tipula paludosa* in ventral view.

several of which occur in bogs. One of the most widespread and characteristic is *Chrysops relictus.* Two other common bog species are *Haematopota pluvialis* and *Haematopota crassicornis. Hybomitra montana* is a species that appears to favour areas of lowland blanket bog, though it is also seen on raised bogs. The generic names for these flies are very apt: *Chrysops* means 'golden-eyed', and *Haematopota* means 'blood-drinker' in Greek [**Figures 11.20, 11.21**].

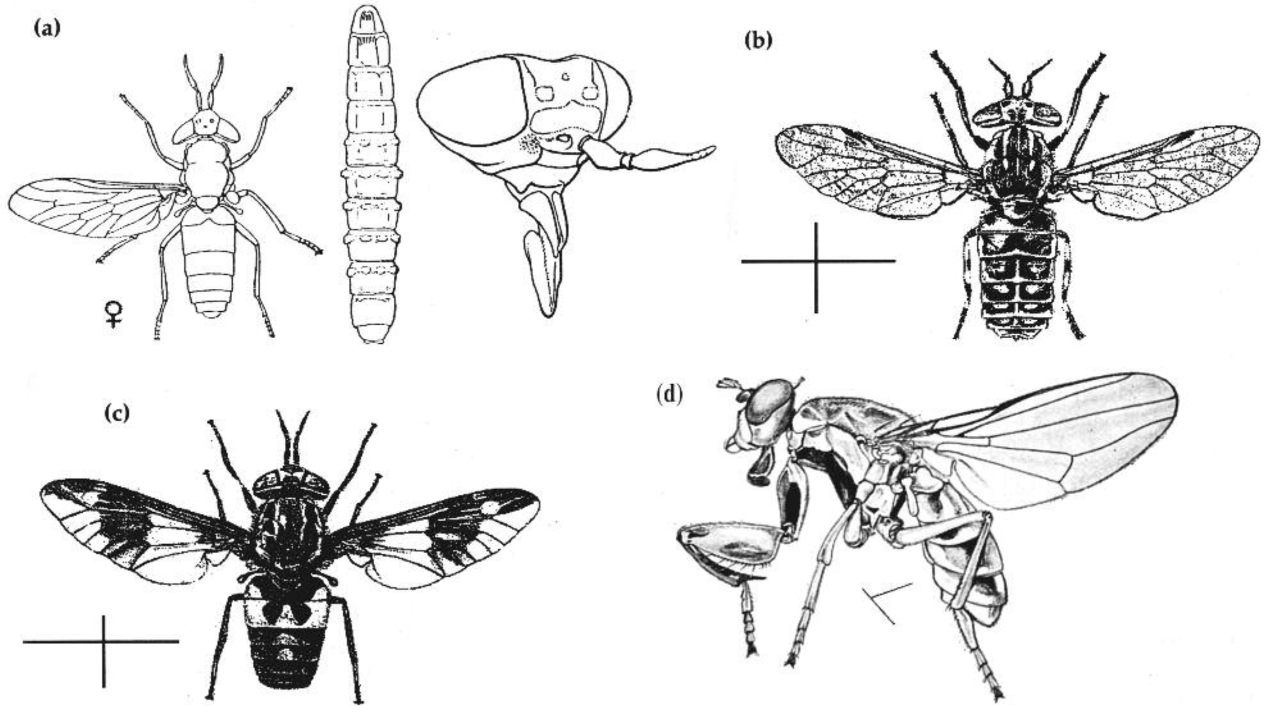
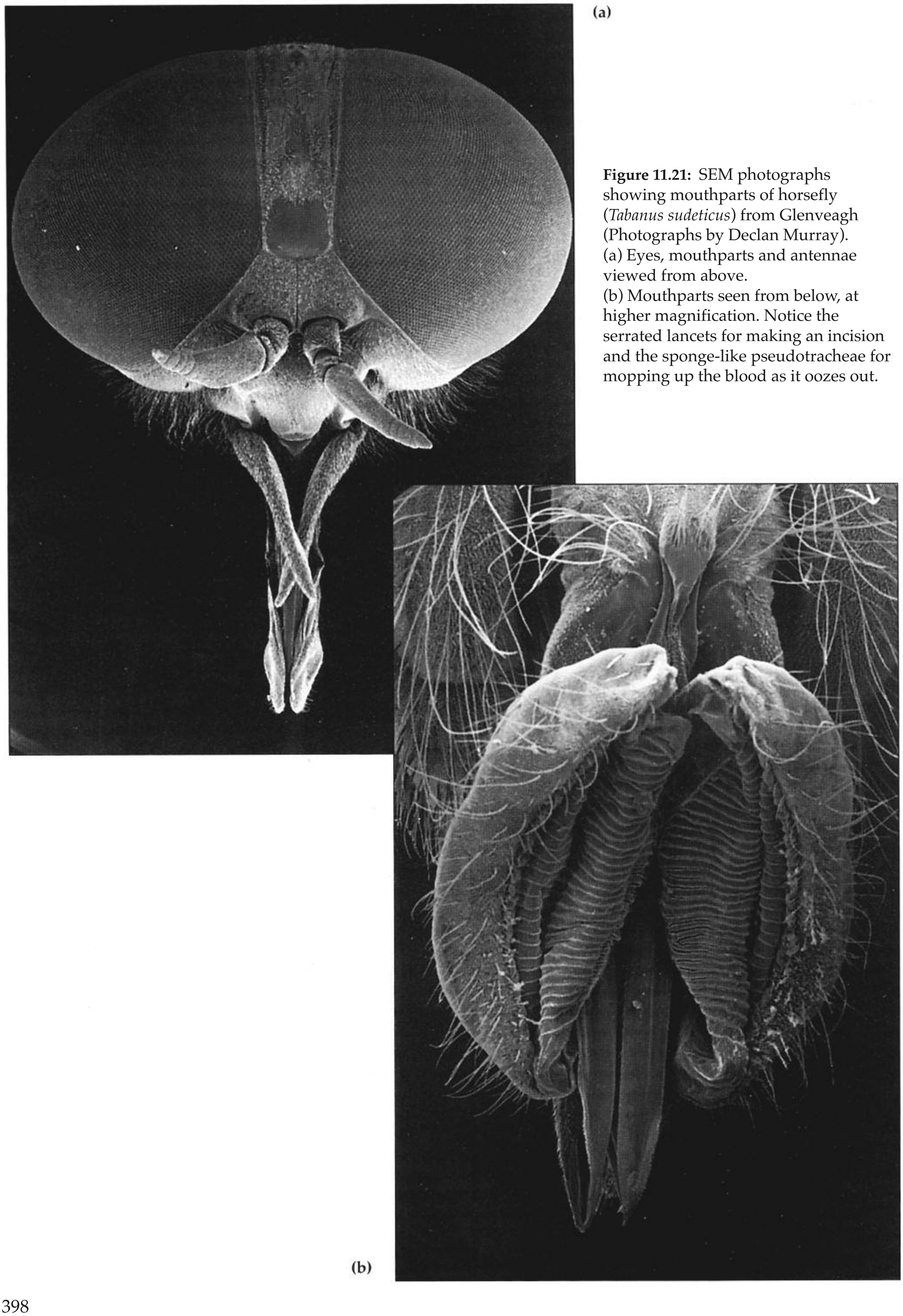


Figure 11.20: Horseflies and clegs.
(a) *Haematopota pluvialis:* adult female, larva, head of female.
(b) *Haematopota crassicornis* (female).
(c) *Chrysops relictus* (female). (d) *Octhera mantis.*
[(a) from Seguy; (b), (c) and (d) from Colyer and Hammond].

Tachinid flies are among the most fascinating – not to say horrific – of all insects. The larvae develop as internal parasites of other living arthropods, especially butterfly and moth caterpillars and other insects. They are the ichneumons of the fly world, only causing the death of their hosts when they have finished their own development and are ready to pupate. They are likely to be found wherever their hosts occur; *Tachina* species parasitise a great variety of Lepidoptera, so they are among the most typical bog tachinids. One common species found on bogs is *Tachina grossa*; others include *Linnaemya vulpina*, often seen feeding on bramble flowers, and *Gonia picea*. Another family of parasitic flies are the Conopidae, whose larvae develop inside adult bees and wasps. They are wasp-like themselves in appearance, and the species recorded from bogs include *Sicus ferrugineus,* which is a parasite of bumble bees, The family Calliphoridae also have their bogland representatives. This is the family that includes the blue bottles or blow-flies (*Calliphora*), the green bottles (*Lucilia*) and the grey flesh-flies (*Sarcophaga*), which feed as larvae on carrion and other decaying animal matter. Other species are blood-suckers or infest sores and wounds in mammals; others again feed on the food-stores of burrowing bees and wasps. One such species that is sometimes encountered on bogs is *Brachicoma devia*, which is larviparous; the eggs hatch inside the mother and the larva is laid by the mother in a bumble bee nest, where it wanders freely before attacking and entering a prepupal bee, inside which it completes its development.

The Ephydridae are a family of wet places, including bogs, which includes many predators in its ranks. The most fascinating is *Octhera mantis*, a rare fly recorded on Killaun bog in Offaly but perhaps occurring more widely than our limited records suggest. It has long, spiky legs like nutcrackers, which it uses to catch prey in much the same way as a mantis does. The curved tibia of the foreleg folds against the flattened femur just like pocket knife [**Figure 11.20**].



(a)

(b)

Figure 11.21: SEM photographs showing mouthparts of horsefly (*Tabanus sudeticus*) from Glenveagh (Photographs by Declan Murray).
(a) Eyes, mouthparts and antennae viewed from above.
(b) Mouthparts seen from below, at higher magnification. Notice the serrated lancets for making an incision and the sponge-like pseudotracheae for mopping up the blood as it oozes out.

Because they are such watery places, bogs are a paradise for those most dreadful little flies, the biting midges, which belong to the family Ceratopogonidae. Many kinds feed on the blood of larger insects, such as butterflies, caterpillars and dragonflies. Of the thirty or so species in Ireland, only four attack people. The mammal-biting midges so abundant on bogs in the summer belong to the genus *Culicoides*; so irritating is their bite, and so abundant are they, that they make work – or just a walk on the bog – a real ordeal, especially in sultry weather. The varying abundance of midges at different times of the day or in different kinds of weather is due to variation in light intensity; the critical light level is 260 watts per square metre, and whether this is due to cloud, shade or the time of day, once the light gets below this the midges come out in swarms from their hiding places in the vegetation. They are unable to fly when the wind gets above a certain intensity, when they will quite suddenly disappear. The commonest biting midge on the bog is *Culicoides impunctatus* [**Figure 11.22**]. The larvae are tiny, thin, worm-like creatures that live in mud or wet peat or at the surface of ponds and similar places. Small biting flies of other families will also be found on some bogs. Where moving, well-aerated water provides a suitable home for their fascinating larvae, small biting flies of the family Simuliidae are often common; they are widely encountered on blanket bogs.

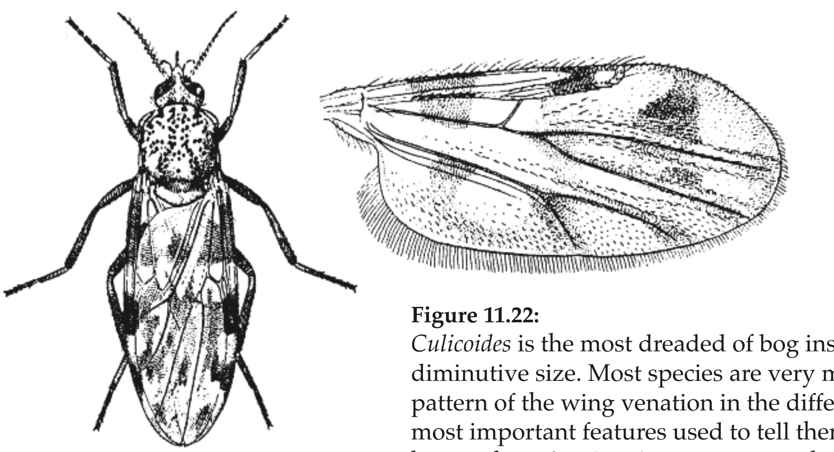


Figure 11.22:
Culicoides is the most dreaded of bog insects, in spite of its diminutive size. Most species are very much alike; the distinctive pattern of the wing venation in the different species is one of the most important features used to tell them apart. The wing shown here is that of *Culicoides impunctatus,* the commonest bog species.

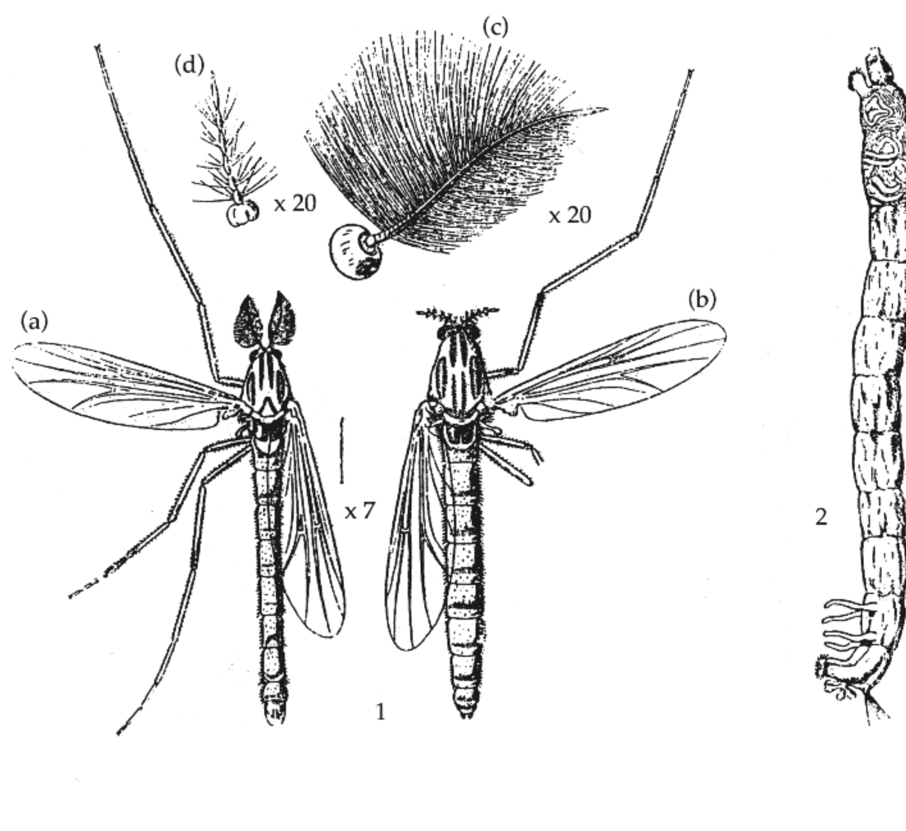


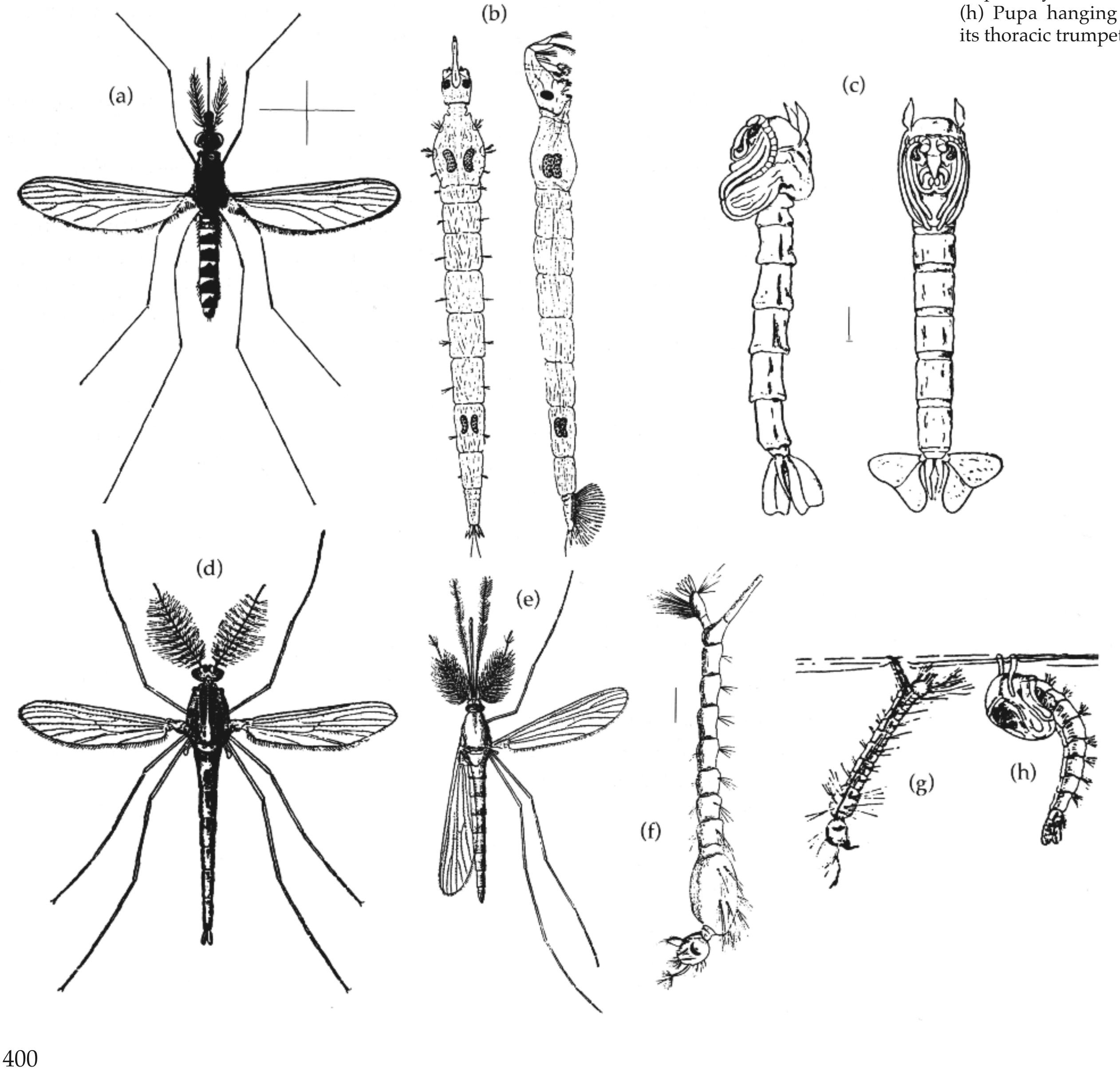
Figure 11.23:
Non-biting midges.
1. Fly of *Chironomus;*
(a) male fly;
(b) female fly;
(c) antenna of male;
(d) antenna of female.
2. Larva of *Chironomus.* Near the head (top) are seen the rudiments of the wings and legs of the fly, enclosed within the larval skin.

But not all small flies or midges bite. Large swarms of non-biting midges (family Chironomidae) are a common sight near water, and their larvae are among the most abundant animals of wet peat. Some species are known as blood worms because of their red colour, which is due to the haemoglobin in their blood: the same oxygen-binding pigment as we have in our own blood. This haemoglobin enables them to make the most efficient use of the scarce oxygen resources in their peaty surroundings. They build turrets or tubes of muddy debris at the surface of wet ponds or mud – 'settlements' of these are a common sight on parts of the bog. Through the tips of these turrets they poke their heads in search of decaying plant matter, hooking themselves to the walls of their towers with elegant hooked 'feet' [**Figure 11.23**].

It comes as a surprise to many people to learn that we have mosquitoes in Ireland, but in fact there are many Irish species of mosquitoes – or gnats as they are more generally more known in Ireland – and up to the end of the last century at least one of them carried 'ague', a type of malaria now extinct here. Few European mosquitoes carry disease, but their bite is none the less effective for all that. The larvae live in water bodies of different kinds; one bloodthirsty species that is more typical of the acid water in boggy or peaty habitats is *Aedes punctor* (*punctor* means what the sound suggests: one who punctures or injects). As with most other biting insects, it is only the females that bite. Whatever we may think of their parents, the larvae and pupae of mosquitoes are fascinating creatures [**Figure 11.24**]. The larvae of *Aedes punctor* live in pools with rotting leaves on the bottom.

Figure 11.24: Mosquitoes and their relatives
(a) *Aedes punctor.*
(b) Phantom larva (Corethra).
(c) Pupa of Corethra:
(d) Adult fly.
Dorsal view on left, side view on right. The two pairs of air sacs which enable it to remain suspended in the water are seen in the first and eighth segments behind the head.

Culex pipiens.
(e) Adult male gnat.
(f) Larva in side view.
(g) Larva hanging by its abdominal respiratory tubes.
(h) Pupa hanging by its thoracic trumpets.



A family very closely related to the mosquitoes are the Chaoboridae. The adults are very mosquito-like, but the larvae could hardly be more different from those of mosquitoes: and are among the most extraordinary creatures to be seen in bog pools. They are known as ghost or phantom larvae, because they are transparent. Most of their internal structure can be identified from outside – including the little beating heart, pumping away. *Chaoborus* maintains an absolutely motionless horizontal position in the water, unnoticed by passing water fleas and other small crustaceans that are impaled by its razor-sharp fangs [**Figure 11.24**].

Wherever there are fungi there will be fungus-gnats (Mycetophilidae); they abound in the rotting fruit bodies of the large agarics that are so abundant in the autumn birchwoods. One of the many common species is *Cardyla crassicorne*, whose larvae are nearly always present in decaying *Russula*. Species that are common everywhere include *Microcera cinerascens*, *Boletina gripha* and *Boletina trivittata*. Other interesting species include *Bolitophila cinerea* and *Microcera stigma*, which are probably widespread on bogs, but have seldom been recorded. Small empidid flies are frequently seen in swarms on the bog; they are killer flies that prey on still smaller flies and other insects; a common species is *Empis tesselata*.

One of the commonest flies on reclaimed bogland areas is the little fever fly (*Dilaphus febrilis*, family Bibionidae), which is sometimes seen in enormous numbers in spring, and whose larvae may cause damage to the roots of grasses and cereals. Another fly belonging to the same family, which is often abundant in and around bogs in spring is the Saint Mark's fly (*Bibio marci*), a large, hairy black fly, with a distinctive sluggish flight. The majority of flies in the family Cecidomyiidae live inside plants, where they give rise to galls. A common species is *Rhadbdophaga rosaria,* which causes rosette galls on willows.

Another family of flies that live in plants are the leaf-miners and stem-borers (family Agromyzidae). Different species specialise in the mining of different plants, and the form of the mine is often a tell-tale clue as to the identify of the miner. The larval agromyzid is uniquely well off. From birth it is sheltered comfortably indoors with an insulating roof and floor of cellulose to protect it from the variation in humidity and temperature outside, and surrounded on all sides by an inexhaustible storehouse of food. Through this mountain of food the little miner eats its meandering way, totally mindless of the world outside – except when (as often happens), it is attacked by parasitic Hymenoptera. Species of *Cerodontha* mine the leaves of various grasses, but the most obvious species is *Phytomyza ilicis*, which causes the blotch mines so common on holly. Other common dipterous leaf miners to be looked for in and around the bog include *Pteridomyza hilarella* on bracken, *Stigmella splendidissimella* on bramble and *Phytamyza xylostei* on honeysuckle.

A number of species of the tiny flies known as owl midges or hairy moth flies, which belong to the family Psychodidae, are abundant on peatlands. These are midge-like flies with unusual-looking hairy wings that are distinctively ovate and somewhat pointed in outline. *Sycarax silacea* is a fen species, the adults of which are believed to feed on amphibian blood. *Psychoda minuta* is a species that is very rarely seen away from peatland localities. *Telmatoscopus maynei* is a very rare species so far recorded in Ireland only from Scragh bog.

All of this gives no more than the merest glimpse into the lives of some of the more characteristic flies found on the bog. It is one of the areas where there is a whole world of investigating and research still to be done.

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Chapter Twelve

Water in bogs

The soile is low and waterish, including diverse little islands invironed with lakes and marrish. Highest hills has standing pools at their tops ...

'Of the Nature of the Soil and other incidents'; Chapter 2 in the 2nd Volume of the Chronicles, compiled by Richard Stanihurst (1586).

Introduction

In the nineteenth century, when people were beginning to look at them in a more scientific manner, it was thought that bogs behaved like giant sponges, absorbing excess moisture in times of heavy rainfall and so preventing excessive runoff, and giving up some of the water in their peat reservoir in times of drought. Some of the early observers, among them Richard Griffith thought that the water in the bog 'sponge' was supplied by springs beneath the bog; his colleague Townshend on the other hand believed that the wetness of bogs was due to rainwater, and that the springs did not penetrate up through the bogs. Although the hydrology of peatlands is much more complex than this, both of these views contain a measure of truth. The bog does accumulate rainwater and retains it like a sponge, and so it does not act as an extra source of water entering streams and rivers. The affect of the bog on local climate is today generally regarded as very local, but the proceedings of some of the hearings held in connection with Arterial Drainage in the last century (e.g. along the River Barrow) suggest that then, at least, these affects were quite considerable.

But the bog is not an evenly-textured sponge. In raised bogs in particular, the upper sphagnum peat is light and spongy, whereas the lower part is dark and heavy and dense, so that in level bogs there may be a tendency for water to accumulate between the two layers. Sometimes this trapped water behaves rather like a river. Such a quagmire or 'wet vein' was described as running all through the chain of bogland that stretches south-eastwards from Dromard below Knocknahaw (which is near Rathdowney, in County Laois); the Great Southern and Western Railway ran over a small bit of this bog at Dromard, and great expense was incurred as a result. Large cavities were said to exist in Dromard bog, 'into which considerable streams flow and disappear beneath it'.

The lakes that formerly occurred in the centre of many bogs were a sort of hydrological heart, and they were often the target for 19th century drainage; If their waters could be tapped, the bog would be deprived of its heart. Shaking bogs often mark the site of an entombed *laughlin* or *slough* on a bog, formed by the overgrowing of the open water; the water may still be trapped as a lens beneath. Under the right conditions, such bogs were particularly prone to burst. Springs occur in many bogs, causing 'soak' areas, where upwelling mineral-rich water gives rise to a pocket of fen-like vegetation quite different to that of the surrounding bog, and often supporting rare and interesting species. Because of the disappearance of the larger raised bogs, and the drainage of others, soaks are now rare features. These springs may have their source a considerable distance away, especially in limestone districts, and in times of very heavy rain they may act as conduits.

The hydrology of bogs

The bog behaves like a giant sponge; when the sponge is less than full, very little of the rainwater falling on the bog seeps away. Once the sponge has been recharged, the rest of the water runs off. Since water is the very life of the bog, an understanding of these aspects is an important matter, especially in the areas of peatland management, conservation and rehabilitation. From a hydrological viewpoint, the main anatomical distinction in a bog is between the actively-growing sponge of sphagnum at the surface, generally between 0.1 and 0.3m deep – called the *acrotelm* – and an underlying *catotelm* made up of saturated peat in which there is very little biological activity or movement of water [**Figure 12.1**]. The water table in a bog is almost at the surface; like the surface itself, the water table of a raised bog is domed, as a consequence of the low hydraulic conductivity of the catotelm. The catotelm must remain saturated in order for the acrotelm to remain so too. If the water level falls for any length of time by 0.1-0.2m below the vegetation cover, sphagnum growth will cease. In very dry periods during which there is little rainfall, the sponge can keep the acrotelm active by sagging, thus maintaining the high water level on which sphagnum depends. Shrinkage results in an increase in the storage co-efficient, which means an increase in the ability of the acrotelm to absorb water when it does rain. If the catotelm loses water as a result of drainage, it will attempt to compensate by soaking up essential water from the living acrotelm above. The hydraulic conductivity declines by a factor of 100-1,000 between the bog surface and the base of the acrotelm. Because of oxidation of organic carbon by micro-organisms, the C:N quotient falls from 100 or more at the surface to typical values of 25-35 at the base of the acrotelm. If the catotelm begins to dry out, bacteria and fungi will rapidly initiate decomposition of the peat.

The electrical conductivity of bog water is only slightly less than that of rainwater, and since this is a measure of the dissolved ionic content, it is a reflection of the low level of nutrients present in bog water [**Table 12.1**]. The amount of bicarbonate is even lower than in rainwater; the only ion that is substantially higher is sulphate. In bogs, sulphate is normally converted to sulphide by anaerobic bacteria, but this is a slow process, which is most active just below the water table at about 0.25m, so sulphate tends to accumulate, and is readily leached.

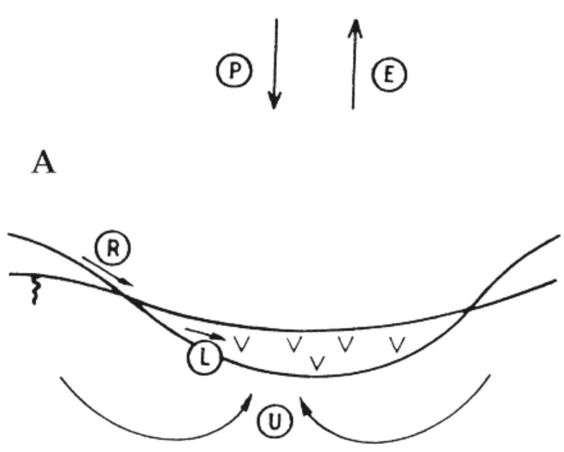
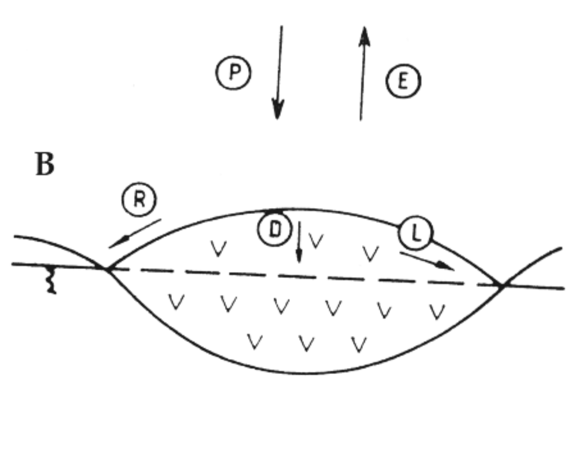


Figure 12.1: The water movement in peatlands.
(a) Fen with concave relief: P - E + R + L + U or - D = ΔS.
(b) Raised bog with domed relief: P - E - R - L - D = ΔS.
P = precipitation, E = evaporation, R = surface runoff or supply, L = lateral seepage, D = downwards vertical seepage, U = upwards vertical seepage, ΔS = change in storage capacity.
(From Streefkerk and Carparie 1989).



The domed profile of an intact raised bog ensures that it will be *ombrotrophic,* i.e. it relies on the rain for its water supply. Most of this rainwater is lost by evapotranspiration. A little infiltrates into the peat, but a significant amount is lost as surface run-off, and this horizontal 'surplus' flow is vital to the healthy continued growth of the peat-forming sphagnum and the maintenance of the oligotrophic (low-nutrient) status of the bog. Hydrological isolation from the influence of nutrient-rich ground water, or from the influence of drainage water from surrounding land, are also essential to the maintenance of this oligotrophic status. However, the low-nutrient status of the bog can be altered if there is an increase in the nutrient levels present in the rainfall, which may happen as a result of atmospheric pollution. Sphagnum is especially sensitive to SO_2 levels.

Table 12.1: ELECTRICAL CONDUCTIVITY OF WATER IN NATURE

TYPE OF WATER	ELECTRICAL CONDUCTIVITY IN m Sm^{-1}
Rainwater	5 to 6
River water	50
Bog water	5

The horizontal discharge of water from the bog has two components: rapid discharge of genuinely superfluous water across the surface, and what is called system linked discharge, which makes its way more – slowly through the acrotelm. The detailed pattern of discharge depends on the nature of the surface topography and the overall morphology of the bog – and in turn influences that pattern, as well as the spatial variation in peat-accumulation processes taking place on the bog. The discharge water must leave the bog if its oligotrophic status is to be maintained: evaporation of water that is stagnant would cause nutrient levels to rise, and would also alter the pH.

Bog drainage lowers the water table, depriving sphagnum in the acrotelm of its essential water supply. Air replaces water, and allows decomposition of dead plant material to set in. This raises the nutrient status and the pH, and the shrinkage caused by the loss of water tends to increase their concentration. Moreover, drainage decreases the downward dissipation of heat; the surface stays warmer, facilitating the germination of seeds as well as microbial activity. Drainage increases surface run-off in the winter half year and causes it to decrease in the summer half-year, because the capacity of the drying peat is greater and it will take up more of whatever rainfall the summer brings.

Permeability is very much greater in the acrotelm than in the catotelm, but water in the acrotelm moves very much faster horizontally than vertically. Within the catotelm, the reverse is true. Only 10-15% of total discharge, which is as little as 3-6% of the total precipitation, reaches the catotelm, where it moves slowly through the peat in a predominantly vertical direction. This permeability decreases down through the peat as pore volume is reduced because of increasing humification and pressure; in the poorly humified upper layer it may be as great as 1m/day, whereas at the bottom of the profile it is hardly moving at all.

Calculation of the water balance will give a minimum value for the formation and maintenance of bog growth. In Holland this is 700mm/year, of which 550mm is lost by evapotranspiration and 110mm is required for system-linked discharge. The pattern of distribution of rainfall through the year and mean annual temperature are also limiting values.

So for a bog to remain healthy, the annual rainfall needs to be considerably higher than that which is returned via evapotranspiration and the small amount that is 'lost' by infiltration down into the catotelm. The microenvironment in the hummocks is likely to be more acid because they tend to be more completely flushed: water flows from hummocks towards hollows, and thence peripherally towards the bog margins, carrying most of the dissolved nutrients with it. One consequence of this peripheral removal of nutrients is that the habitats of the bog margin will often tend to be mesotrophic rather than oligotrophic. What little the acrotelm retains in the way of nutrients appears to follow the following table of preference:

Mg>N>Ca>K>Mn>Na

so the likelihood or extent of removal moves in the opposite direction.

Only at Clara and Raheenmore bogs has a study of the detailed hydrology, the distribution of spatial patterns within the peat and the mechanics of peat formation on a very local scale, been carried out in a way that allows a truly intimate understanding of how the circulation of a raised bog works. This work was carried out as part of the Irish-Dutch Raised Bog Geohydrology and Ecology Study in the early 1990s. The research shows that two separate groundwater flow regimes exist in Clara bog: one in the underlying till and the bedrock beneath, and the other in the bog itself. The groundwater flow moves from an area of recharge in the ridges of sand and gravel which overlook the bog on the north, into the Silver River and its tributary drains to the south. In the raised bog on the other hand, the groundwater flow radiates outwards from each of the two bog domes on the bog (the road across the bog having split the original single dome into two). The hydrology in the fringing lagg zone at Clara is more complicated. Here there is often a mixing between the two regimes, with correspondingly complex and interesting ecological effects. Although no other bog has been investigated in such detail, it is clear that this pattern of two separate regimes is (or was) found in many bogs, and that there are often interactions between the two at the edges and through a conduit system of cracks and faults in the peat.

This study provides a detailed picture of the overall hydrology of a relatively intact raised bog. However, different sorts of processes and patterns operate in bogs of other kinds, and the detailed hydrological picture in any particular raised bog is a good deal more intricate than this simple account might suggest. The system-linked drainage outlined above maintains the summit vegetation of a mature bog, but each of the many species of sphagnum has subtly different ecological preferences, and hydrological variation brought about by alteration of the bog often introduces a shift in the spectrum of opportunity, which new species can take advantage of as long as the water table remains high and the impermeable peat foundation remains intact.

Hydrological considerations are important in the regeneration of peatland, and of raised bogs in particular. It will be remembered that these bogs began as minerotrophic fens; they did not develop on a mineral substrate. As the fen evolved and the peat became deeper, the influence of calcareous ground water decreased. At a certain point in time the influence of rainwater rather than groundwater became predominant in the upper layer, causing acidification and leading to the invasion and eventual dominance of sphagnum mosses.

Prom field studies in acidifying bodies of water carried out in Holland it appears that luxurious growth of sphagnum will only occur at very high carbon dioxide levels in the soil solution and water layer. This suggests that CO_2 probably plays an important role during the initial phase of colonisation by sphagnum. When peat is removed from a bog, the CO_2 concentration in the bog water or the remaining peat depends on the pH and on the nature of the substrate. In fen peat the production of CO_2 is probably high, and should facilitate sphagnum growth. Where no fen peat remains, however, the level of CO_2 may not be high enough to encourage active sphagnum regrowth.

Bog bursts

I remember George Francis Fitzgerald accounting for the large number of local bog-flows by the suggestion that the frequency of political tremors in Ireland shook the bogs down the mountain-sides; but he thought that a *grave objection to this theory lay in the fact that only three had been recorded from Ulster!*

R. Lloyd Praeger, *The Way That* I *Went*

Of all the phenomena associated with bogs, the most dramatic are certainly bog bursts, in which great chunks of bog begin to move as a unit due to the liquefaction of the peat lower down. Bog bursts are a peculiarly Irish phenomenon: they occur only rarely elsewhere. Large bog bursts are not frequent events, but they can be destructive of life and property. The catastrophic burst of Poulevard or Castlegarde bog in Limerick in 1708 swallowed up three houses, claiming 21 lives. Eight people lost their lives in the Knocknageeha bog burst near Killarney in 1896. On 10th October in 1900 a bog slide at Ballaghline near Lisdoonvarna in Clare overran a house, killing two people, and caused much damage to land. In 1909 a bog slide occurred at Kilmore in Galway which overwhelmed the small village; the liquid peat rose to the very roof-tiles and one woman was suffocated in her sleep. Over 40 bog bursts have been described in the last hundred years or so; some of the better known are listed in Table 12.2 [See also **Figure 12.2**].

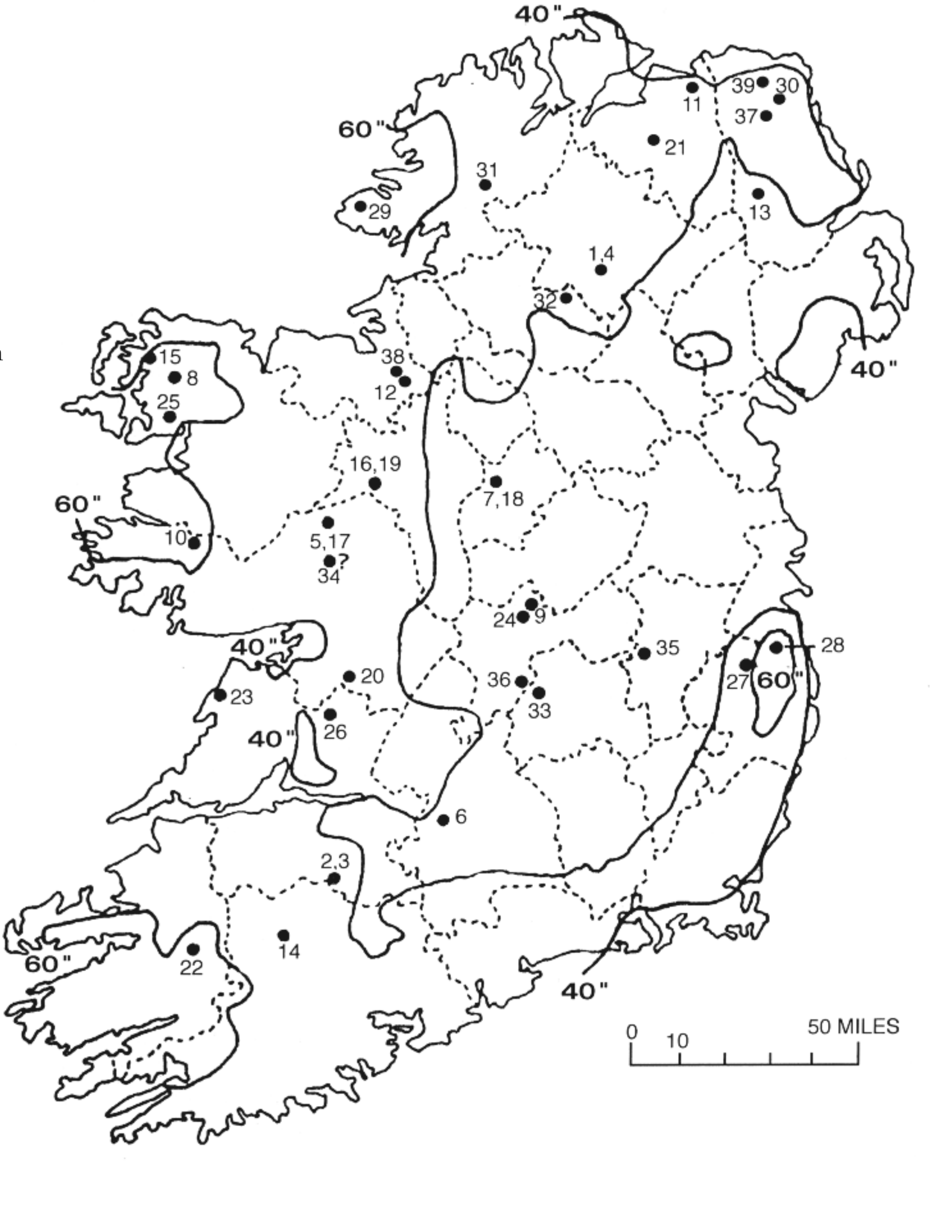


Figure 12.2:
Bog bursts in Ireland.
(For locations see Table 12.2).
The heavy black lines are the 60" and 40" isohyets for the period 1901-30: after Colhoun *et al.* (1965).

Table 12.2: Some recorded bog bursts [Based in part on Sollas *et al*. (1897), Kilroe (1907) and Colhoun *et al*. (1965)]

1488	The *Annals of the Four Masters* describe a 'fairy wind' which may have been connected with a bog burst.
Before 1640	Clogher, County Tyrone [1].
1697, June 7	Kapanihane bog, County Limerick, near Charleville. Meadow and pasture adjoining the bog moved over valuable land of similar nature, and was followed by a mass of the bog. Thereupon the 'rising' in the middle of the bog sank flat [2].
1708	Poulevard or Castlegarde bog, County Limerick, moved along a valley, burying houses and twenty-one people. It was over 1.5km long, .4km wide and about 6m deep in some parts. It ran for many kilometres 131.
1712, March	Clogher [4].
1745, March 28	Bog of Addergoole, Dunmore, County Galway. Ten acres of bog moved down a stream course, covering thirty acres of pasture by the side of the river, and by damming the water destroyed some 50 or 60 acres besides [5].
1786	Gorteenameale in Slieve Bloom: Camden's *Brittmlia* describes a bursting of the bog which it attributes to 'a body of lightning or electric matter' 133].
1788, March 27	Bog near Dundrum, County Tipperary. A large bog of 1,500 acres burst, deluging a vast tract of fertile land with mud [6].
1788, May	Knocklayd, County Antrim [39].
1809, December 16	Bog of Rine, Camlin river, County Longford. 'Twenty acres of bog burst asunder in numerous places'. The debris dammed the drainage so as to submerge 170 acres, which were relieved of water only at considerable cost [7].
1819, January	The Owenmore Valley, Erris, County Mayo. The overflow of a mountain tarn brought about the bursting of the large bog which confined the waters of the lake. The bog carried boulders and bog timber along with it, as well as the stones, roofs and inhabitants of houses in a small hamlet which lay in its path [8].
1821, June 19 and 26	Kilmaleady bog near Clara, County Offaly, 500 acres in area, and 50 feet deep in places. Part of this bog moved 3 miles, covering an area of about 150 acres when it came to rest. Another account, regarding the events of the second date aune 26) states that the bog moved 'at the rate of about two yards an hour, with a front of 200 yards wide and about 8 feet deep' [9].
1821, September	Joyce Country, Galway [101.
1824, December	Ballywindelland, County Derry [11].
1832, January	Geevagh, County Sligo 112].
1840, January	Kanturk, County Cork [14].
1835, September	Randalstown, County Antrim [13].
1867	Glen Castle Hill, Belmullet, County Mayo [15].
1870, December 14	Tulia bog, near Castlereagh, County Roscommon. The deposit of mud left on the low ground extended six or seven miles along the valley of the Suck, covering 165 acres [16].
1873, October 1	A bog, three miles to the east of Dunmore, County Galway, slowly moved down the valley of the Dunmore river, burying three farmhouses and covering 300 acres of pasture and arable land under 2m of peat [17].
1883, January 25	A bog between Moor and Baslick, near Castlereagh, County Roscommon. The bog flow covered 4,000 acres of land; three houses had to be abandoned, and several roads were blocked, including the Ballinagare road, which was covered with upwards of 5m of peat [19].
1883, January 30	A bog near Newtownforbes, County Longford, started to move, covering turf and potatoes [18].
1890, January 27	Bog at Loughatorick North, County Galway (Slieve Aughty Mountains) after a thaw. An area of 100 acres was covered with a foot of peat, the upper part of the bog subsiding 10 or 12 feet. Visited and described by Praeger in 1897 [20].
1895, August 9	Dungiven bog, County Derry, 10 to 30 feet deep, burst and flowed downstream without doing damage, the gradient being steep - one in twelve in the bog itself - and the adjoining land not being under cultivation [21].
1896, December 28	Knocknageeha bog above the Ownacree Valley, County Kerry: eight people killed [22].
1900	Ballaghline, near Lisdoonvarna, County Clare: two people killed and much damage caused to land [23].
1906, June	County Offaly, near Ballycumber [24].
1909	Kilmore, County Galway: woman suffocated in her sleep when liquid peat overwhelmed the small village 134].
1931, February	Lake Carrowmore near Bangor, County Mayo: loss of animals and damage to land [25].
1934, October	Slieve Aughty Mountains, County Clare [26].
1937, spring	On the slopes of Mullaghcleevaun, Wicklow Mountains [27].
1938, July	Lough Bray, County Wicklow [28].
1945, January	Glen Valley, County Donegal [29].
1954	Derrylea, County Kildare [35].
1963, November	Cushendum, County Antrim [30].
1963, November	Barnesmore, County Donegal [31].
1965, January	Slieve Rushen, County Cavan [32].
1973	Slieve Bloom, edge of plateau on Offaly side; many earlier flow scars in evidence [36].
1980	Seven slides in the Slieve-an-Orra hills, County Antrim, all at around the same time [37].
1984	Straduff, County Sligo: the fourth flow recorded here since 1831. This flow had a volume of 81,OOOm^3 [38].
1988	Above Gorteenameale, Slieve Bloom, County Laois [33].

The majority of bog bursts have occurred on the blanket bogs of the west and mountains, where rainfall is highest; here they tend to be more frequent during the autumn and winter months, whereas on raised bog this seasonal pattern is not so evident. The causes of bursts are different in the two kinds of bogs; with raised bogs a build-up of water within a peat 'sandwich' is usually likely to be responsible, but in blanket bogs the water usually accumulates at the base of the peat. In the case of blanket bogs, slope is an important factor. Because of their peculiar topography, geology and hydrology, certain upland areas are especially prone to bog bursts. One which occurred at Straduff in County Sligo in 1984 was the fourth such flow recorded since 1831, and there is evidence for others. Evidence for unrecorded earlier flows and slides is widespread on slopes around the edges of the Antrim plateau; at the time of the Glendun bog flow in 1963 **[Figure 12.3]** local residents recalled several others that had occurred within the last fifty years. The healed scars of earlier flows can also be seen in Slieve Bloom and on other mountain ranges. Bog bursts are especially likely to occur where there is a break of slope at the edge of an upland plateau of blanket peat (e.g. Slieve Bloom, Slieve-an-Orra, Straduff). Other factors which increase the likelihood of a flow are the pattern of recent rainfall or melting snow, the presence of impermeable material below the bog, and the extent of interference (by burning and turf-cutting for instance) with the surface vegetation and the peat itself. The opening of turf banks or drains parallel to the edge of the bog can often lead to a bog burst, because it provides a way for the pent-up water below, the peat to break out and escape. Bog bursts in the mountains were so widespread that the practice of opening banks *perpendicular* to the bog margin became general in many upland areas around the middle of the last century. Bog bursts may simply be part of the natural cycle of development of blanket bog on sloping ground, occurring at a stage when the upper peat reaches a critical mass, at which point water triggers the instability, and the burst acts as a safety valve to restore equilibrium.

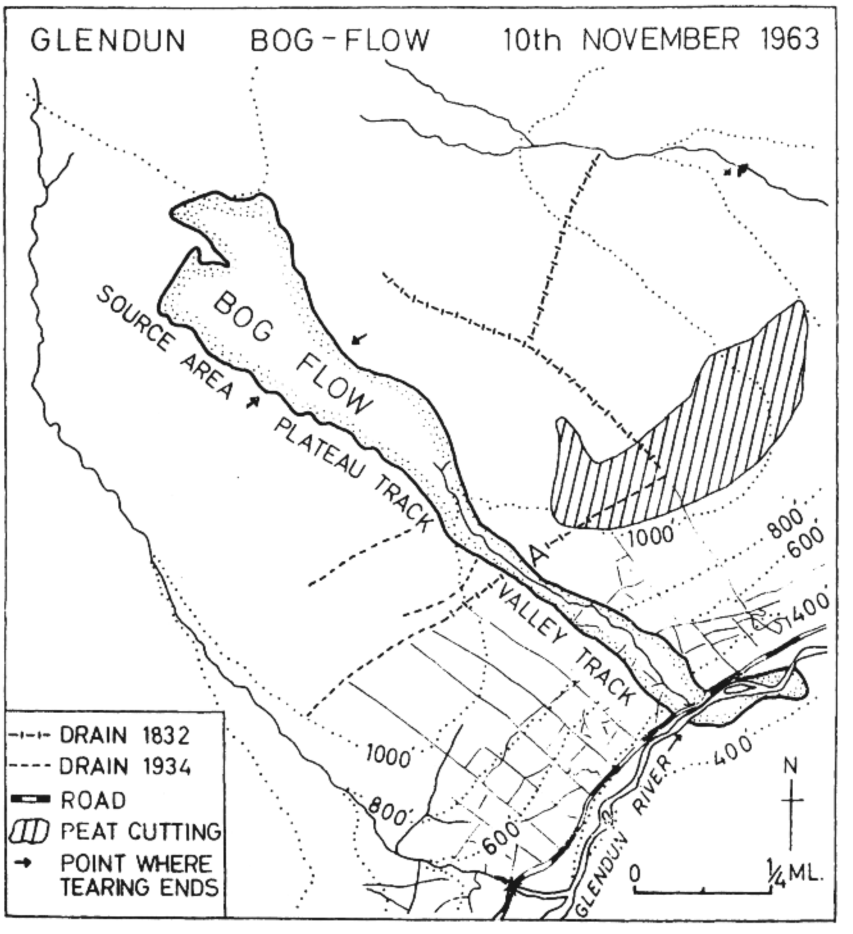


Figure 12.3: The Glendun bog flow. (From Colhoun *et al.*, 1965).

Occasionally the peat moves as a large, coherent raft, carrying upright trees on its surface, and there is little liquid peat involved. Such flows are sometimes distinguished as bog slides and they frequently follow heavy storms. Such slides are frequent above the glens that dissect the Antrim basalt plateau. No fewer than seven took place around the same time in the Slieve-an-Orra hills in Antrim following a freak thunderstorm with torrential rain on 1st August 1980. So too with the bog burst which took place early in 1937 on Moanhane, at 705m on the western slopes of Mullaghcleevaun in the Wicklow Mountains. Here an area of bog some 100m x 60m in size moved downhill in coherent blocks up to 20m across, splitting into two flows as it did so, but it ended up only 200m from its place of origin [**Figure 12.4**]. A small flow that occurred near Lough Bray in the Wicklow Mountains in 1938 was also in the nature of a slide, very little water being involved. In this case a largely coherent block of upper peat some 35 x 40m slid forward down a slope of 6° towards a stream below. In other words, the lower peat did not *flow out from beneath* the upper peat. About 15cm from the base there was a surface where a change of texture took place within the highly humified lower peat, and this acted as a slip plane along which the upper block moved after the plane was lubricated by heavy rainfall.

More usually, the flow is a chaotic jumble of large blocks of drier, coherent surface peat, and very wet basal peat. A blanket of peat on a mountain slope is very sensitive to gravity, and particularly after heavy rainfall is likely to move, because the water may lubricate a slip layer of greasy peat towards the base. Where the basal layers become semi--liquified, a slope of 4° is sufficient to cause a bog burst, but even without this 6° may be enough. Indeed, a bog burst has been known to take place on a slope of as little as 2°.

Although they tend to occur mainly at night and in remote places, several bog bursts have been observed and recorded. The sequence of events is more or less as follows. The bog first begins to quiver, a black seam appears at the lower end of the separating block, and then the bog 'begins to walk'. Here is an eye-witness description of the 1821 Clara burst:

> It happened in June, on a Friday, during dinner-hour. The cows saw it first, for they all began running away from the bog, and we thought it was the flies were at them; but then the barrow and slanes began to tumble about, and the bog to move up and down like the waves of the lake. It moved as far as the cabin on the bog that day, but on the following Monday it again moved across the road, and up the side of the gravel ridge (Esker); it tore up the marl with it, and carried it along. We considered that it was such a dry year, that the lough on the east side of the bog got under it and floated it away.

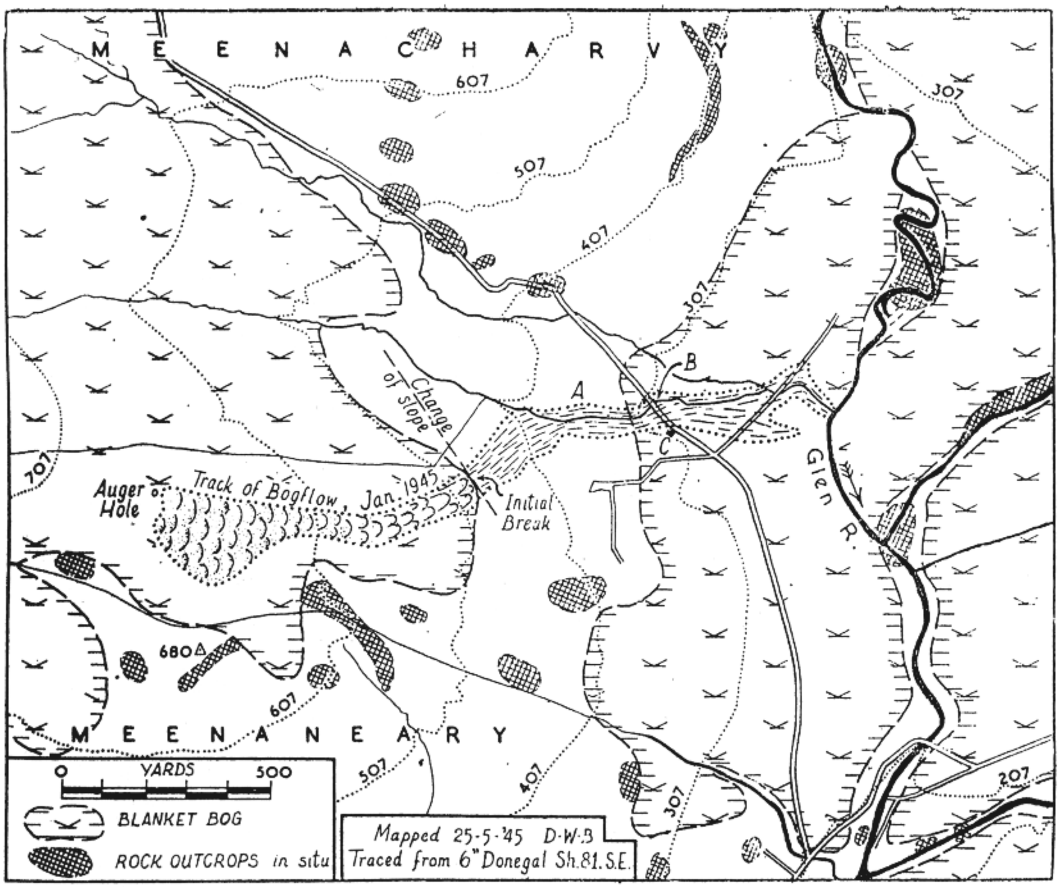
Richard Griffith's description of this bog flow, written in a letter to the Royal Dublin Society in 1821, is one of the earliest scientific descriptions of the phenomenon. The bog in question is Woodfield bog 3km or so north of Clara in County Offaly, which was then known as Kilmaleady bog, and had the reputation of being the wettest bog in the country. Woodfield is a classical example of a small raised bog, up to 12m deep and around 200ha in extent, rising steeply at its edges to a height that was originally about 6m above the general level of the surrounding land. It is hemmed in by hills and ridges of glaciofluvial gravel and sand on all sides except the south, in which direction it drains via a stream that flows into the Brosna.

1821 was a very dry year, so that the local turf-cutters were able to excavate peat to a greater depth than was usual, right down to the underlying blue clay in fact. Many of the turf banks had faces 9m high as a result, and it was this that precipitated the bog burst:

> At length, on the 19th day of June, the lower pulpy and muddy part of the bog, which possessed little cohesion, being unable to resist the great pressure of the water from behind, gave way, and, being once set in motion, floated the upper part of the bog, and continued to move with astonishing velocity along the valley to the southward, forcing before it not only the clamps of turf on the edge of the bog, but even patches of the moory meadows, to the depth of several feet, the grassy surface of which heaved and turned over almost like the waves of the ocean; so that in a very short space of time the whole valley,

Figure 12.4:
(a) Bog flow at Meenacharvy and Meenaneary, County Donegal. (From Bishopp and Mitchell, 1946).
(b) Bog flow on the slopes of Mullaghcleevaun in the Wicklow Mountains. (From Mitchell, 1938).

(a)



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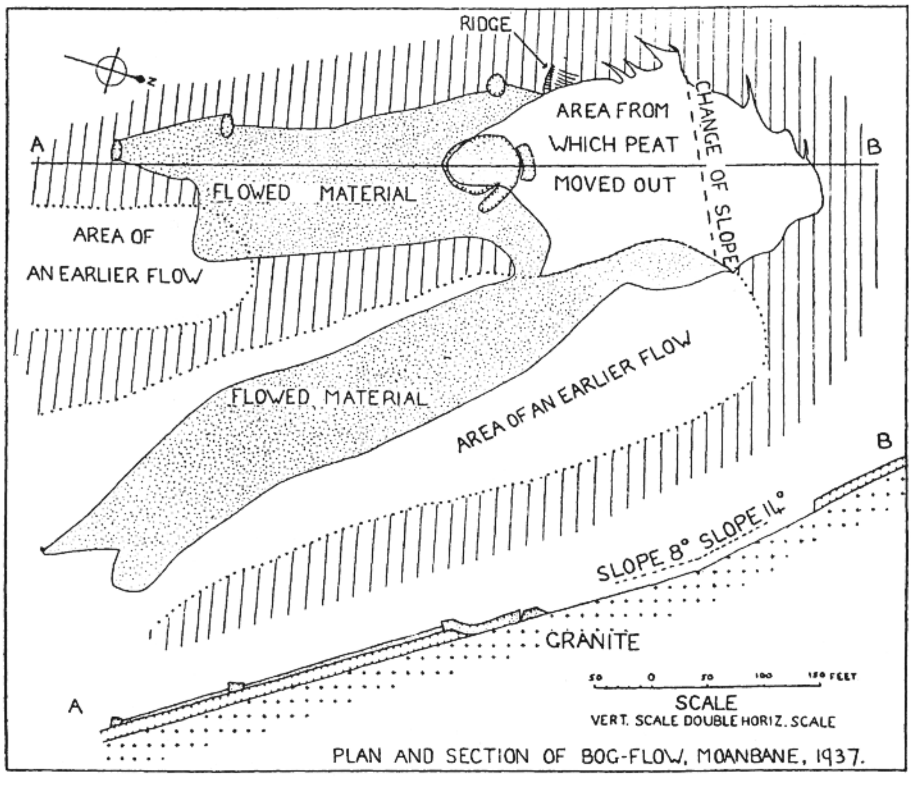


> for the breadth of about a quarter of a mile between the bog edge and the base of the hill of Lisanisky, was covered with bog to a depth of from eight to ten feet, and appeared everywhere studded with green patches of moory meadow.
>
> ... in the centre of the bog, for the space of about one mile and a half in length, and a quarter of a mile in breadth, a valley has been formed, sloping at the bottom from the original surface of the bog to a depth of thirty feet, where the eruption took place. In this valley or gulf, there are numberless concentric cuts or fissures with water nearly to the top.

The burst flowed south as far as Lisanisky hill, which diverted it to the west [Figure 12.5]. From head to toe the burst extended for about 5km and eventually covered an area of about 60ha with up to 3m of peat. In fact, after it had settled down the slide looked just like a small bog. It left in its wake a valley 9m deep, 2.5km long and about 0.5km wide. It became the subject of a lawsuit, because the valuable peat mass had left one property and came to rest in another! The 'numberless concentric cuts' survive today as linear sphagnum-filled hollows.

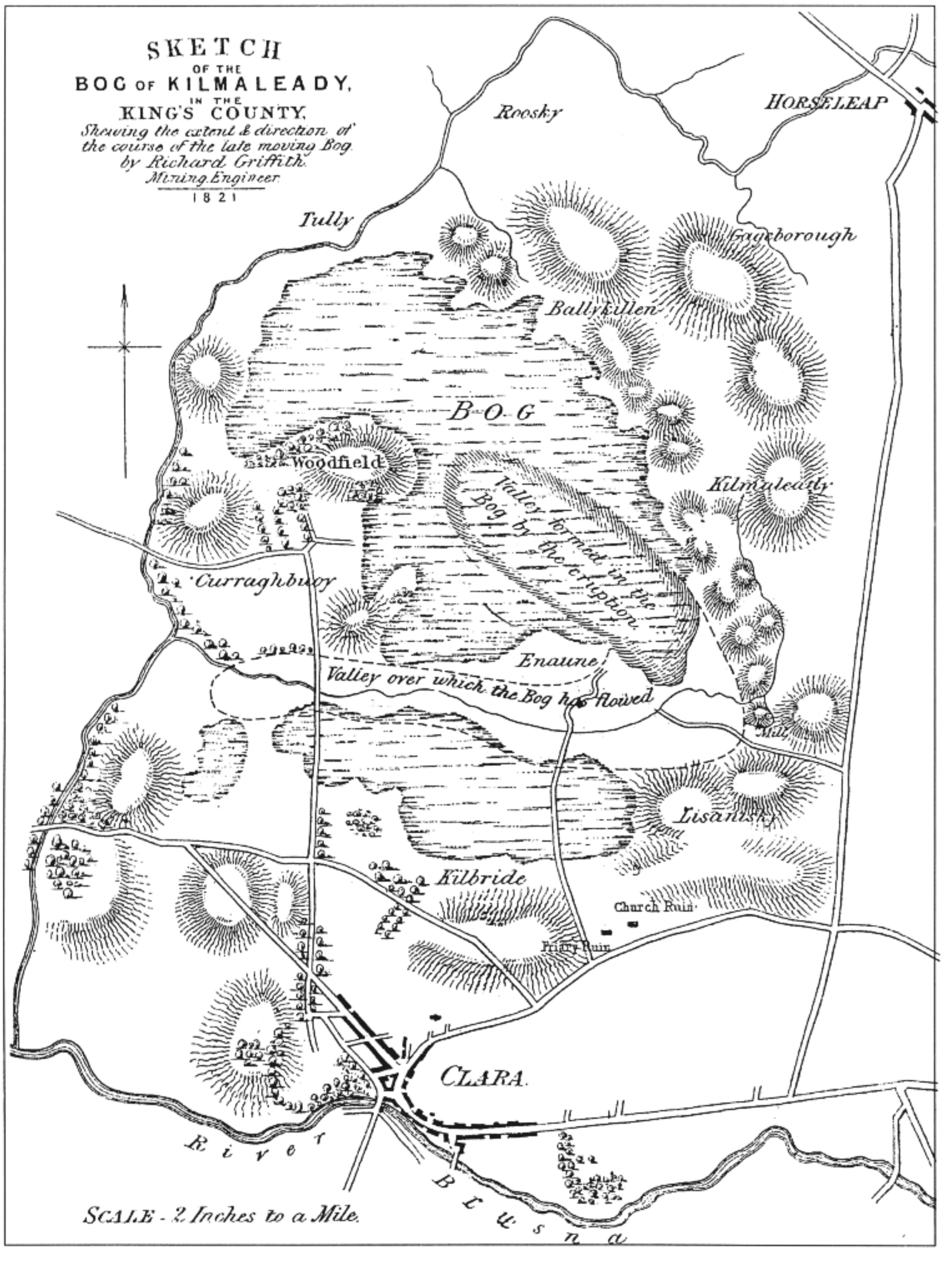


Figure 12.5: The bog burst at Kilmaleady, near Clara in County Offaly. (From Griffith, 1821).

The earliest modern record of a bog burst appeared in a letter published with a detailed description and map by John Honohane in the *Philosophicnl Transactions of the Royal Society* in 1697. The flow took place in Kapanihane bog in County Limerick, near Charleville. Here the accumulation of water (either at the base of the bog or in the middle of peat sandwich) caused the bog to swell up, and the pressure forced the water out under an adjoining grassy moor and meadow, which also rose and eventually burst, followed by the bog:

> On the 7th Day of June, 1697, near Charleville, in the County of Limerick, in Ireland, a great Rumbling, or faint Noise was heard in the Earth, much like unto a Sound of Thunder near spent; for a little Space the Air was somewhat troubled with little Whisking Winds, seeming to meet contrary Ways: And soon after that, to the greater Terror and Afrightment of a great Number of Spectators, a more wonderful thing happened; for in a Bog stretching North and South, the Earth began to move, viz. meadow and Pasture Land which lay on the side of the Bog, and separated by an extraordinary large Ditch, and other Land on the further side adjoining to it; and a Rising, or little Hill in the middle of the Bog hereupon sunk flat.
>
> This Motion began about Seven of the Clock in the Evening, fluctuating in its Motion like Waves, the Pasture-Land rising very high, so that it over-run the Ground beneath it, and moved upon its Surface, rowling on with great pushing Violence, till it covered the meadow, and is held to remain upon it 16 Feet.
>
> In the Motion of this Earth, it drew after it the Body of the Bog, part of it lying on the Place where the Pasture-Land that moved out of its Place it had before stood; leaving great Breaches behind it, and spewings of Water that cast up noisom Vapours: And so it continues at present, to the great Wonderment of those that pass by, or come many Miles to be Eye-witnesses of so strange a thing.

Another account of this flow appears in Gerard Boate's *Naturall History:*

> A greed noise was heard in the earth like thunder, attended with whirlwinds. Soon after, to the terror of the spectators, a bog stretching north and south began to move, as well as the pasture land, which lay on the side of it, separated by a very large ditch, and a small hill in the middle of the bog sunk flat. The ground f1uctuated like a wave, the pasture land, rising very high and rolling on with great violence, covered a meadow sixteen feet deep. In this motion it drew after it a great part of the bog into the place where the pasture land stood before, and the chasms spurted out water and noxious vapours, and continued to do so. Numbers of people went from all places to sell this surprising phenomenon, the account of which was communicated by William Molyneux, Esq" who had a farm adjoining the bog.

In one of his reports to the Bogs Commissioners Richard Lovell Edgeworth gave an account of a burst that occurred during a thunder storm on the night of December "18th 1809 in the Bog of Rine on the bank of the River Camlin in County Longford, during which

> ... about 20 acres of the Bog burst asunder in numerous places, leaving chasms of many perches in length, and of various breadths, from ten feet to three inches; the rifts were in general parallel to the River but in some places the smallest rifts were at right angles to it; not only the Bog, but the bed of the River was forced upward; the boggy bottom filling up the channel of the River, and rising three or four feet above its former banks: in a few hours one hundred and seventy acres of land were by this means overflowed, and they continued in that state for many months, till the bed of the River was cleared by much labour and at considerable expense

There was much speculation at the time as to the cause of the phenomenon. Hydrological explanations were considered the most likely, 'that the Bog had been undermined by rains, or by the swelling of the River, or by water descending under the Bog from the neighbouring rising grounds, and that in consequence the whole Bog slid toward the River'. It was also suggested (but dismissed by Edgeworth for lack of evidence) 'that a large chasm had been suddenly formed underneath the Bog, by the falling in of a subterranean vault, and that this chasm had swallowed part of the Bog'. The possibility that earth movement had triggered the burst was considered:

> It is remarkable that several earthquakes were felt about the sixteenth of December 1809, in distant countries, when the phenomenon, of which I have given an account, happened at Rine in the county of Longford; and though the distance between the places where they ocurred and Ireland, is so very great as to make it improbable, it is not absolutely impossible that a communication may exist between them.

One of the most dramatic and disastrous bog bursts took place in January 1819 in the valley of the Owenmore in Erris; it carried away an entire hamlet during the night, including a picket of highlanders whose bodies were later recovered in Tullaghan Bay, the estuary of the river. In the same area in 1867 a townland on the Glancastle Hills slipped into the sea, depriving the inhabitants of all they possessed and forcing them to emigrate. This burst was preceded by two months of drought. Then, on 19 July, there was a deluge, which lifted 16ha of bog right off the side of the mountain, from which it slid down into Broad Haven, causing destruction along the way. The movement may have been triggered by a mea ring ditch cut across the edge of the bog. Had the burst taken place at night, those in its path would have lost more than their property.

One of the most detailed accounts of a bog flow describes the mud deluge which burst from the edge of Knocknageeha bog 19km north-east of Killarney in County Kerry at 3 a.m. on the morning of 28th December 1896. The bog gave way along the line of a 1-3m deep turf cutting; the deluge of peat mud swept away the Kingwilliamstown road which ran along the western edge of the bog and carried off the cottage in which Cornelius Donnelly, Lord Kenmare's quarry stewart, was sleeping with his wife and six children: all eight lost their lives. Further along its course it threatened the cottage of Jermiah Lyne, rising nearly 2m against its wall. A storm raged through the night, and though the noise of this kept many people awake, none was aware of the rapid and silent flood of destruction flowing down the Ownacree valley, which channelled the flow for most of its course **[Figure 12.6**]. A man who went out in the middle of the night to collect two calves narrowly escaped with his life as the flood bore down from the north on Annagh Bridge. The dilution of the peat mud by the water in the river allowed it to travel much further than would otherwise have been the case. Even where the Ownacree flowed into the Flesk - one of the main rivers feeding the Lower Lake of Killarney – 16km downsteam, the banks were smeared with a layer of peaty mud, some of which was carried a further 15km down the Flesk into the lake itself.

Some 300 acres of farmland were buried, sometimes by a metre of peat: 'The appearance of this extensive sea of black peat, with its protruding stumps of blackened trees, overlying fertile fields, was a sight melancholy in the extreme'. To the geologist Grenville Cole the peat flood was like the outpouring of a volcano: 'the oozing of the material through the hedges reminds one of the thin lava-sheets of Hawaii'. A committee comprising Professor W. J. Sallas, R. L. Praeger, A. F. Dixon and A. Delap was dispatched to report on the phenomenon by the Royal Dublin Society; it is to them and to Cole that we owe our detailed knowledge of what happened. The flow was attributed by the committee to earth movement along a fault that underlay its area of origin. It was supposed that the movement was triggered by the Hereford earthquake that occurred at that time. When the flow had stopped, there was a saucer-shaped depression more than a kilometre across and no less than 15m deep in the centre, at the place from which the bog had burst.

Another bog burst of which we have a detailed account, written in this case by A.D. Delap, A. Farrington, Praeger and Louis Smyth, occurred in February of 1931 in the hills to the south-east of Lake Carrowmore, near Bangor in County Mayo. This took place around ten o'clock in the morning, which was just as well because a local farmer whose house stood in its path was able to see it 200m away as it rounded a bend in the valley in which he lived, advancing on him like a tidal wave with a noise like 'fifty carts loaded with stones'. The man, a Mr Moran, was able to carry his invalid sister to safety, but his animals were less fortunate; although he had time to release them, seven of his cattle and a donkey were swallowed by the advancing flood.

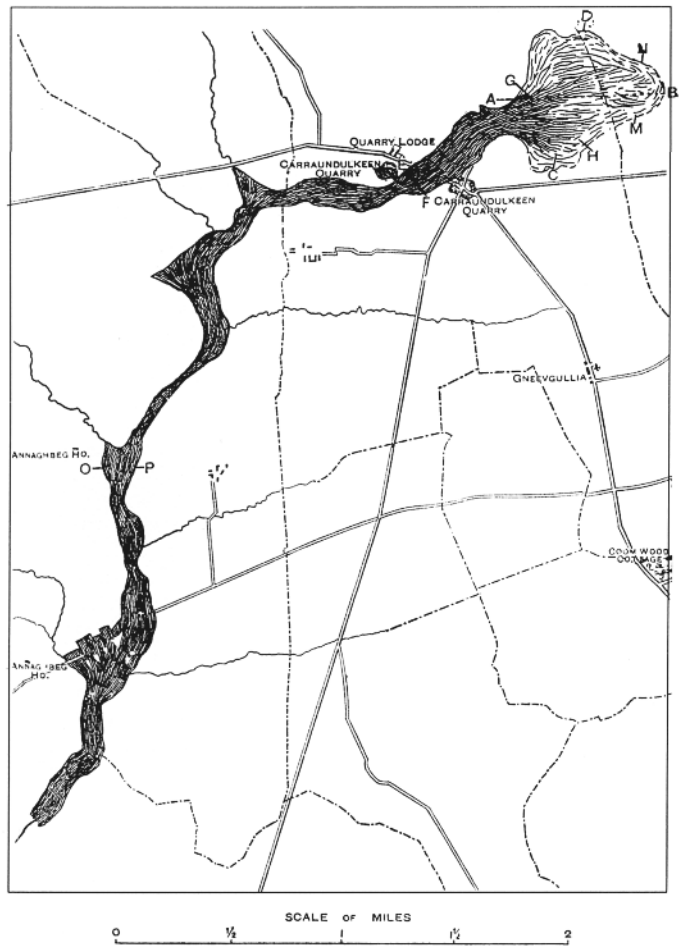
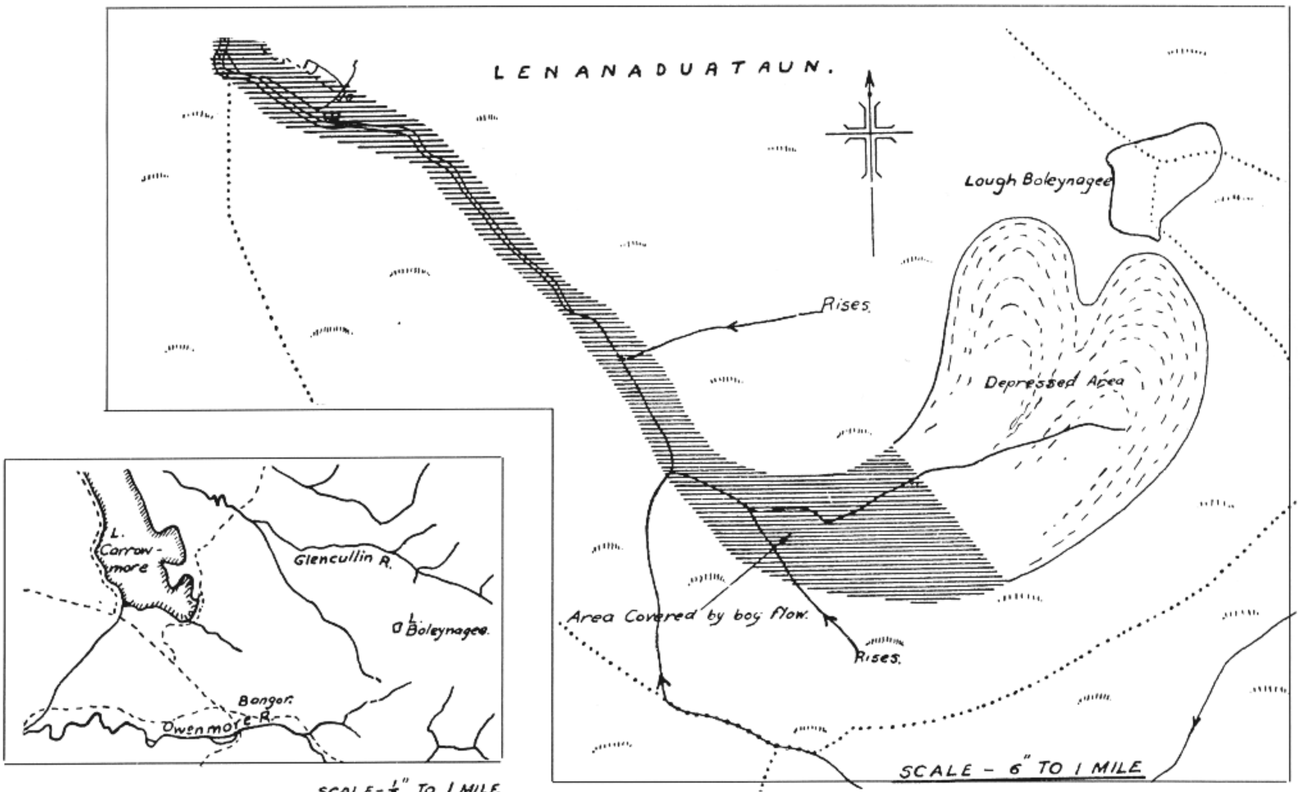


Figure 12.6: The 1896 burst at Knocknageeha bog. (Sollas *et al.*, 1897).

The burst occurred on the hill slope a short distance below a little mountain lake called Lough Boleynagee [**Figure 12.7**]. There was no apparent outlet to this lake but significantly – there was a stream rising about 520m downslope from the lake, which flowed on down the hill to the Muingnakinkee stream in the valley below. The overflow from the lake apparently made its way through the peat before coming to the surface at this rising. The exceptionally prolonged rains of the preceding summer had gorged this peat to the point where it exploded from its confinement at a point half way down the hill where a slight increase in slope created a line of weakness.

The lighter, more coherent upper peat was carried on top of the black slurry, breaking up into a series of rafts separated by deep chasms as the liquid peat spread out. The avalanche charged down the hill to the stream below at great speed, and surged up the opposite side to a height of 7m or so before its movement was checked by the steep slope and it took a direction at right angles, running down the valley. Above the line of the burst the upper peat broke into a series of great peat floes 5-6m wide and as much as 6m long, separated "by deep chasms 1-2.5m wide filled with semi-liquid peat (later sketched by Hugo Osvald: **Figure 12.7b**). The flood of liquid peat flowing down the valley was nearly 5m deep in places, filling the bed of the Glencullin River into which the Muingnakinkee flowed, and flooding its banks with peat mud.

The flow continued all day, the front slowing to a final halt around nightfall some 2.5km from its point of origin. Moran claimed that as it advanced it was covered 'as by a cloud or mist, and that lights were playing over it'. The burst emptied the liquid peat reservoir area which had been building up under the surface between the lake and the stream rising. The volume of this displaced reservoir was estimated at between 245,000-300,000m^3.



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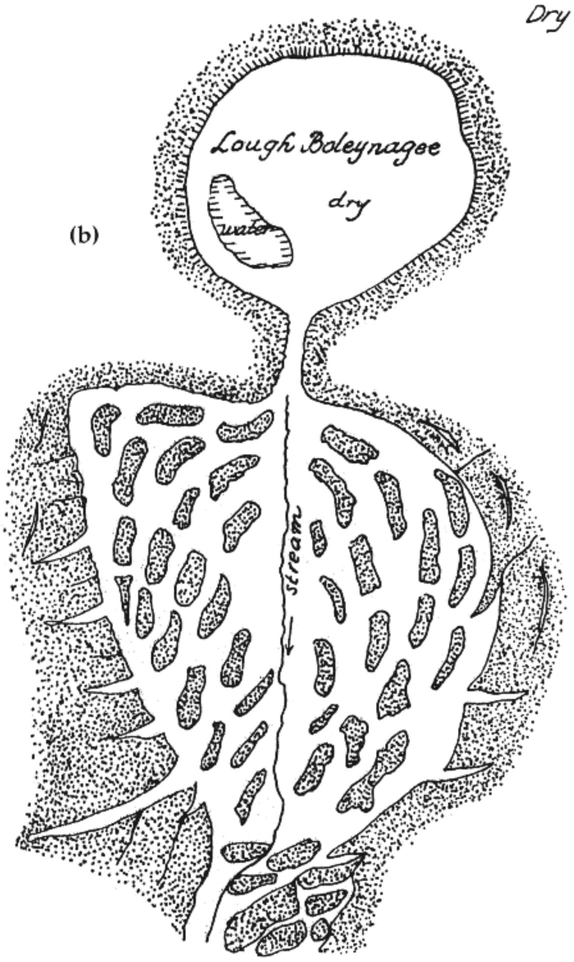
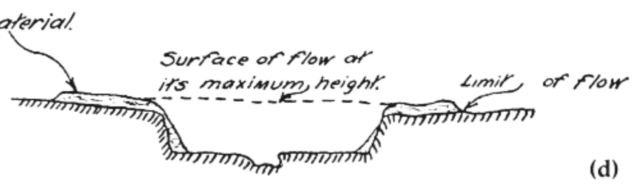
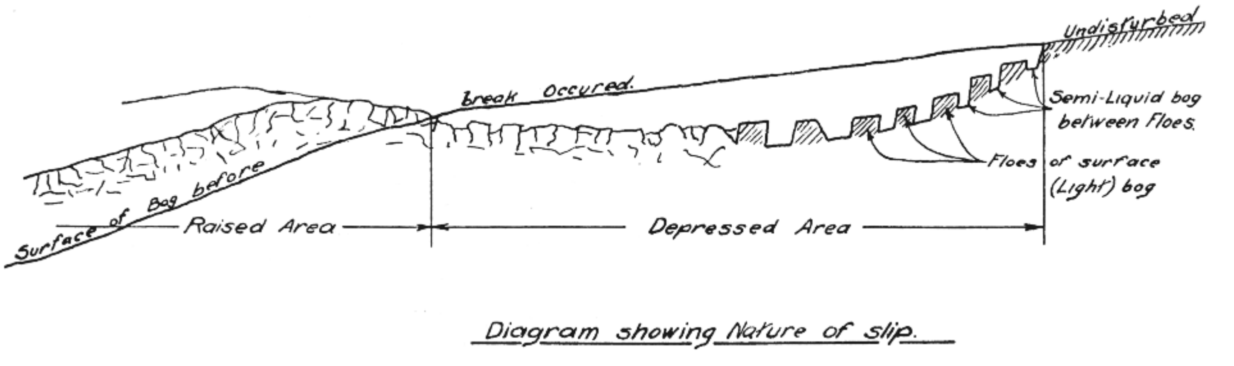




(d)

Figure 12.7: The Lough Boleynagee burst of 1931.
(a) Map of the flow.
(b) A contemporary sketch by Hugo Osvald, showing the solid blocks of the higher peat (measuring up to 20m in length and 3m across) stranded at the upper end of the flow
(c) Section through the same area as (b).
(d) A Section across the river valley after the flow.
[(a), (c), (d) from Delap *et al*., 1932].



(c)

The rate at which a peat flow moves will obviously depend on such local factors as slope, volume of material and so on. In the 1984 flow at Straduff (near Geevagh) in County Sligo the volume was estimated at 81,000 m^3 (comprising 4,200 tonnes of peat and 73,000 tonnes of water). It flowed for most of its length at rates of between 3 and 6m/s (maximum 7,8m/s), which represents a discharge of somewhere between 45 and 140m^3/s, the variation being due to the nature of the topography and the varying resistance offered to the flow at different places along its length. This particular flow moved for a distance of several kilometres, affecting an area of nearly 50,000m^2 altogether, before finally spreading out and coming to rest at the foot of the mountain.

In 1988 a bog burst at Gorteenameale in Slieve Bloom swept away part of the Slieve Bloom long-distance walking route. Nuala O'Faolain described it in the *Irish Times:*

> A river of black turf seemed to have poured down the mountain, blocking our way, spreading out everywhere it could, even down the track, unmoving now, but two or three feet deep at its edges. We didn't know how deep it was in the middle, or whether we should try to scoot across. We threw in a rock. Glug, glug, disappear. We had our sandwiches. It was a long way back, but the thing looked dangerous, No, we'd have to go back.

This burst started towards the edge of the extensive plateau bog on the summit of this part of Slieve Bloom, where water must have built up below the peat after the recent wet weather. Fifteen years earlier there was another burst on the opposite side of the same plateau, and the scars of older flows that have now healed can be seen elsewhere on the slopes. An event, which must have been one of these earlier bursts, was graphically described in Camden's *Brittania,* published in 1786:

> In the mountain of Gurtccnamallagh about 10 years ago a very extraordinary phenomenon occurred, A body of lightning or electric matter seemed to have burst, and instead of penetrating the ground it furrowed and threw up the bog on each side of its course to 10 feet in height, without leaving any marks on the loamy surface beneath the bog. The common people call it the Burst Mountain, supposing the rise of springs caused these effects, but this cause would be scarcely adequate to the coacervation of such heaps of turf and to such a height.

It has to be confessed that when we first read this dramatic description we considered the possibility that the phenomenon might have been caused by the impact of a meteorite. However, the 'common people' were nearer the truth.

Bog bursts are so silent and mysterious that they were very often attributed to some supernatural or extra-terrestrial agency, and were indeed not infrequently believed to be the work of the Fairies. This is partly because most of them take place at night, and often in out-of-the-way places. Several are referred to in the Annals, generally in miraculous terms. The local disturbance of air circulation above the bog produced by the burst sometimes caused a hot wind to blow: a fairy wind, believed to be brought about by the passage of a host of Fairies. One reference in the *Annals of the Four Masters* (1488 A.D.)

describes a fairy wind *(sidhe gaoithe)*, which struck a party of turf-cutters *(methel móna)* while they were at work on a turf bank *(tuaim móna)*. One was killed and the faces of the others were caused to swell up. Bog slides even inspired music on occasion – there is a tune called 'The Moving Bog' in one of Petrie's collections!

Although they are such violent and catastrophic events, the erosion scars of bog bursts heal with time. When Praeger re-visited the site of the Kerry flow 35 years later he found little trace of the chaos of 1897. Many upland areas show the healed scars of several generations of old bursts, which can often be recognised clearly from the air **[Plate 12]**. The improved drainage consequent on the erosion and removal of the area where the peat mud had accumulated, along with the gouging out of a deep channel on the sloping ground below – often flanked by a 'lateral moraine' of chaotic peat blocks – results in an increase in the growth of heather (especially on the dislocated peat rafts) and a decrease in species such as purple moor-grass and cottongrasses. This gives such areas a distinctly browner colour from a distance. The source area of the burst is sometimes marked by a distinct saucer-shaped depression.

Areas where large volumes of semi-liquid peat have been deposited as a result of a bog burst show little sign of the event after a few years, because once the peat dries it makes excellent and valuable fuel and is quickly removed. Where the transported peat ends up in a river or lake, however, the damage to aquatic life may be considerable. Much of the peat mud from the Loughatorick burst in 1890 for instance ended up in a small, deep lake of 60 acres, filling half of it with sediment. In 1897 (when Praeger visited it) 'where formerly good pike-fishing was obtainable, there now stretches a useless black slimy flat, and the fish in the portion of the lake that still remains are few and small', Around the edges, however, the peat was rapidly being colonised by the characteristic plants of the lake shore.

A bog burst is a phenomenon that can sometimes grow in the telling, acquiring ever greater stature as the sensational report is passed on. On 20 June 1906, Praeger read in a Dublin newspaper of a dramatic bog burst which had taken place the previous day near Ballycumber in County Offaly, during which l.5ha of bog had been 'torn up and scattered as if by an explosion', one man narrowly escaping premature burial. Terrified local people had driven their cattle from the fields around the bog, and abandoned their homes, while the bog 'kept heaving in all directions'. Praeger departed post haste for the scene of the great disaster in the company of Henry Seymour – a geologist with the Geological Survey – reading further dramatic details in the morning papers as they traveled westwards on the train: twelve farmers had had their lands smothered in oozing peat; any further movement would choke the Brosna and flood large areas of crops.

> Tramping out of Ballycumber under a scorching sun, laden with cameras and other implements of the chase, we therefore hoped to catch the bog-slide in the very act, *flagrante delicto.* As we approached the scene of the disaster, enquiries from a passing girl only elicited a smile and a "Never heard of it". Further enquiries were more successful, and we were directed to a spot where several men were peacefully cutting and stacking turf, aided by a donkey and cart. There was no destroyed fuel or crops, nor ground covered by outbursts of peaty matter; nor was there any interruption of the tranquil life in the cottages whose chimneys peacefully smoked some few hundred yards distant. The "swiftly flowing Brosna", little more than a stagnant ditch, was nearly a mile away. Eating our lunches on a dry bank in the middle of the "explosion", we heard from one of the heroes of the tragedy his account of the affair. It was the usual story – the bog had not been drained in advance of the cutting, and the cut face consequently slipped forward by about thirty feet, covering the cut-away part. All was over in ten minutes, and some of the men engaged in saving their peat did not even leave their work. Is it any wonder that one becomes sceptical regarding local reports of these and other unfamiliar occurrences of the country-side?

We cannot leave the subject of bog bursts without briefly mentioning one of the most dramatic descriptions of the phenomenon in the literature – but one that concerns an entirely fictitious event. The novel on which Bram Stoker sharpened his literary teeth was

The Snake's Pass, published in 1890, seven years before *Dracula*, neither work attracting much attention during the author's lifetime. As inspector of Petty Sessions in Ireland, Stoker was very familiar with happenings in the countryside, and with the contemporary interest in bog development; he was obviously fascinated by the notion of the moving bog. The story of *The Snake's Pass* revolves around the legend of the shifting bog of Knockcalltecrore in the mountains of the west of Ireland, where the king of the snakes lurks, having resisted Saint Patrick's attempts to banish him into the sea along with his orphidian subjects. The evil, lurking serpent is embodied in the treacherous bog, a 'carpet of death ... floating on a sea of ooze and slime – of something half liquid half solid, and of an unknown depth ... as bad a bit of soft bog as ever I saw'. The climax of the novel is the inevitable bog burst, which makes up in dramatic impact what it lacks in accuracy of detail.

> The whole surface of the bog, as far as we could see it in the dim light, became wrinkled, and then began to move in little eddies, such as one sees in a swollen river. It seemed to rise and rise till it grew almost level with where we were, and instinctively we rose to our feet and stood there awestruck, Norah clinging to me, and with our arms round each other.
>
> The shuddering surface of the bog began to extend on every side to even the solid ground which curbed it, and with relief we saw that Dick and Joyce stood high up on a rock. All things on its surface seemed to melt away and disappear, as though swallowed up. This silent change or demoralization spread down in the direction of Murdock's house – but when it go to the edge of the hollow in which the house stood, it seemed to move as swiftly forward as water leaps down a cataract.
>
> Instinctively we both shouted a warning to Murdock – he, too, villain though he was, had a life to lose. He had evidently felt some kind of shock or change, for he came rushing out of the house full of terror. For an instant he seemed paralysed with fright as he saw what was happening. And it was little wonder! for in that instant the whole house began to sink into the earth – to sink as a ship founders in a stormy sea, but without the violence and turmoil that marks such a catastrophe, There was something more terrible – more deadly in that silent, causeless destruction than in the devastation of the earthquake or the hurricane.
>
> The wind had now dropped away; the morning light struck full over the hill, and we could see clearly. The sound of the waves dashing on the rocks below, and the booming of the distant breakers filled the air – but through it came another sound, the like of which I had never heard, and the like of which I hope, in God's providence, I shall never hear again – a long, low gurgle, with something of a sucking sound; something terrible – resistless – and with a sort of hiss in it, as of seething waters striving to be free.
>
> Then the convulsion of the bog grew greater; it almost seemed as if some monstrous living thing was deep under the surface and writhing to escape.
>
> By this time Murcock's house had sunk almost level with the bog. He had climbed on the thatched roof, and stood there looking towards us, and stretching forth his hands as though in supplication for help. For a while the superior size and buoyancy of the roof sustained it, but then it too began slowly to sink. Murdock knelt, and clasped his hands in a frenzy of prayer.
>
> And then came a mighty roar and a gathering rush. The side of the hill below us seemed to burst. Murdock threw up his arms – we heard his wild cry as the roof of the house, and he with it, was in an instant sucked below the surface of the heaving mass.
>
> Then came the end of the terrible convulsion. With a rushing sound, and the noise of a thousand waters falling, the whole bog swept, in waves of gathering size, and with a hideous writhing, down the mountain-side to the entrance of the Shlecnanahcr [the snakes' pass] – struck the portals with a sound like thunder, and piled up to a vast height. And then the millions of tons of slime and ooze, and bog and earth, and broken rock swept through the Pass into the sea.

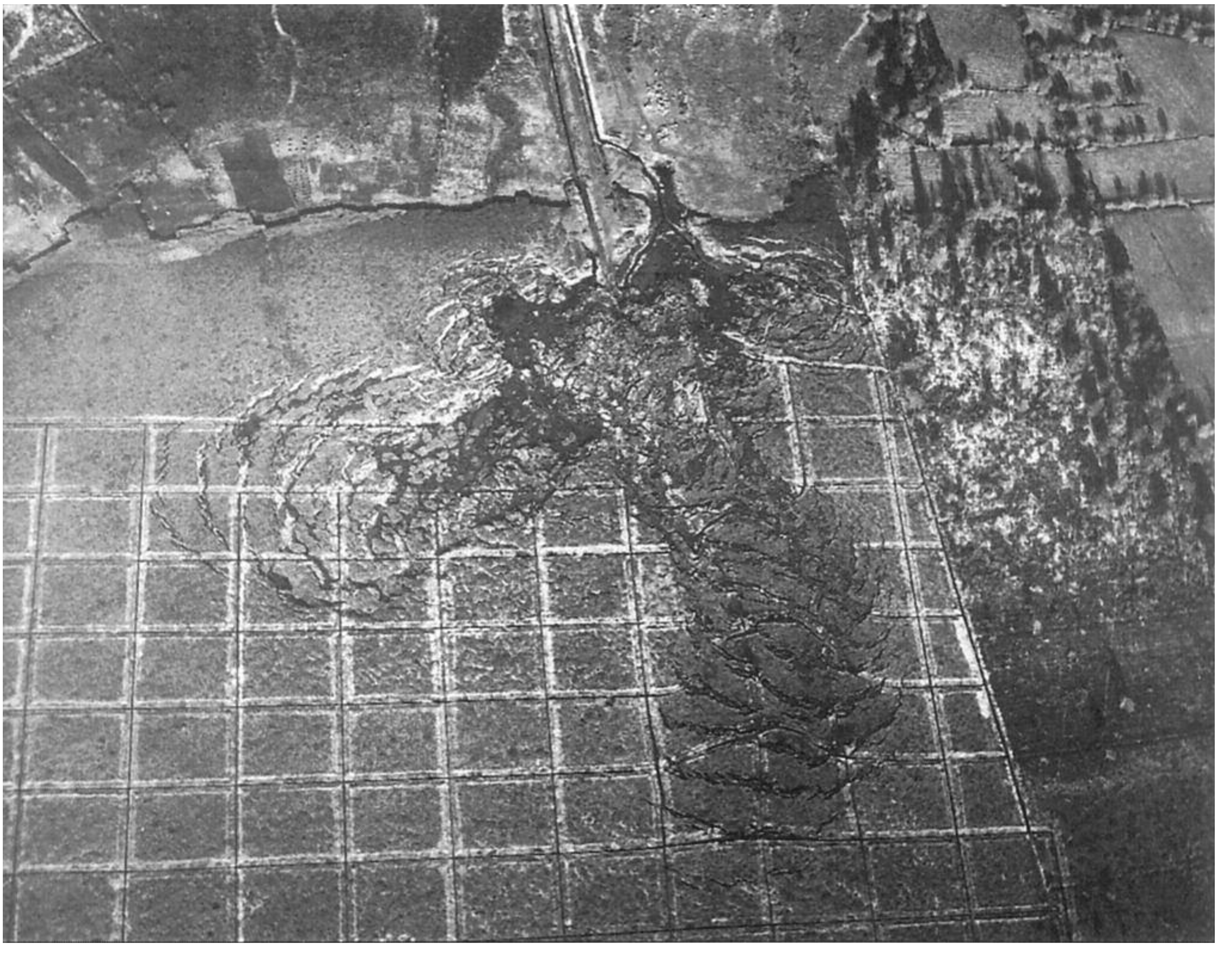


Figure 12.8: Bog burst at Derrylea in 1954.

Life in the water

> *Yes, a stagnant pool, though but a few feet wide, hatched by the sun, is an immense world, an inexhaustible mine of observation to the studious man and a marvel to the child. All these creatures of the water: what are they all doing here? I do not know. And I stare at them for ever so long, held by the incomprehensible mystery of the waters. The worlds of the ponds are so vast, I should lose myself in their immensities, where life swarms freely in the sun. Like the ocean, they are infinite in their fruitfulness.*
>
> J. Henri Fabre

The diverse phytoplankton in bog water has already been described in Chapter 9. This galaxy of life forms, many present in the pools in enormous numbers, provide food for innumerable animals, and make up the foundation of the food web of the bog pools. The larger animals have been described in Chapters 10 and 11, but these are only a fraction of the total. There are myriads of smaller animals everywhere, feeding among the forests of filamentous and attached algae, and wheeling in their multitudes through the constellations of the planktonic algae, as diverse almost as the tiny producers themselves. The name Infusoria used to be given to these tiny creatures. They are especially common among decaying vegetation: half-animal, half-plant Euglenas patrolling the water above the bottom ooze of bog pools in their droves in spring and autumn, cilated Paramecia, armoured Peridinia, sedentary Vorticellas and Stentors. Tiny shelled protozoa called rhizopods are among them, and they are always to be found hunting in the upper surface of the ooze at the bottom of bog pools or among submerged sphagnum. Here various species of Euglypha can be seen prowling, safe in their tiny chitinous shells **[Figure 12.9]**. Difflugia is often to be seen among masses of Spirogyra, whose cells it bites open to engulf the green chloroplasts inside. Other common prowlers include Phryganella and Vampyrella. Vampyrella also feeds on the chloroplasts of filementous algae, but in this case it breaks the thread open where two cells join, and makes its entrance this way. Among the larger and most unforgettable of the protozoa is the green stentor *(Stentor polymorphum),* colonies of which are frequently encountered in stagnant bogholes. One hint of the kinds of association which may be going on in the pond is the way schools of Vorticella sometimes hover around the openings to the utricles of bladderworts, waiting, as it were, for crumbs from the table. Rotifers (wheel animalcules) too, belonging perhaps to several dozen species, are abundant, especially in less acid waters. These are a large group of tiny but highly complex animals that are essentially confined to fresh water, of which they are among the commonest inhabitants. They are so small that they can easily be mistaken for protozoa, and very little is known about their role in the ecology of bog waters.

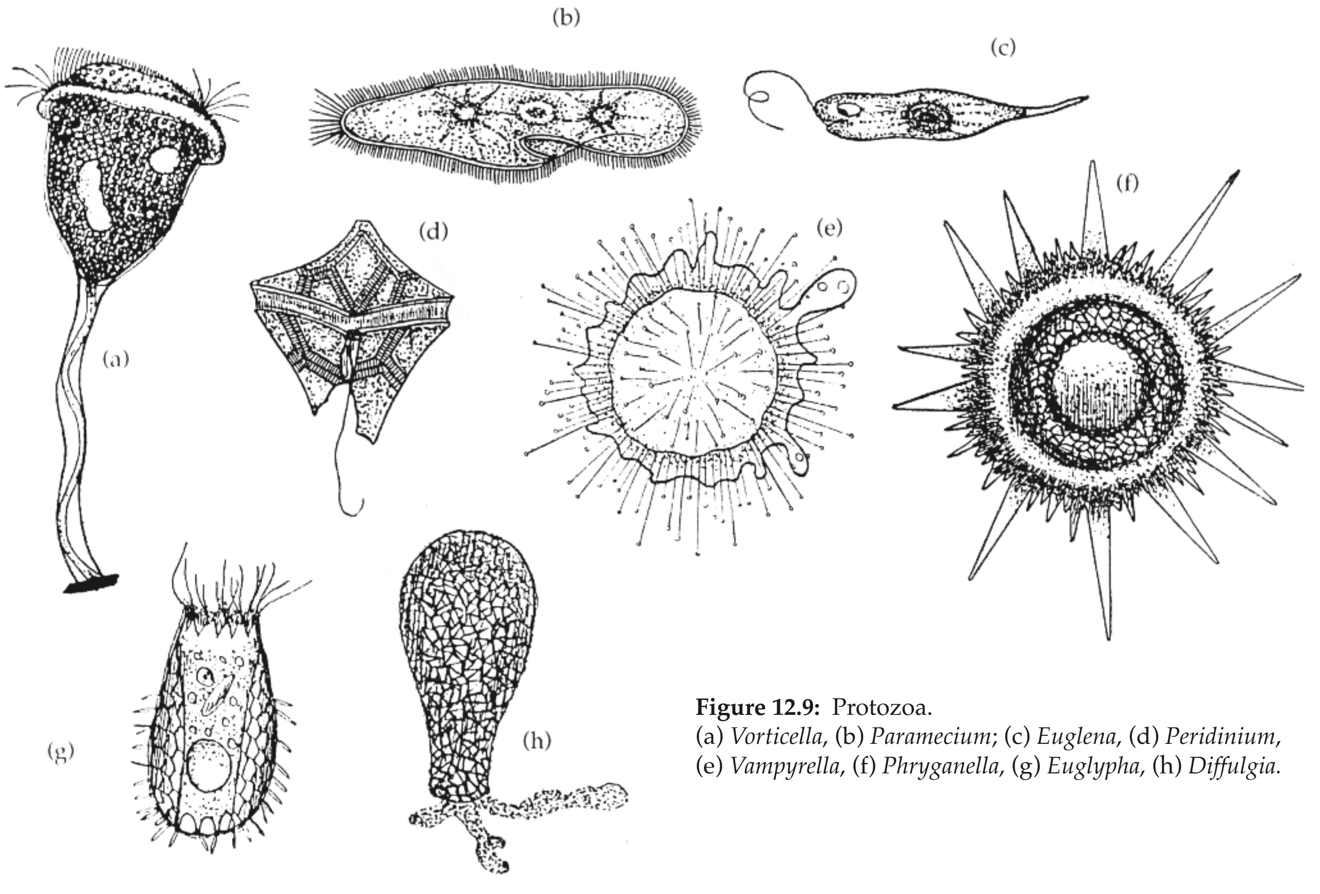


Figure 12.9: Protozoa.
(a) *Vorticella*, (b) *Paramecium*; (c) *Euglena*, (d) *Peridinium*, (e) *Vampyrella*, (f) *Phryganella*, (g) *Euglypha*, (h) *Diffulgia.*

Many kinds of nematodes, cladocera, mites and a few species of flatworms also occur in bog pools. The large phylum Coelenterata, which includes the jellyfishes, corals and sea anemones, has only one freshwater representative, but it is one of the most mesmeric of the small animals of these habitats. Hydra looks like a tiny, slender sea anemone; it is a relatively large animal, as long as 2 or 3mm at full stretch, big enough to be seen clearly against good background light. Of the several species, the one that seems to be most particularly associated with bogs is *Hydra viridissima,* which is occasionally abundant in drains and pools overgrown with duckweed or pondweeds **[Figure 12.10]**. It is an unmistakable and beautiful emerald green, the colour being due to the presence of green algae *(Chlorella)* in the inner lining of cells in the animal's body. It is among the most graceful animals of the water; it lives attached to waterweeds, blindly searching its surroundings with graceful sweeps of its tentacles for the small animals on which it feeds. These are captured by extraordinary harpoon-like stinging structures called nematocysts, which are produced in special cells (cnidoblasts) that cover the tentacles and upper part of the body.

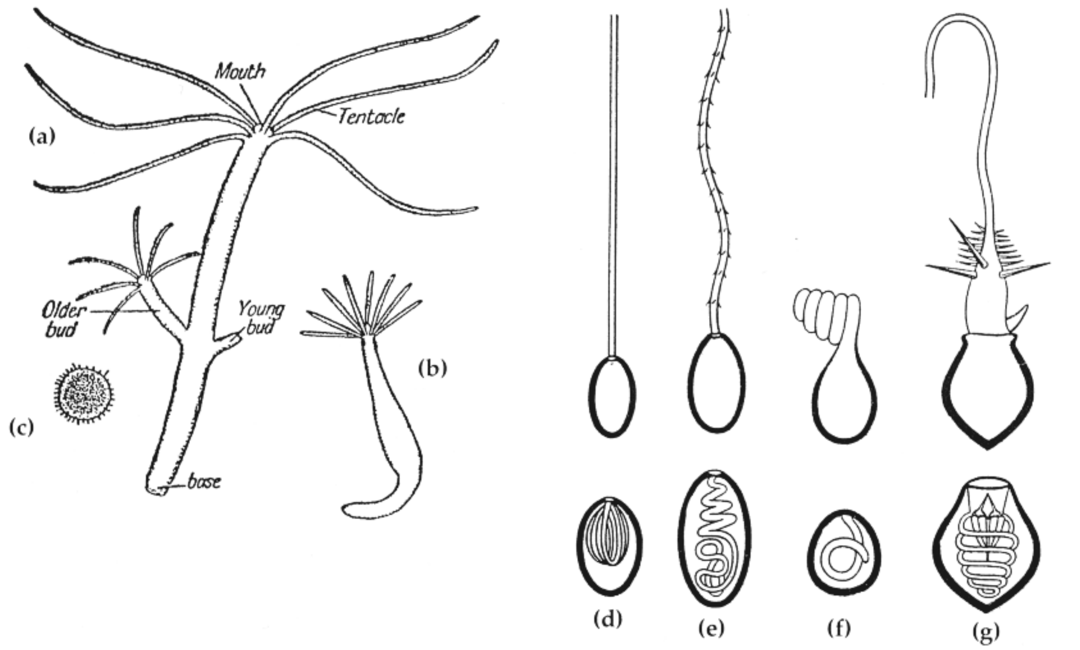


Figure 12.10: *Hydra* and its stinging structures (after Clegg, 1974).

Hydra has four different kinds of nematocysts. They are kept tightly packed inside little pear-shaped sacs, like very complicated inverted glove fingers, until they are stimulated. When the nematocyst is stimulated the hollow thread inside is ejected, being turned inside out in the process. The *penetrant* nematocysts are barbed at the base, and a paralysing fluid is injected with them. They can only be used once, but new ones replace them when they have been fired. The *volvant* nematocysts are like lassoos; they eject smooth threads which entangle the hairs and bristles of the prey. *Glutinant* nematocysts produce sticky threads, but these seem to be used for locomotion rather than for capturing prey. (After Clegg, 1974).

(a) Hydra in feeding position; (b) partially retracted; (c) young Hydra in protective cyst.
Nematocysts: (d)(e) glutinants; (f) volvant; (g) pentrant. Discharged above, undischarged below.

Protozoa and other microscopic animals in sphagnum

The remarkable aquatic environment provided by cushions of bog mosses, most notably in carpets and forests of sphagnum, is a truly extraordinary world, quite unlike that of any other habitat. It is a world subject to extremes of temperature, light and moisture level. The surface may become very hot during the day, but since sphagnum is a poor conductor of heat it always remains cool at depth: there is little diurnal temperature variation below 10cm, so at night it is warmer here than it is at the surface. Below 10cm light intensity is also very low, and little photosynthetic activity can go on below this depth in the carpet. Below 20cm there is little free oxygen either, and the pH of the water is of course always low, say between 3 and 5.

The fauna of this unique habitat includes groups of tiny creatures which are rarely seen in abundance elsewhere; there are gastrotrichs and tardigrades, rotifers and nematodes, mites, heliozoans, ciliates, flagellates and many other kinds of small animals. Some members of this 'sphagnophile' fauna have been regarded as survivors of the post-glacial tundra fauna which was much more widespread after the Ice Age, but is today confined to a few ecological 'corners'. It includes such creatures as *Moraria* (Harpacticidae), *Elosa woralli* (Rotifera), *Acantholeberis curvirostris* (Cladocera), several tardigrades (including *Diphascon scoticum)* which use their hooked claws to cling to the tufts, and a number of rhizopod protozoans, such as *Nebela.* Most of the remaining creatures in bog waters may be considered as a 'selection-fauna': those members of the freshwater biota that can meet the demanding conditions of life that occur here.

A number of species of rotifers belonging to the genus *Habrotrocha* are confined to sphagnum, living inside the outer retort cells of the moss. Protozoa occur in enormous numbers; 10,000 individuals per gram of dry sphagnum would be a small community. Many of these primary and secondary consumers in this jungle are very small, too small to swallow their prey, but they have stylets with which to break open and suck out the contents of algal or animal cells. Larger animals weave a somewhat restricted path through the microscopic jungle as well. Deserving of special notice is the midge *Lasiodiamesa sphagnicola,* a species confined to this habitat. However, the creatures that predominate in this unique microcosm are the shelled or testate rhizopods. These little creatures are tiny amoeba-like animals (Protozoa) whose body is a single cell, enclosed in a shell or test that the animal either secretes around itself or manufactures from building materials it collects from its surroundings. The test of each species is different, so the empty shells are an invaluable guide to identification, and are often very beautiful objects. The primary producers in this world are unicellular green algae, so many of the testate rhizopods also qualify as producer organisms, because they contain symbiotic zoochlorellae inside their cells; others are primary or secondary consumers, ingesting algae, protozoans and small metazoan animals such as rotifers.

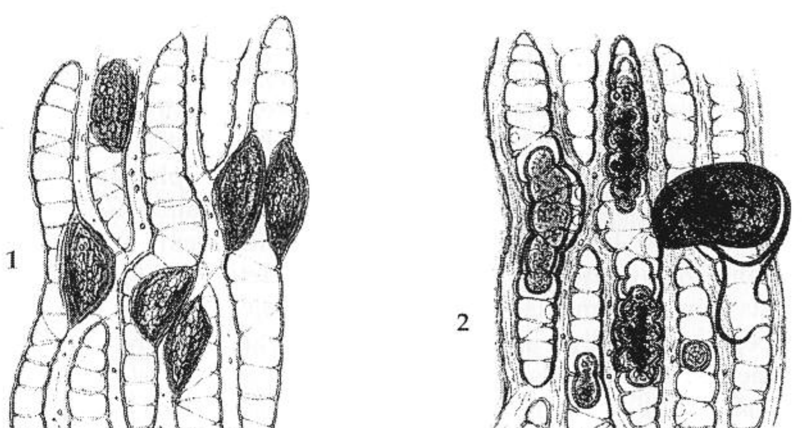
Dozens of different species of testate rhizopods occur in carpets of sphagnum, and the associations of species that are found in bogs are different to those that are found in fens. Studies in England showed that there is an association of about 25 species which can be considered as *characteristic* of fens (where the pH is above 5); there is a different association of about 16 species *characteristic* of bogs (pH 3.2-4.6), and some 13 species are 'eurytype': found in both situations. In sphagnum carpets in Great Britain no fewer than 98 species were recorded by Heal. They are active only in summer, dying off or encysting for the winter or when conditions become dry. Different bog species are confined to particular microhabitats in the sphagnum carpet. Most prefer to live deep in the sphagnum, where the temperature and moisture variations are not great, and where there is an abundance of food and test construction materials. Submerged sphagnum contains the richest faunas, not only of rhizopods but of most other small animals. The larger species tend to occur here also, because there is more room for them to move about; *Difflugia bacillariarum* and *Difflugia bacillifera* are two very characteristic bog pool species which make their tests from diatom frustules. Another is *Amphitrema wrightianum.* By contrast, the only species which live in the surface layers are those which contain symbiotic zoochlorellae inside their cells, such as *Hyalasphenia papilio, Heleopera sphagni, Amphitrema flavum, Amphitrema stenostama; Placocista spinosa* is another species found especially in the upper green layer of sphagnum growing in bog pools. Hummock species include *Assulina seminulum* and *Amphitrema flavum.* These species need to stay where there is light enough for their green prisoners to photosynthesise; they have clear, yellowish-pink or colourless tests which they secrete, so they don't need the building materials for which they would need to go deeper. On the other hand, these species need to be able to withstand periodic desiccation; this they do by encystment.

The most characteristic genus in sphagnum is *Nebela,* species of which have tests like inverted flasks. Common bog species include *Nebela flabellulus, Nebela tincta* and *Nebela militaris;* common fen species include *Nebela callaris, Nebela dentistoma, Nebela galeata, Nebela bigibbosa* and *Nebela penardiana.* Another large genus is *Euglypha*, especially in fens. Common fen species include *Euglypha acantaphora, Euglypha tuberculata, Euglypha rotunda, Euglypha ciliata; Euglypha strigosa* is a common species in bogs.

Most of these tiny creatures will be found in many other kinds of water bodies apart from those in bogs. But there is one rhizopod that stands out, even in this galaxy of diversity and wonder, because it is such an extraordinary creature [**Figure 12.11, Plate 11**]. It also appears to be a true bog specialist, and has apparently only been described from Ireland. This little rhizopod goes by the striking name of *Chlamydophrys labyrinthuloides.* It lives within the tissues of sphagnum and other aquatic plants early on in its life; how it gets inside the cells is something of a mystery.

It is roughly urn-shaped, a single naked cell enclosed in a many-layered envelope of cellulose. The colour is green streaked with red, the green being chlorophyll, because this is one of those creatures which is half-plant, half-animal, moving about and actively feeding and yet possessing the ability to manufacture its own food from the raw materials and sunlight which filter through the opaque walls of its strange little aquarium. It spends most of its time quietly dormant or encysted inside this armour, but from time to time it wakes up, and the creature emerges from an opening in the envelope and expands into a most amazing tree-like development, covered with tiny egg-shaped swellings, and with extremely slender ramifications along which a galaxy of mysterious little globular bodies move in procession from the trunk of the tree. This creature is known both from the midland bogs and from the bogs of western Ireland; it has been claimed that it is sometimes so abundant that its presence can be recognised from the reddish colour it gives to water when it is in its dormant or encysted state.

The little shells of rhizopods persist when the animals die, and enormous numbers may accumulate over the years. One estimate puts the figure at 16 million living and 20 million shells of dead amoebae per m^2 of a sphagnum carpet 12cm below the surface. The tests sink slowly through the watery jungle and accumulate in vast numbers among the dead sphagnum below about 20cm. Since the pioneering work of Grospietsch, the study of fossil rhizopods is attracting new interest as a tool for elucidating climate and habitat in the past.



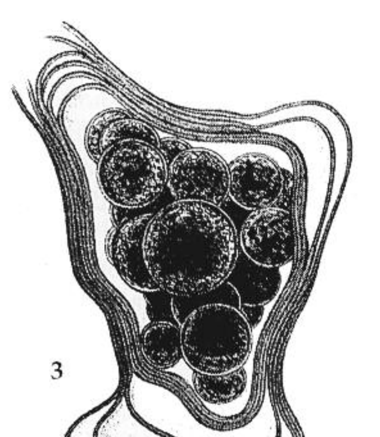


Figure 12.11: Stages in the development of *Chlamydophrys labyrinthuioides*. (From Archer - 1875-7).
1. A group of sphagnum cells showing what are believed to be embryonic *Chlamydophrys*.
2. *Chlamydophrys* at different stages of development. The 'torulose' form of the larger ones is due to constriction by the annular thickenings of the sphagnum cell wall. The one on the right has become extruded and has re-encysted outside the sphagnum cell.
3. Here the creature has divided into a cluster of separately encysted 'daughters', all enclosed within the multi-layered parental envelope.

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Chapter Thirteen

Archives in the peat 1:
Annals from the unwritten past

When he stripped off blanket bog
The soft-piled centuries

Fell open like a glib:
There were the first plough-marks,
The stone-age fields, the tomb
Corbelled, turfed and chambered,
Floored with dry turf-coomb.

A landscape fossilized,
Its stone-wall patternings
Repeated before our eyes
In the stone walls of Mayo.

Seamus Heaney: ***Belderg***

Introduction

The bogs were the last areas to be invaded by the advancing tide of agriculture - just as they had earlier been the last great wilderness areas to appear in the Irish landscape. We know that when people first set foot in Ireland, and for many thousands of years afterwards, there was very little bog. When people first took to farming, the country was largely covered with dense woodland; we suspect that interference with the protective woodland cover, at a time when climate was deteriorating, had something to do with the spread of the bogs (See Chapter 14). But how do we know all this? Where do we get our evidence about what the vegetation of Ireland was like before people arrived here - and about what happened to it subsequently?

The evidence is in the bogs themselves. The bog is not only a reservoir of solar energy trapped by the plants which grew at its surface in earlier times; it is also a repository of information about the human past, and particularly about the ways in which successive human communities used or abused the landscape which supported them.

This story is told in the bog's pollen archives. Pollen grains - or at least the resistant skins that protect the precious reproductive nuclei within - are among the most durable and permanent of all plant structures. They are also among the most distinctive: the pollen grains of most plant species can generally be easily distinguished with practice, using a good quality light microscope, while scanning electron microscope techniques show up the finer details. Every year the plants on the bog flower and produce large quantities of pollen, much of which falls as pollen rain upon the surface, and is engulfed within the upward-growing bog where it is preserved with the other plant remains in the peat. Essentially the same process happens in bog lakes, where the accumulating sediment on the bottom entombs the pollen rain falling upon the lake surface year after year. More importantly, pollen produced by the vegetation of the surrounding land is carried into the bog, and preserved in the growing peat. Careful analysis of the pollen in the bog profile, therefore, gives us a picture of the changing vegetation in the surrounding countryside.

About 11,000 years ago, the glaciers of the Ice Age withdrew from Ireland. As the temperature increased, vegetation re-colonised the land, and it is the pollen rain produced by trees and other flowering plants each year, and preserved in the peat of the growing bogs and the mud of lakes, that constitutes our best record of how the green surface of Ireland has evolved, how it has responded to changing climate and to human impact, in the millennia since the Ice Age. Climate improved steadily after the Ice Age, and the trees and other vegetation which had been banished by the cold began to migrate back into the country, across the land bridges which appear to have linked Ireland to Britain and the continental mainland until around 9,000 years ago. The climate reached its post-glacial optimum, with higher summer temperatures than today, at about 5000- 4000 B.C. After this it started to become wetter and cooler in an irregular way, with periods of relative stability separated by periods of rapid deterioration. One of the better known periods of climatic deterioration began in the mid-13th century and lasted until the mid-19th century. Because of its severity, particularly at higher latitudes (e.g. Scandinavia, Iceland and Greenland), it is known as the Little Ice Age.

Those who first studied the pollen record concentrated their attention on the trees, and the time since the Ice Age was divided into a number of stages on the basis of succession in the tree cover. The trees which dominated the post-glacial forests changed as climatic conditions altered, allowing the spread of new species, and as a result of human interference. Over all these thousands of years, pollen produced in abundance by the wind-pollinated trees rained down on the lakes and bogs, and became entombed in the upward-growing peat and in the slowly accumulating lake muds, preserving a record of the late-glacial and post-glacial vegetation and climate of Ireland. Scientists first learned to decipher this record at the turn of the century (1916 is regarded as a landmark date in the development of palynology). As research advances from year to year, the story it reveals, of how the forests of Ireland evolved following the Ice Age, is told in ever greater detail. The technique of pollen analysis (palynology) was developed by Lennart von Post, and introduced into Ireland by the Swede, G. F. Erdtman, who visited Ireland in 1924 and 1926. This post-glacial evolution of the vegetation is consistent over large areas, so that the time since the retreat of the glaciers can be divided into zones on the basis of changes in the composition of the forest, as recorded in the pollen record. This provides an outline calendar against which to measure all sorts of natural and cultural changes in the landscape. This time scale was devised originally by Blytt and Sernander, and although their calendar is now known to be rather simple and generalised, and of limited relevance in describing the way the vegetation of Ireland has evolved, its main concepts still lie at the heart of the post-glacial calendar [**Table 5.7**][1]. The most significant early work on Ireland's pollen record was that carried out by Professor Knud Jessen of the University of Copenhagen in the mid 1930s and early 1940s [**Figure 13.1**]. As a result of his work, the Irish post-glacial period was divided into a number of zones which were later modified by Frank Mitchell; this zonation scheme has ever since been the basis for subsequent work and analysis [**Tables 13.1 and 13.2**].

Figure 13.1: Knud Jessen, of the Danish Geological Survey and Professor of Botany in the University of Copenhagen, the great pioneer archivist of the Irish bogs.

Peat profiles have been studied from many bogs all over the country, and diagrams have been plotted which show how the proportions of different kinds of pollen wax and wane through time in the peat profile, reflecting the changes in the local vegetation. Pollen diagrams from different parts of the country have many features in common, reflecting developments which took place all over the country, but at the same time each diagram is different, a unique record of local events.

1 The inter-relationships between the Blytt and Sernander system and the Irish zonal scheme used to date post-glacial time are indicated in Tables 2 and 3. Both the calibrated (sidereal) and non-calibrated ^{14}C time scale may be used. Note the substantial divergence of the ^{14}C time scale (non-calibrated) from sidereal or 'true' years, especially prior to 3000 B.P. In this book 'true' ages are used, e.g. coming of the first farmers dates to c. 3100 B.C. or about 6,000 years ago (calibrated B.P. - before present). From 2500 B.P. to the present there is little difference between the two. For changing from the ^{14}C scale to sidereal time a very rough rule of thumb is as follows: from 0 to 3000 B.P. leave well enough alone; from 3000 to 4400 B.P. add 100-500 years as you go backwards. From c. 4400 B.P. add almost 1000 years, so that 5000 B.P. (the Elm Decline) becomes almost 6000; 10000 B.P. becomes 11000 years ago.

Table 13.1 : Event stratigraphical scheme for Ireland: pollen/vegetation

Holocene environmental change in Ireland. I. Vegetation — M. O'Connell, 1994

Date (^{14}C yr BP)	Date (cal.- AD/BC) [1]	Blytt-Sernander	Jenssen (1949)	Mitchell (1956)	Regional Pollen Assemblage Zones	Other diagnostic species and events
0	1950			X (modern)	AP ↓; 2° ↗ Pinus [2]	Planting of exotics 1
				IX Christian	*Q-Alnus-Gramineae*	
1000	1020	Sub Atlantic	VIII			Final ↘ in *Ulmus* and *Fraxinus*
						Late Iron Age woodland regeneration
2000	10			VIIIb (pagan)	*Q-Fraxinus-Betula*	
	AD ↑ BC ↓					Woodland ↘ sharply Q and Alnus↘. sharply
3000	1230					
						Pinus ± ↓ in W. Ireland
4000	2480/ 2550	Sub-Boreal	VIIb	VIIIa (pagan)	*Q- Corylus-Fraximus* (*Ulmus* still important in midlands)	*Pinus* ± ↓ in N. Ireland *Fraxinus* ↑ *Taxus* ↑ ↑'(W. Ireland)
5000	3780					Neolithic Landnam ELM DECLINE
						Ilex expands
6000	4865 4910	Atlantic	VIIa	VII	*Ulmus-Q-Corylus-Alnus* *Q-Alnus-Pinus-Corylus* in W. Ireland	*Alnus curve* ↑ [3]
7000	5825					*Pinus* peaks prior to establishment of *Alnus* (seen mainly in lake profiles)
8000	6810 6910	Boreal	VI	VI	*Corylus-Q-Ulmus* *Corylus-Q-Pinus-Ulmus* in W. Ireland	
9000	8030				*Corylus* peak zone	*Ulmus* and *Q* ↑ *Corylus* post-glacial maximum (c. 80%)
			V	V	*Betula* peak zone	*Corylus invading*
10 000	9160/ 9240/ 9370	Pre-Boreal	IV	IV	*Salix* *Juniperus*	Tall shrub replaces herb-dominated vegetation
Late-glacial						

Q: *Quercus*; ↑: curve expands for first time; ↗: increase; ±↓: almost extinct.

1: Two or more dates given where there is a bad wiggle in the ^{14}C calibration curve, the greater part of which is based on 7272-year Irish-German oak chronology (Pilcher *et al*. (1984) Nature 312, 150-152).

2: AD 1600: 1/8 of Ireland under woodland; 1800: only 1/50 (McCracken, E. (1971) *Irish Woods Since Tudor Times*, David and Charles, Newton Abbot)

3: *Alnus* expansion not synchronous; 6700 BP in Connemara; upland areas, N. Ireland, as late as 5200 BP.

Table 13.2 : Event stratigraphical scheme for Ireland: geology, archaeology and climate

Holocene environmental change in Ireland. II. Geology, archaeology and climate — M. O'Connell, 1994

Date (^{14}C yr BP)	Date (cal.- AD/BC) [1]	Geology	Archaeology/History	Climate
0	**1950**	Drainage and widescale peat cutting	The Great Hunger (1845-46) 1600s: widescale felling of oak and planting of exotics begins	Little Ice Age
1000	**1020**	Relative rise in sea-level in SW and W coasts	Normans in Ireland (AD 1169) First Viking settlements (AD 790s) Ireland's 'Golden Age' Early Christian period and renewed farming activity	Lesser climatic optimum Cool (little building; fcw oak timbers AD 524-648)
2000	**10**		Late Iron Age lull (mainly in pollen record)	Warm
	AD ↑ **BC ↓**	Bad wiggle in ^{14}C cal. curve, the so-called 'Halstatt disaster'	LBA/EIAJ arable farming at Carrownaglogh, NE Mayo	
3000	**1230**	Hekla III (3100 eal.-Bp)[4] Recurrence surfaces in raised bogs	High population pressures (farming on marginal land)	Narrow rings in Irish bog oak4
4000	**2480/** **2550**	Widespread initiation of blanket bog Hekla IV (4200 eal.-BP); ^{14}C years substantially longer than calendar years	LN/EBAJ: wedge tombs (cf. Burren) LN: Passage tombs (Newgrange) Ceide Fields, N. Mayo - 1000^{+} ha of Neolithic fields	Drier periods facilitating establishment of pine on bog surfaces in W. Ireland and Midlands
5000	**3780**	High sea-levels on E and NE coasts[5]	Oldest human bones (Neolithic) from Poulnabone portal tomb; court tomb construction; first evidence of farming (Landnam) at L. Sheeauns	
6000	**4865** **4910**		Larnian culture (L. Mesolithic) Mesolithic settlement at Newferry	Post-glacial climatic optimum Summer temperatures 2-3ºC >today?
7000	**5825**	Diatomite deposition begins at Newferry, L. Bann Low lake levels		↗ ppt facilitating ↑ of Alnus? ↘ ppt or ↗ evapo-transpiration resulting in lower lake tevels
8000	**6810** **6910**	End of landbridge to GB Reedswamp and fen is replaced by Sphagnum-dominated raised bog vegetation in Midlands	L. Boora, Offaly (Early Mesolithic)	
9000	**8030**	Large arcas of open water in mid-Shannon basin and Midlands where raised bog later developed	Mount Sandel, Coleraine·(Early Mesolithic)	
10 000	**9160/** **9240/** **9370**	Solifluction ceases	No evidence of Palaeolithic peoples	Max. summer insolation in N. Hemisphere Rapid rise in temperature
		Late-glacial		

f: Curve expands for first time; ↗: increase; ↘: decrease.
1: Two or more dates given where there is a bad wiggle in the ^{14}C calibration curve, the greater part of which is based on 7272-year lrish-German oak chronology (Pilcher *et al*. (1984) *Nature*, 312, 150-152).
2: RS: Recurrence surfaces in raised bogs.
3: LN: Late Neolithic; EBA: Early Bronze Age; LBA: Late Bronze Age; EIA: Early Iron Age (Halstatt).
4: Very narrow rings in Irish bog oak 1159-1140 cal.-BC (Baillie and Munro (1988) Nature, 332, 344-346; Baillie (1994) *Current Archaeology*, **117**, 310-313).
5: Carter, Devoy and Shaw (1989) *Journal of Quaternary Science*, **4**, 7-24.

An attempt is made in what follows to outline the main story told by the pollen record, but it needs to be remembered that local factors are all-important, and that the story for each place is unique. That unique local record is preserved in the bogs of each district, and one reason for a more local focus to peatland conservation is the fact that the pollen story preserved in each bog is an irreplaceable archive of the early phases of the unique history of the locality in which it is located.

It is very useful to find objects of archaeological significance in a bog or lake mud, because the associated palynoflora enables us to see where it fits in terms of the post-glacial calendar, and in terms of the environment in which the people associated with the objects lived. It also enables the sequence of cultural development to be related to stages of environmental evolution. The subject of archaeological finds will be treated in greater detail in a later chapter, but a few introductory remarks will be useful here. The earliest archaeological finds come from Jessen's Zone V: these are flints from the shores of Lough Neagh, and Mesolithic implements from Cushendun Beach. The Zone VII/VIII boundary, i.e. the so-called Boreal! Atlantic transition, marks an important point in the early post-glacial record. The feature that defines Zone VII is that quite suddenly, large quantities of alder pollen appear for the first time, and pine becomes less important than before. It was during Zone VII, in the Atlantic period, that the climatic optimum was reached. Natural succession, probably triggered by a regional drop in the water table, encouraged the spread of fen and bog outwards from the post-glacial lakes where the early development of these ecotopes had been concentrated.

In the beginning, the peat only accumulated slowly, and was well-humified because of the high temperature prevailing at the time. During this period the fens of the Midlands began to be replaced by raised bogs in which well-humified sphagnum peat accumulated. As climatic conditions improved during the Atlantic period, trees were able to colonise the bogs, especially on the mountains and all over the west, a spread which is reflected in the dramatic increase in the proportion of pine pollen in profiles at this time. Zone VIII opens around 1230 B.C., and in Ireland it is characterised by a substantial increase in the amount of birch pollen as conditions became cooler and wetter.

The pollen record tells us that the country was covered with closed tall-canopy woodland by around 7500 B.C. The composition of the woods varied from region to region. The forests of the Midlands were predominantly oak-elm-hazel woods, for example, while in much of the west they were oak-pine-hazel woods. The scarcity of grass pollen shows that there were very few open spaces, and there is no hint of cereal pollen or of pollen belonging to the many opportunist plants which follow farmers and their cultivation practices. One of the most important of these weeds is ribwort plantain which is usually regarded as an almost certain indicator of pasture, and which produces an abundance of wind-dispersed pollen.

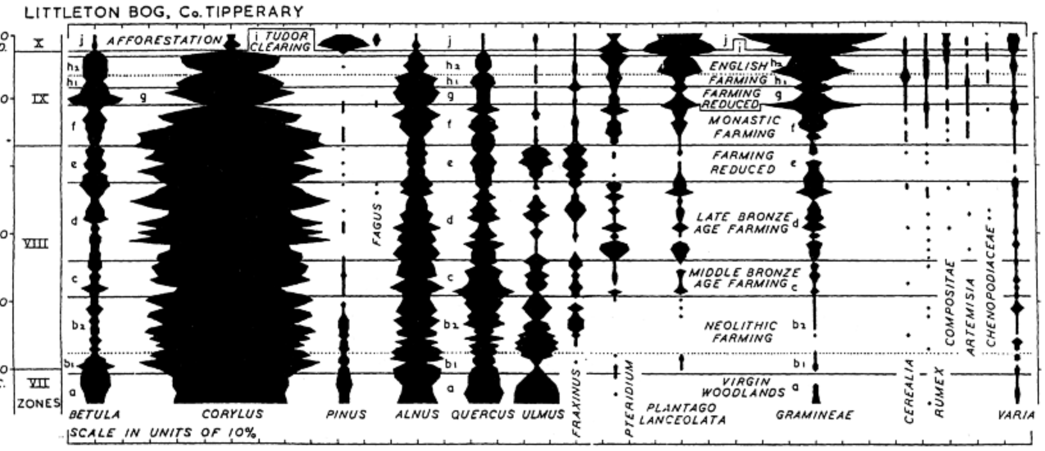


Figure 13.2: The Littleton pollen diagram. The width of the black bands is a reflection of the abundance of any particular species at a given time. (From Mitchell, 1965).

Then, quite suddenly, towards the beginning of the fourth millennium (i.e. c. 3000 B.C.), there is a dramatic decrease in tree pollen, and an equally dramatic increase in the representation of grass and weed pollen. These changes record the earliest Landnam – the exclusive reclamation of the wildwood for farming in Neolithic times. Little cereal pollen is found at the level of the Neolithic Landnam in Irish pollen diagrams, partly because cereal pollen seldom travels very far, but perhaps mainly because the Neolithic farming economy which this great clearance of woodland represents was in parts of the country anyway, primarily pastoral. Detailed analysis of the pollen record suggests that pastures were closely cropped, so it is likely that sheep as well as cattle were important in the farming economy by this time.

Tipperary

One of the outstanding reconstructions of the evolution of the landscape after the Ice Age from the pollen record was Frank Mitchell's study of Littleton Bog in County Tipperary **[Figure 13.2]**. Professor Mitchell's now classic pollen diagram shows, at the base of the record, the return of herbs, grasses and sedges to the bare surface of a land recently abandoned by the ice. These were later displaced by low bushy vegetation, which in turn gave way to woods of pine and hazel around 8000 B.C. There is a sudden and temporary decrease in the area covered by pinewood around 6888 B.C., and at the same time hazel and herbs become more widespread; oak and elm begin to invade the woods, followed later on by alder. From the archaeological evidence - especially the excavations at Lough Boora (Chapter 15) - we know that the first people arrived in the north Midlands quite early in the Mesolithic period around 8000 B.C., just about the time that hazel suddenly and dramatically expanded at the expense of birch, and the broad-leaved forests began to take over. Hazel nuts are always abundant at Mesolithic sites, indicating that they were an important food item. At around 5500 B.C. there is a sudden decrease in the area of pine forest, and forests of oak, elm, alder and hazel came to dominate the landscape. It is interesting that ash failed to expand at this time. Apparently the disturbances in the natural woodlands that resulted from early Neolithic farming were necessary before it could find the opportunity to expand at around 2500 B.C.

Around 3800 B.C. the pollen record shows a sudden and dramatic decrease in the area under forest, and particularly elm. This is the so-called Elm Decline which is known from pollen diagrams throughout north-west Europe but is best seen in Irish pollen diagrams because of the particularly sharp and dramatic decrease in the elm pollen representation here at that time. Needless to say, the search for the cause of such a dramatic change has exercised the minds the palynologists since it was first discovered by J. Ivesen in Denmark in the 1940s. From this time onwards the pollen record shows an oscillation between periods of agricultural activity accompanied by woodland c1earance, and periods of forest regeneration, and Professor Mitchell attributed the main periods of decrease in the tree pollen to the activities of farmers during particularly prosperous or innovative periods: the Neolithic itself around 3800 B.C., the Middle Bronze Age around 1600 B.D., when metal was becoming increasingly available, the Late Bronze Age (1300 B.C.), when still more efficient tools, including the socketed axe, were coming into use, the early Christian period (500-800 A.D.) and the Anglo-Norman period (1200 A.D.).

In the centuries before the arrival of Christianity, from around A.D. 400, a great reduction in farming followed upon more than a thousand years of vigorous agriculture spanning the Middle and Late Bronze Ages. Why this should have occurred at this time is far from c1ear. There is no obvious gap in the archaeological record. The Bronze Age gave way to the Iron Age in Ireland about 800 B.C., so it is unlikely that this collapse in agriculture is a reflection of the social and political upheavals that late Bronze Age society experienced as it accommodated itself to Celtic dominance and the arriva1 of iron. It is more likely that the cause lies in the disastrous impact on agriculture of a downturn in the climate which occurred in the early centuries of the first millennium A.D. The consistency with which woodland recovery is recorded in pollen diagrams from other parts of the country at this time suggests that the decline in farming activity was not confined to South Tipperary, but was a regional phenomenon.

When agriculture did recover, around 300-400 A.D. at a time when new continental farming techniques were being introduced into the country, the soils under elm and ash were quickly recovered for farming, and these trees never regained their former importance in the landscape. The introduction of the new medieval farming techniques by the Cistercians in the 12th century, and the coming of the Normans, led to further advances in the reclamation of land from the wilderness.

Professor Mitchell's linkage of the pollen story to developments in the archaeological and historical record is neat and satisfying. But the evidence of the pollen does not always match the documentary record so neatly, and perhaps this is only one interpretation of a complex dataset where a relatively loose dating system is used to guide the interpretation of vegetational change. The failure of the pollen record to corroborate historical or archaeological data is sometimes due to peculiarities associated with a particular site (e.g. short-term interruption of the growth of peat or lack of sufficiently detailed analysis), or to our inability to read and interpret the record correctly. It may also be that the neat written record of the course of history is very often a later oversimplification or distortion of events, so that the written records, which are often scanty anyhow, also need to be interpreted with care.

Connemara

The detailed palaeoecological studies of Michael O'Connell, Karen Molloy and their students at UCG provide us with windows into the past of particular places in a most extraordinary way, using the evidence of buried pollen and bog-smothered walls to tell the story of ancient, vanished farming communities and their relationship with the growing bogs. Most of the Galway work has concentrated on Connemara and North Mayo, but many other windows will open in the years ahead, and the details can be expected to vary, because each place has its own unique history.

At Lough Sheeauns, near Cleggan in north-west Connemara, where an exceptionally detailed pollen record of early farming is available, the Neolithic Landnam phase of intensive pastoral farming lasted for almost two centuries, centred on 3750 A.D., after which there was a dramatic reversal, reflecting great reduction in fanning, and the return of the abandoned farmland to forest **[Figure 13.3]**. Similar phases of decline are known from many other areas, and they have often been attributed to exhaustion of the soil. But if this had happened, there should be evidence for the expansion of heath or bog at this time in the pollen record, and this is not the case, at Lough Sheeauns at any rate. Nor do the sediments in which the pollen rain is trapped suggest that the soils were becoming podsolized - as they should if this were happening.

But the landnam which is so dramatically evident in the pollen record does not record the beginning of farming in Ireland. The persistent presence of small amounts of grass and plantain pollen, and the occasional grain of cereal pollen in the profile at around 3900 B.C. suggests that farming was being practiced several centuries before this, and the same is probably true of other parts of the country. There is also a big increase in the representation of holly in the pollen record, and this is significant, because the flowering of holly is greatly favoured by breaks in the woodland canopy. So for these first few hundred years of Irish farming, the isolated farms centred around small clearings in the wildwood, and these clearings were probably for crops rather than pasture; the cattle and pigs foraged for themselves in the woods. This system flourished for about two centuries, before it was replaced by a much more centralised and organised social structure, with a farming economy in which the clearance of extensive areas of woodland for pasture was central. Elucidation of the cultural and social changes that underlay these developments is one of the challenges that await a future generation of researchers.

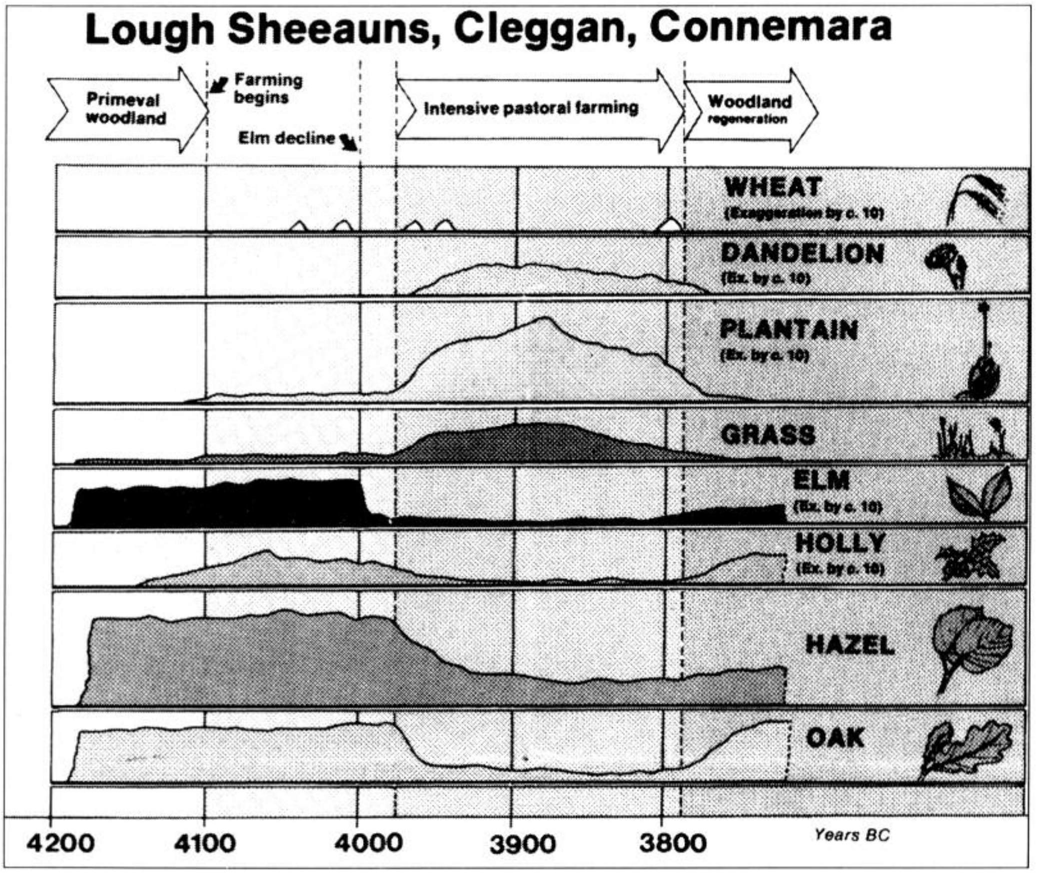


Figure 13.3: The pollen story in Connemara. This simple diagram by Michael O'Connell and Karen Molloy, summarises much detailed research. The height of the shaded bands in this case is a reflection of the abundance of any particular species at a given time.

North Mayo

The pattern of pre-bog farming has been carefully studied in the townland of Carrownaglogh on the lower slopes of the Ox Mountains, where a Bronze Age farm lies buried beneath the bog. Bog began to grow in a low-lying basin to the south of this farm around 1950 B.C., and the pollen record from this bog enables us to piece together the farming history of the area in remarkable detail. Even at this time, the only woodland remaining in the area was secondary woodland - mainly birch and hazel scrub, with a little oak and pine – because the primeval woodland had been cleared for farming long before. The climatic deterioration which had already taken place by this time prepared the ground for the expansion of bog growth, but the activities of the early farmers played a significant role.

There were three periods of particularly intense farming activity in the area of Carrownaglogh: around 880 B.C., A.D. 50 and A.D. 1000 **[Figure 13.4]**. The first of these periods is most likely the one to which the ridges in the enclosure date, and the pollen assemblages from the sub-peat soil here show that cereals were cultivated on the ridges possibly a rotation involving barley and wheat. The pollen story tells of a dramatic reduction in tree cover (mainly oak and birch) and an expansion in bracken, followed by an increase in the area of open land. Pollen of corn spurrey is strikingly abundant, indicating that it was very common on the cultivation ridges as a weed in the cereal crops: but it may also have been planted as a crop in its own right, because its seed is a good food source. An abundance of grass, plantain and clover pollen suggests that grassland was not far away. This first episode of intensive farming lasted for less than two centuries.

As the short-lived generations succeeded each other, the expanding bog was creeping slowly up the hill. The formation of a thick iron pan beneath the cultivation ridges, impeding drainage, probably played a role in the initiation of peat accumulation over the ridges. A significant point is the fact that these early ridges were laid out along the contours of the hill slope, compounding drainage problems after the development of the iron pan. Recent ridges are always laid out at right angles to the contours to facilitate runoff.

To begin with, the dry surface of the bog that had formed in the basin provided grazing, but as the years grew to centuries it became increasingly wet, especially in winter, and by the 8th century A.D. it was no longer a valued resource. A thousand years after it had begun to accumulate in the basin below, the growing bog engulfed the walls and fields and soils on the ridge, and sealed the pollen record which enables us to read the story of the final years of the Iron Age farm.

At about A.D. 50, i.e. six hundred years after the first, there was a second phase of agricultural expansion. This was probably not as intensive as the earlier landnam, but it lasted for 350 years, and when it came to an end woods of hazel, oak and elm moved in

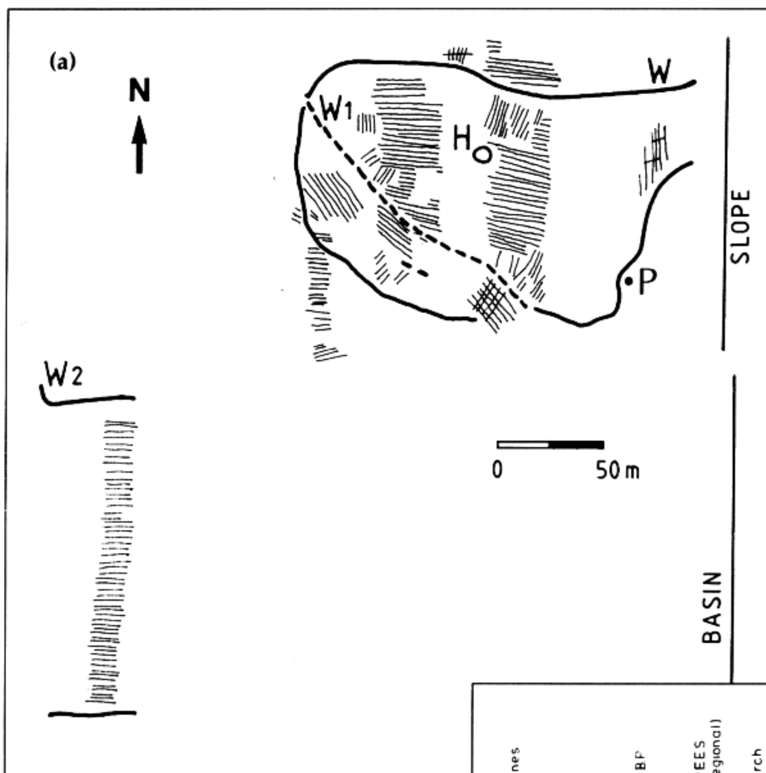
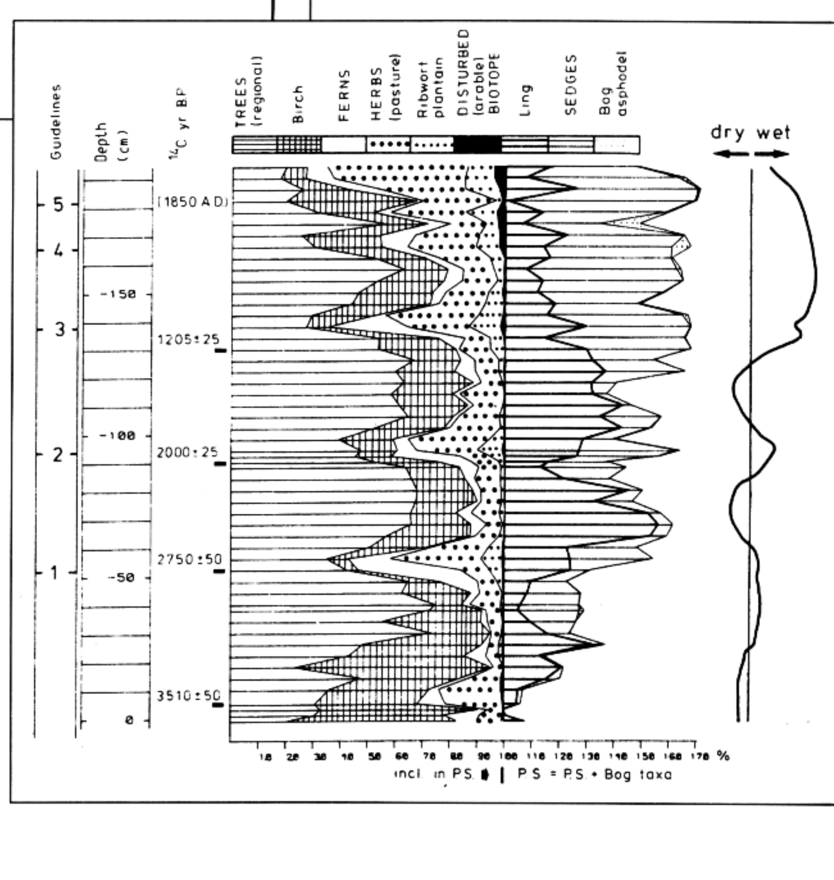


Figure 13.4: (a) Prehistoric farm at Carrownaglogh townland overlooking the Glenree River, on the western slopes of the Ox Mountains in County Mayo. Stone field walls are indicated by thick lines; W is the main enclosure wall; WI is a wall which has been robbed of its stones; W2 is a wall constructed partly on peat. Cultivation ridges exposed by removal of the peat during archaeological excavation of the site are shown schematically - their full extent is much greater. The location of the pollen diagram shown in (b) is at P; H is the circular enclosure with hearth.
(b) Percentage pollen diagram from Carrownaglogh, pollen of local bog origin omitted so as not to obscure vegetation changes on the surrounding farmland. Among the most obvious features of the diagram are the phases of tree clearance. (O'Connell, 1990).



to reclaim the farmland once more; by this time blanket bog had totally enveloped the cultivation ridges on the knoll.

A third clearance phase which dates to shortly before A.D. 1000 is reflected in the pollen evidence by a decline in the representation of hazel pollen from c. 30 to 10% – from which low level it never fully recovered. This suggests a fundamental change involving the widespread clearance of hazel scrub and an increase in farming activity which included both pastoral and arable components. Between this and the present day, there are two further notable features in the pollen record. A further reduction in woody vegetation, especially oak and ash, takes place shortly after A.D. 1500. Expanding population and farming activity continues to be reflected in the pollen record until at 12cm below the top of the present day surface of the bog, there is a major peak in birch pollen which dates to c. A.D. 1850. This indicates a strong local development of birch scrub, probably on the marginal peaty land in the general vicinity of the sampling site and is doubtless a consequence of abandonment of this marginal land following the ravages of the Great Famine (1845-47). This regeneration of woody vegetation was short lived, so that the uppermost part of the pollen record shows the developments of the present century. The stabilisation in the amount of fossil tree pollen at this uppermost level is not, however, due to natural regeneration but to the extensive conifer plantations of the present century.

The studies at Littleton Bog and Carrownaglogh are just two examples of the detailed record of our history, and especially local history, the archives of which are preserved in the bogs, waiting to be deciphered and interpreted thanks to continuous improvements in existing techniques (e.g. pollen and macrofossil analyses, radiocarbon dating, dendrochronology, etc.) and the development of new techniques. Perhaps the most exciting of these new techniques is tephra analysis: the detection and study of volcanic ash layers - usually of Icelandic origin – which can be used to provide precise dates for particular horizons. Rosaleen Dwyer of Trinity College's Department of Botany has been studying tephra in the blanket bogs of north-west Mayo. She has identified seven tephra horizons at Croaghaun East, one of which occurs at the level of the main humification change in the peat. The shards shown in [Plate 11], which were recovered from a layer 56cm below the surface of this bog, have been shown by geochemical analysis to come from an eruption of the Icelandic Volcano Hekla in 1104 A.D. Tephrochronological studies have also been carried out in the Mourne Mountains and elsewhere.

Although the picture of how the local Irish landscape evolved in the millennia following the Ice Age is especially detailed and accurate for the special areas in which the modern studies summarised above have been carried out, the early work carried out by Knud Jessen and Frank Mitchell in bogs all over Ireland in the 1930s and 40s remains a storehouse of information for other areas. The two key papers in which they published their work (1946 and 1951 respectively) are still an essential starting point for further local studies.

Our knowledge of what was happening at particular times in Irish history enables us to invest the silent pollen changes which chronicle the events with human detail and colour. We can invest the earlier changes with no such sympathetic detail, but here too we know we are touching the fringe of other tragedies or triumphs, the detail of which may well be elucidated in years to come by archaeological and palaeoecological research. In the decades ahead palaeoecology will open ever more windows on the prehistory of other parts of the country, shedding further light on the variable local detail of the fluctuating relationship between farming, woodland and the bogs. It is important that we understand all of this: it is important for us to see where we stand in relation to the past we inherit, and the future we face, a future in which climatic change and all its consequences for human society, will be more important than it has ever have been in all the millennia since the last Ice Age.

Buried farms

The growing bogs captured more than the invisible pollen rain falling on them through the millennia of their growth. The parts of Ireland over which blanket bog began to spread at around 2500 B.C. as climate deteriorated were farm landscapes. The growing bogs buried and preserved the very fields of prehistoric Ireland, and sometimes the homes of those who tilled them. One of many examples is the discovery in the 19th century of a house measuring 12′ square and made with rough oak planks 9′ high no less than 26′ below the surface of DrumkeIin Bog in County Donegal, adjacent to a stone causeway **[Figure 13.5]**. An extensive series of cultivation ridges preserved beneath the peat at Carrownaglogh enables us to see and touch the fossil fields and gardens where people once laboured at the activities which directed the record of human activity we read in the pollen record. The great stone burial places of the earliest farm people were also often enshrouded in bog: like the early Neolithic court tomb in Carrowleagh near Carrownaglogh, and others at Carrownaglogh itself and in the Behy-Glenulra area.

The invasion was a slow process, and the abandonment of the west to bog was a gradual, and no doubt reluctant process, as the inexorable effects of the climate on the landscape, linked to social and economic pressures, made farming increasingly difficult and finally impossible. Pre-bog fields are now known from many parts of Ireland. At present we know of some 50 sites where the bog has preserved the ghosts of ancient farm landscapes, mainly in the west and north, but others continue to come to light from beneath the blanket bogs in many other parts of the country. Even in the very heart of Ireland, on the Great Heath of Maryborough north of Portlaoise, ancient cultivation ridges lie buried beneath the peat. The farmland which was lost to the bog was never entirely forgotten, and in parts of the country a local knowledge or tradition of pre-bog fields survived to modern times.

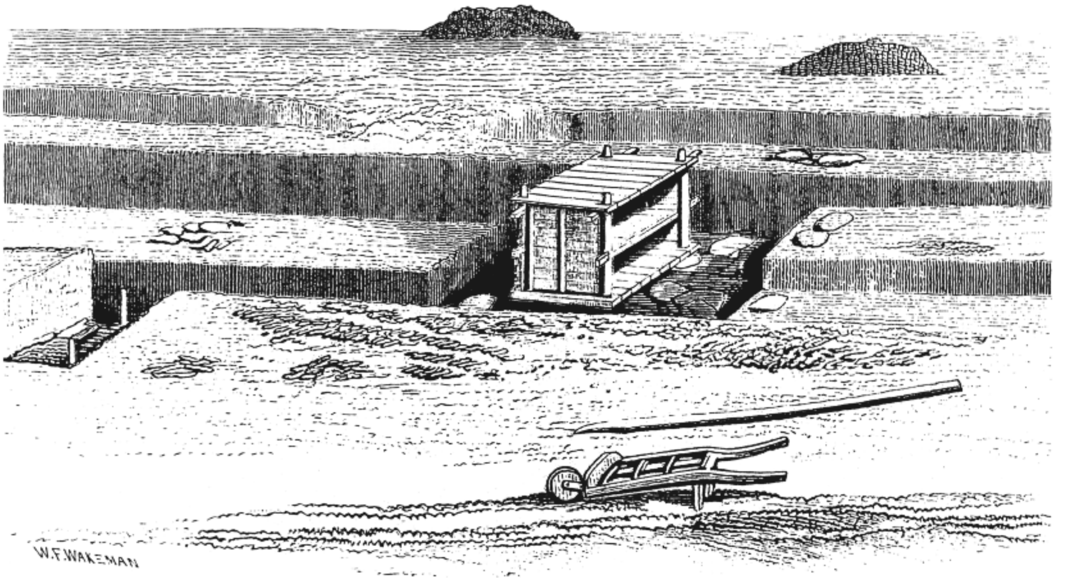
One of the first sites to be investigated in detail was the area of the Céide Fields to the west of Ballycastle on the coast of north Mayo. After 25 years of probing and excavating, the hidden fossil farmscape beneath the bogs in this area is now better known than any other. It covers an area of more than l,000ha - perhaps much more - making it the most extensive system of prehistoric field boundaries known in north-west Europe, perhaps in the world **[Figure 13.6]**. We used to think that farming in Ireland was a primitive business in the beginning, that the Neolithic farm landscape consisted of temporary clearances in the natural woodland cover which were abandoned after a few years when the natural fertility of the soil was exhausted. But what we find under the blanket bogs of the north Mayo coast is an extensive, organised system of fields bounded by stone walls, within which a system of mixed farming, with a strong pastoral bias, was carried on. This stretch of the Mayo coastline first became farmland in the Neolithic, but there were still people actively farming here in Early and Middle Bronze Age times, even though suitable land was now greatly reduced in extent by the growth of bog.

The main feature at the prehistoric farm site at Carrownaglogh on a shoulder of the western slopes of the Ox Mountains is a granite wall which encloses an area of 2.2ha; inside this were the cultivation ridges described earlier, as well as the remains of a circular Bronze Age farmhouse, some 7m in diameter, with the hearth in the middle. Archaeological, pollen and radiocarbon evidence all indicate that the ridges were used for a considerable time - from Late Bronze Age to well into the Iron Age. The presence of the remains of a house add a further dimension to the site. Houses from the early prehistoric period are not common in the archaeological record, partly because they were made of wood rather than stone - one reason being the abundance of timber at this time. Another reason why weatherproof stone houses were not the fashion in these times is that the climate was considerably warmer – perhaps 20° C higher than today.

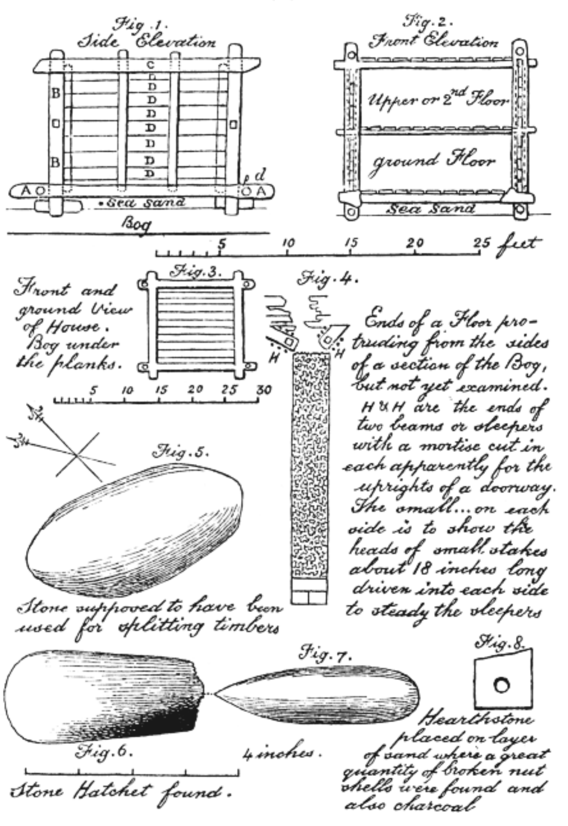
The occurrence of charcoal in the peat may be an indicator of the presence of people, though natural causes must also be considered a possible explanation. Perhaps the most significant soil horizon in this respect is one which occurs with significant frequency at

Figure 13.5: Houses under the bog.
A. Two-story wooden 'hut' discovered under some 8m of peat in Drumkelin bog in County Donegal in 1833. The structure was enclosed within a stake palisade. Inside, a paved causeway resting on hazel timber led from the door to a central hearth, around which ashes, charred wood and half-burned turf were scattered. It was about 4m square and 3m high, made of roughly-mortised oak logs and planks; grease and fine sand had apparently been used to block the cracks. The logs had been split with stone tools; a stone axe and wedge were found inside. Other finds included a flint arrowhead, a piece of leather sandal and a wooden sword. A particularly interesting item of furniture in the hut was a two-inch thick stone slab with a little hole in the middle, together with a number of round beech pebbles: the oldest known nutcracker in Ireland; it was surrounded by large quantities both of whole and broken hazel nuts.
The structure had been built in woodland; it was surrounded on all sides by hardwood stumps.

13.5 A (a)



(b)



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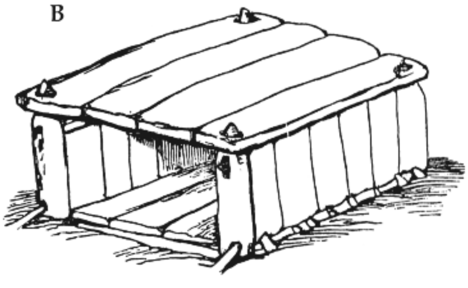
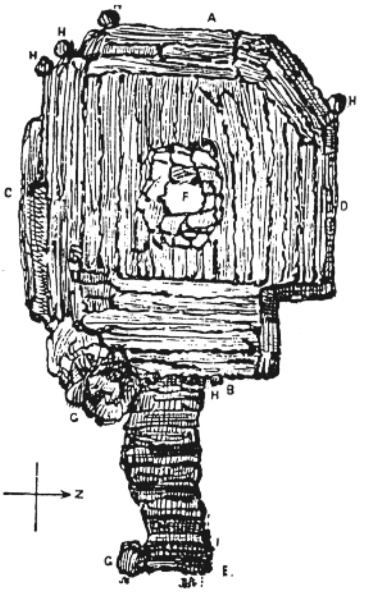


C



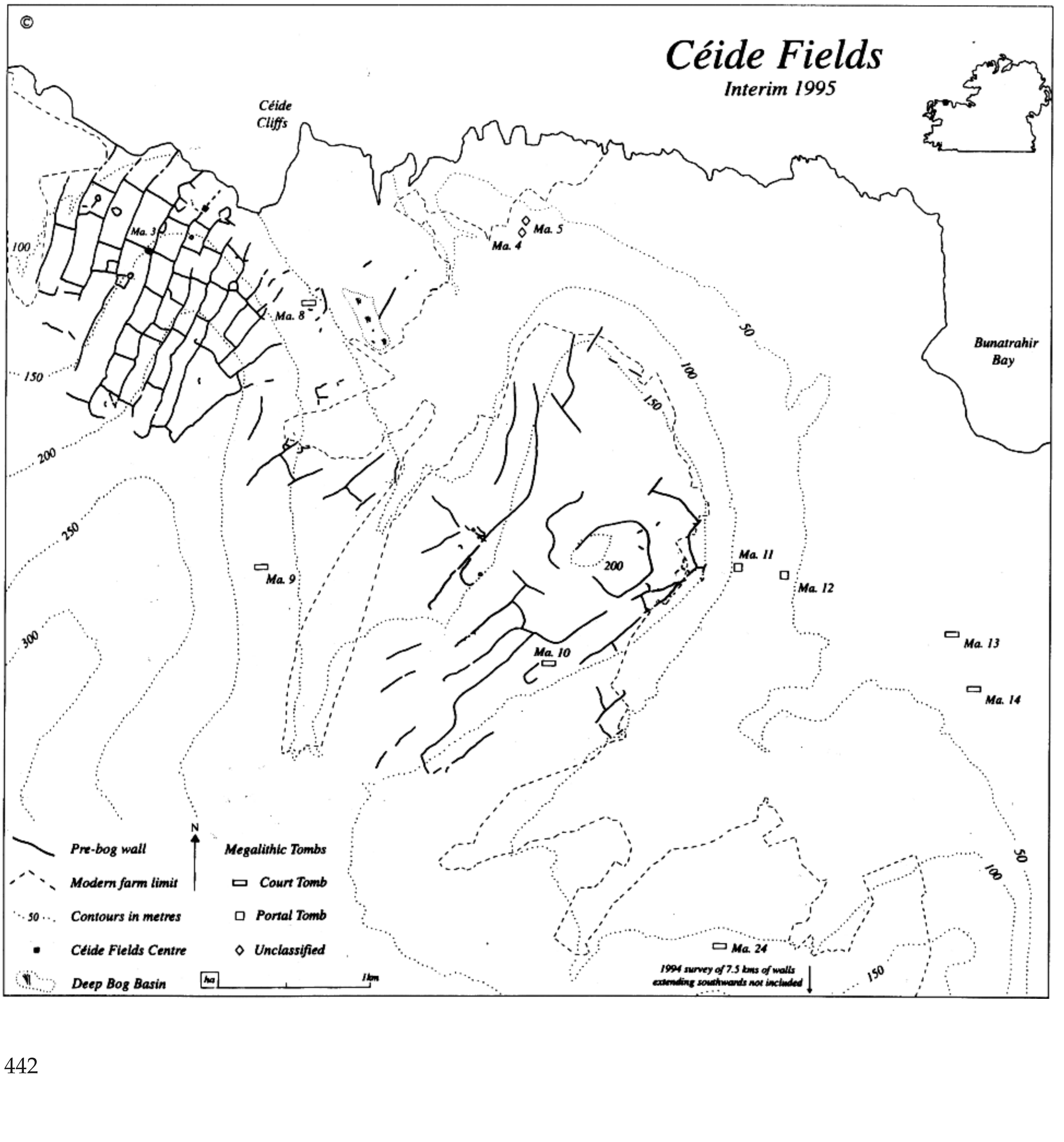
(a) Diagrammatic reconstruction of structure as found.
(b) Front, side elevation, ground plan and some details of the structure.

B. Another stone age hut from bog in Kilnamaddo in County Fermanagh.
C. The foundations of a wooden house discovered under nearly 5m of bog at Cargaghoge near Carrickmacross, County Monaghan, in 1867. This had an oak floor and a central fireplace, which also had an abundance of nutshells and ashes.
A-B: 18'4"; C-D: 17'6"; B-E: 11 '6"; F; fireplace; G: large tree stumps. H: remains of posts; I: dotted line showing ends of planks bared by the tenants.

(Drawings from Wood-Martin, 1886).

the base of blanket peat. This is typically a 5cm layer of grey-black sandy material full of charcoal, and Frank Mitchell believes it is the result of systematic heather burning, possibly followed by animal poaching of the recently burnt surface. He recorded two charcoal horizons from the peat on Valencia Island, one of Neolithic age, the other dating to the Bronze Age. Pete Coxon has studied a woody charcoal horizon under blanket bog near Bangor Erris in County Mayo **[Plate 11]**. It lies beneath 2m of peat on a palaeosol (sub-fossil soil) with iron pan. Woody charcoal is not in itself evidence of the human use of fire: it is known also from peat of Cortian age (250,000 years ago), where there is no indication that Palaeolithic humans were present in Ireland.

Figure 13.6: The Ceide Fields in North Mayo.
The figure shows the extent of the system of pre-bog field walls as it was known in 1995: more of it is surveyed each year. Note that the 7.5km of walls which extend southwards from the lower part of the diagram is not included. (Courtesy of Seamas Caulfield).



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Chapter Fourteen

Archives in the peat 2: Changing climate, buried forests and drowned bogs

"I believe, sir, what you say is right; for besides often hearing of a rock far out seaward, beyond the island of Inniskea, which rises every seven years out 0' the sea, and is covered with church buildings, and has a belfry and a tower, and is therefore called Monaster Lettera - don't I myself know that there are bogs and bog timbers down below the sands, and under where the sea always flows - there was a ship stranded not long ago on the sandy beach off Terran point; in order to raise her, or at any rate to save her timbers, the people dug all around her during the ebb of a spring tide, and cutting as they did down through the sand, and where the sea came in on them so that their labour was vain, yet still at the bottom they found nothing but bog and large pieces of bog fir. "

"That may be very true," says an intelligent coast-guard, who was just now in our company, "for I have often seen in Blacksod Bay of a clear day, when the sea was smooth and as transparent as spring water, fathoms down, the roots of trees that seemed of the same sort as what are every day dug out of our bogs. "

Cesar Otway (1845). *Sketches in Erris and Tyrawley.*

Recurrence surfaces and changing climate

The growth of the bogs was not a continuous, unbroken process. There have been times when growth slowed down or even ceased for a time, and the bog surface was invaded by heather and other plants that like drier conditions. A change in the peat profile from vegetation dominated by heather and sedges to vegetation dominated by sphagnum (especially *Sphagnum imbricatum)* is called a *recurrence surface;* it is also marked by changes in colour, degree of humification etc. Recurrence surfaces were first described at the turn of the century by the pioneer of bog stratigraphy, C. A. Weber, from the then extensive bogs of northern Germany. The most obvious, widespread and synchronous of these surfaces, which is found in bogs throughout north-west Europe is known as the *Grenzhorizont* ('boundary horizon' in German). On the basis of archaeological finds, Weber dated the Grenzhorizont to the Bronze Age / Iron Age transition (c.800 B.C.), and he ascribed it to wetter and cooler climatic conditions. The Swedish bog stratigrapher Granlund described *five* recurrence surfaces which appeared to recur consistently and which he believed to be synchronous; he numbered these RY I – RY V (from the Swedish *Rekurrensytor).* More recent work has shown that these horizons are in fact variable in age, but the main one – RY III – frequently has a date of c. 500 B.C.

Much emphasis was placed at the time on this RY III, and when Knud Jessen first noted the *very* pronounced change from well-humified to poorly-humified sphagnum peat in the stratigraphy of Irish raised bogs in the 1930s, he equated it with the RY III familiar to him from his native Denmark and the neighbouring countries. He also noted that archaeological objects of Middle Bronze Age or older were never found above this horizon, and likewise objects of Late Bronze Age or younger never occurred below it. Not having any independent methods of dating (such as radiocarbon) at his disposal, Jessen used this main recurrence surface as evidence of age [**Figure 14.1**].

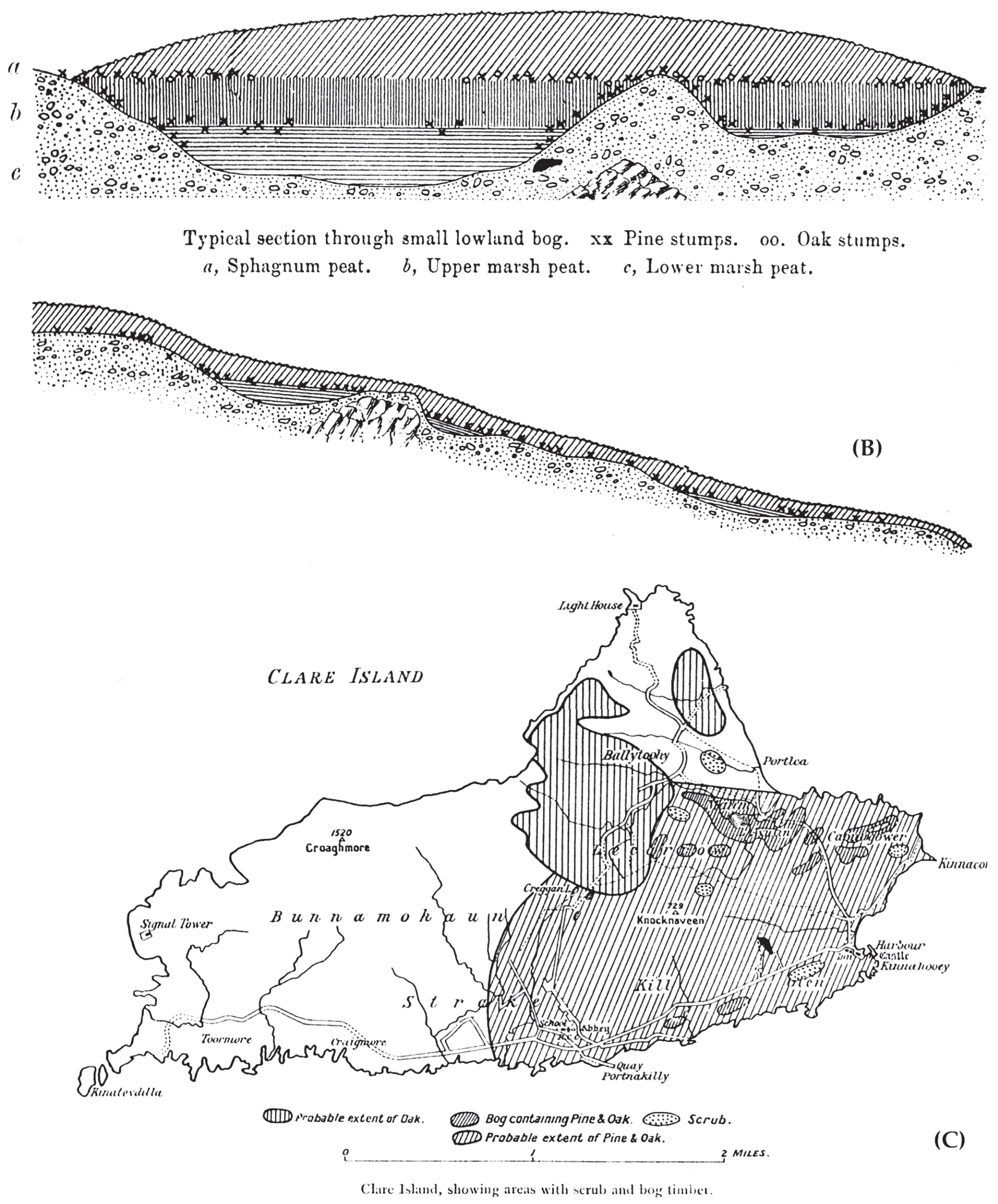


Figure 14.1: Recurrence surfaces in the peat of Clare Island.
Clare Island is today almost totally devoid of woodland, but the record of the bogs tells of a different past. (A) is a typical section through a small lowland bog on the island, showing the distribution of oak and pine stumps beneath and at different levels in the peat, marking two prominent recurrence surfaces. (B) shows a section through a blanket of peat on sloping ground, with a conspicuous recurrence surface. Before the development of this surface, peat occupied the hollows only, and pine grew everywhere on the slope. Later climatic deterioration swamped the trees and allowed peat to blanket the entire slope. (C) shows the probable former extent of the woods of oak and pine on Clare Island. (From Forbes, 1914).

The term *Grenzhorizont* has now gone out of favour in the German bog literature because of the aura of climate change and the fixed, particular age it had acquired, whereas it may mark a change in the bog vegetation brought about by hydrological factors that may have been of purely local significance. It is now generally referred to in German as the SWK – Schwarz-Weisstorf-Kontakt, meaning dark / light-coloured turf contact, which succinctly describes its appearance. In English the neutral term Main Humification Change (MHC), is now used. The *Sphagnum-Calluna* peat below the MHC is highly humified, because the bogs in which it formed were slow growing, and had surfaces that were dry – at least for part of the year.

Why did this change in the climate come about? This is a question that has exercised the minds of climatologists and prehistorians for many years. Jean Grove has calculated that during the 10,000 or so years since the end of the last Ice Age, there have been ten or more 'little ice ages', one *every* thousand years on average, and each producing effects that last for several centuries. The climatic shift of the last millennium B.C. is therefore only one of the many that have occurred since the Ice Age. Climate exhibits natural periodic variation, the causes of which is basically astronomical and are now fairly well understood. These changes affected the nature of the vegetation growing on the surface of the bogs, and so the peat profile is potentially an archive of such climatic fluctuations. In practice, it is not always easy to distinguish whether variation is due to climatic change or to more local factors, and even when it is, it is never easy to work out exactly what kind of change in the annual evaporation-transpiration regime is responsible for the change. Neither is it easy to work out whether the change in climate was sudden, or was it the case that a threshold in the bog's hydrological regime occurred at a time when climate was slowly becoming wetter and cooler? Periodic removal of the woodland cover during episodes of intensified agriculture may also have been a factor: trees intercept rain water and once they are removed, increased run-off and waterlogging increase the chances of bog expansion.

In the light of what we know today about climatic cycles, and about how drying of the bog surface alters the vegetation, we would expect that bog vegetation should respond to climatic change. However, it has been clearly shown that these horizons of change are not always synchronous between the bogs in a particular region, and that in any individual bog a particular horizon is normally younger towards the bog margin. Recurrence surfaces are most obvious in raised bogs, but they can usually be recognised in the peat profile of blanket bogs as well, and very careful analysis shows that they too record the climatic cycles of recent millennia, though much less obviously than raised bogs. Recent work on Danish bogs shows cyclic long-term climatic variation with a periodicity of about 260 years over the past 5,500 years. This conclusion is based on the study of humification change in the peat of hollows, since hummocks are known to persist in the san1e place for as much as 2,500 years, contrary to the alternating hummock-hollow hypothesis (autonome succession, as it is called). Interestingly, this model predicts a downturn in mean temperature and / or wetter conditions for north-west Europe at the end of the century and in the early part of the next century.

The study of the way other components of the peat have been affected may help to clarify the relationship between climate and change. Fungal and algal microfossils are often sensitive indicators of surface conditions, and together with a more careful and detailed analysis of rhizopods and macrofossils in the peat should yield more information as to what exactly happened at these recurrence surfaces. Analysis of peat samples (especially of the pollen profile) and the study of fossil wood also yields valuable information. Another new and promising line of enquiry is the analysis of O^{16}: O^{18} and the ratio of deuterium to hydrogen, techniques that have been much used in recent years to extract climatic records from ice and ocean water cores. A certain amount of work of this nature has been carried out by Dutch scientists on Irish bogs. However, it may be that, in the West at least, where the climate is so oceanic, so wet, the bogs will not have registered many of the smaller climatic changes of the last 5,000 years.

In an earlier chapter we saw how the main development of peat in a typical Irish raised bog can be divided into a lower, well humified darker peat and an upper and less humified 'white' peat, and that this dramatic change in bog composition is attributed to a change in climate around 500 B.C. But does this big break in Irish raised bogs correspond to the Grenzhorizont? In Northern Europe, dates for Granlund's RY III cluster around the transition from the Late Bronze Age to the Iron Age, but in Ireland Late Bronze Age artefacts occur almost invariably in the unhumified peat *above* the major 'recurrence surface'. This means one of two things: either late Bronze Age culture was much later in Ireland than elsewhere - which conflicts with the archaeological evidence – or else the MHC in Ireland is earlier than 500 B.C. We now know that the second explanation is the correct one. On Mongan's Bog the MHC has a date between around 200 A.D. and 50 A.D.; in the blanket bogs of Tyrone it is around 225 A.D.

We need perhaps to exercise considerable caution when using the term 'recurrence surface' in its European sense in relation to Ireland. The term implies a rainfall deficit that is acting as a limiting factor on peat growth (i.e. below c. 700 mm/yr-[1], which can occur in Germany and Scandinavia). It is unlikely that rainfall has ever been the limiting factor for peat growth in the Irish Midlands; dry years here are even wetter than the average year on the continent (c. 750mm). It is likely that annual precipitation in the Irish Midlands was at least 800mm as far back as 5000 B.C.; many centuries before 2500 B.C. conditions in the Irish raised bogs were already very wet, and average precipitation was probably not greatly different from today (c. 860mm). Since then there has indeed been climatic change in Ireland, but it has merely varied from *'very* wet' to 'extremely wet'.

In addition to the MHC, two other horizons in Irish bogs have been described as 'recurrence surfaces', but they are not so clearly or widely developed. Frank Mitchell identified three surfaces, which he dated at around 1715 B.C., 100 B.C. and 600 A.D. The second of these he believed to coincide with the prosperous period of the early Roman Empire, when conditions in Northern Europe were more tempting to Mediterranean conquerors than they might have been some centuries later. Recent work on Mongan's bog also shows three 'recurrence surfaces'. In most Midland raised bogs there is also an abrupt and pronounced change from only slightly-decomposed to more highly decomposed peat about half a metre below the surface. (It ranges from 25-70cm below the surface of living raised bogs; it lies at c. 10cm below hollows and 30cm below hummocks on drained bogs). This is attributed to an increase in wetness that occurred towards the end of the last century.

Although the dramatic shift in bog vegetation at 'recurrence surfaces' is generally so sharp, it is nevertheless an uninterrupted transition, marking acceleration in the rate of growth: there is no sign of a break in growth. Occasionally these surfaces are clearly *erosion* surfaces: at Ardee Bog in County Louth, for example, the upper surface of the lower peat was severely gullied and eroded, and this sharply undulating erosion surface is overlain by layered pool peat dominated by *Sphagnum cuspidatum* [**Plate 12**]. But more remarkably still, in a different part of the same bog, the bounding faces of some of the basal peat pools, now infilled with the finely layered upper peat, are vertical and regular, and bear a striking resemblance to the faces of turf banks. It is not impossible that these were ancient turf cuttings, overwhelmed when the dry surface was swamped, either as a result of climatic change, or more local hydrological changes. In this case, the change was probably amplified by a rise in the water level of the lake beside the bog, the last remnant of an extensive late-glacial lake, which several thousand years of bog growth have choked out in other parts of the floodplain of the River Dee.

Buried forests

The bog surface below major recurrence surfaces was sometimes dry enough for the growth of trees, which were ultimately overwhelmed as conditions became wetter once more. These buried forests are the most immediately impressive evidence of climate change recorded by the peat. But buried forests are even more widespread *underneath* the bogs. In the case of raised bogs these were part of the natural vegetational succession from lake to bog that took place in the Midlands and elsewhere after the Ice Age. They were wet and swampy, dominated by alder and oak. The woodland phase was relatively short *lived,* but where conditions were suitable it may *have* lasted for a *very* long time. There was oakwood on Garry bog near Ballymoney in County Antrim for most of the time between 5000 B.C. and 200 B.C., but this was because of the special conditions brought about by a river meandering through the bog. Oakwood lasted for many centuries also on the Lough Neagh fenlands.

The woods were generally dominated by pine (often referred to as fir or bog deal), oak and birch, but alder, willow, yew, hazel and ash all occur, and no doubt were locally dominant whenever conditions were particularly suitable; yew was so plentiful in Clontiglas Bog near Ballyfin, in County Laois, that it was used by local farmers as roof timbers and gate posts. The oak, alder and yew are found around the edges of the bogs, perhaps extending 100m or so in from the edge, but only birch and pine are found in the centre as a rule. The same relationship holds for trees growing on the recurrence surface underneath the younger sphagnum peat: oak and pine towards the edges, pine and birch mainly in the centre.

Several generations of trees, perhaps 500 to 1,000 years of growth, can sometimes be seen one on top of the other, especially towards the margin of a bog. The roots of pines growing in the bog always spread out laterally, never going downwards, which shows that they were growing under waterlogged conditions, with the water table a few feet below the roots. The trees are seldom densely clustered as they are in a forest; they generally occur in groups and as well-spaced individuals.

Bog trees often attained a large size, and often grew rapidly, especially (in the case of pine) in the first 50 or 60 years. Trees with a breast height diameter of a metre or so are not uncommon, and they *vary* in age from maybe thirty years to *over* 300 years: a specimen of bog yew excavated from the bog at Clontiglass was over 400 years old [**Figure 14.2**]. The National Botanic Gardens at Glasnevin have an impressive ten-foot bog deal plank on which is carved:

A SPECIMEN OF BOG DEAL
from the townland of Aughnadisart
Barony of Knockninny co Fermanagh
Sent for Exhibition
By DOCTOR COLLINS. M.R.D. SOCIETY
Merrion Square
the Tree from which this plank was cut, measured sixty four feet in length.
this portion was taken out of the trunk twenty five feet from the butt.
where it measured seven feet, six inches, in circumference
the entire Tree is in a similar state of preservation.

The pattern of annual rings in a tree preserves a record of its growth from year to year. Wide rings represent years of more active growth, and narrow rings represent less productive years. Because these can be synchronised between different trees, the resulting pattern may be used as a calendar to date them. This tree calendar preserved in bog oak reveals many fascinating details about the past. The tree ring pattern has now been examined in thousands of bog oaks, and because the oak-ring calendar is now so accurate, it is possible to say after careful analysis exactly when a particular bog oak was alive and growing.

Unlike radiocarbon measurements, tree ring chronologies provide *absolute* dates, and so can act as a standard for the calibration of the radiocarbon time scale. The tree ring time sequence based on analyses of oak trees, mainly from Northern Ireland and Germany, now spans a period of nearly 7,500 years. It provides an invaluable tool in archaeology, and for studies in palaeoecology and palaeoclimate.

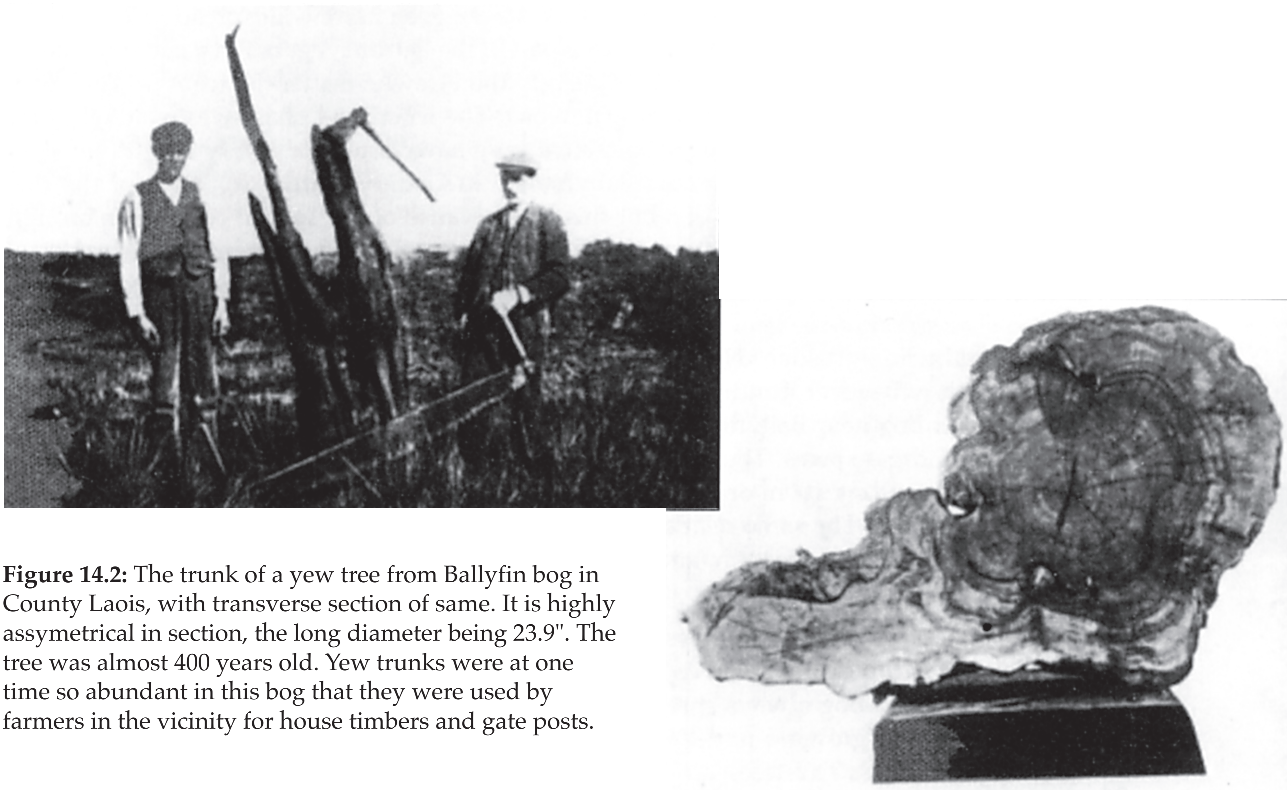


Figure 14.2: The trunk of a yew tree from Ballyfin bog in County Laois, with transverse section of same. It is highly assymetrical in section, the long diameter being 23.9". The tree was almost 400 years old. Yew trunks were at one time so abundant in this bog that they were used by farmers in the vicinity for house timbers and gate posts.

A large number of trees need to be counted and measured to compile the oak tree ring calendar, because variation in growth is due to many factors, and in a particular area some trees may grow well in one year whereas others may not. So dendrochronology is based on variations in the high-frequency pattern of the rings. If all the trees examined have very narrow growth rings in one particular year, it suggests some kind of climatic influence. The tree calendar shows that at intervals there were such special years, when growth was very restricted everywhere. The detective work of Mike Baillie, Jon Pilcher and their colleagues at Queen's University suggests that these years of widespread restricted growth may have been caused by veils of volcanic dust in the atmosphere. This dust is preserved in the peat in the form of tiny slivers of volcanic glass (tephra).

Apart from recording such exceptional catastrophic events, the pattern of tree rings provides an accurate record of short term climate fluctuation. These studies enable us to pinpoint the several major phases of alternating bog growth and tree growth. The major phases of growth are broadly contemporaneous everywhere, although local factors make for considerable overlap. The new studies suggest that the two main periods of bog growth were around 3100 B.C. and 300 B.C., with lesser peaks at 4900 B.C., 3600 B.C., 2200 B.C., and 1700 B.C. These are dramatically shown in Jon Pilcher's skyscraper diagrams [**Figure 14.3**].

Some years ago Tony McNally carried out a fascinating study of the structure of one of the early pine forests in a series of bogs on the Offaly-Kildare border south-east of Edenderry. Using dendrochronology – matching the annual rings on the trees - he was able to show that the forest had been in existence for a period of at least 500 years, and he used radiocarbon dating to establish that this had been between around 2500 and 1800 B.C.

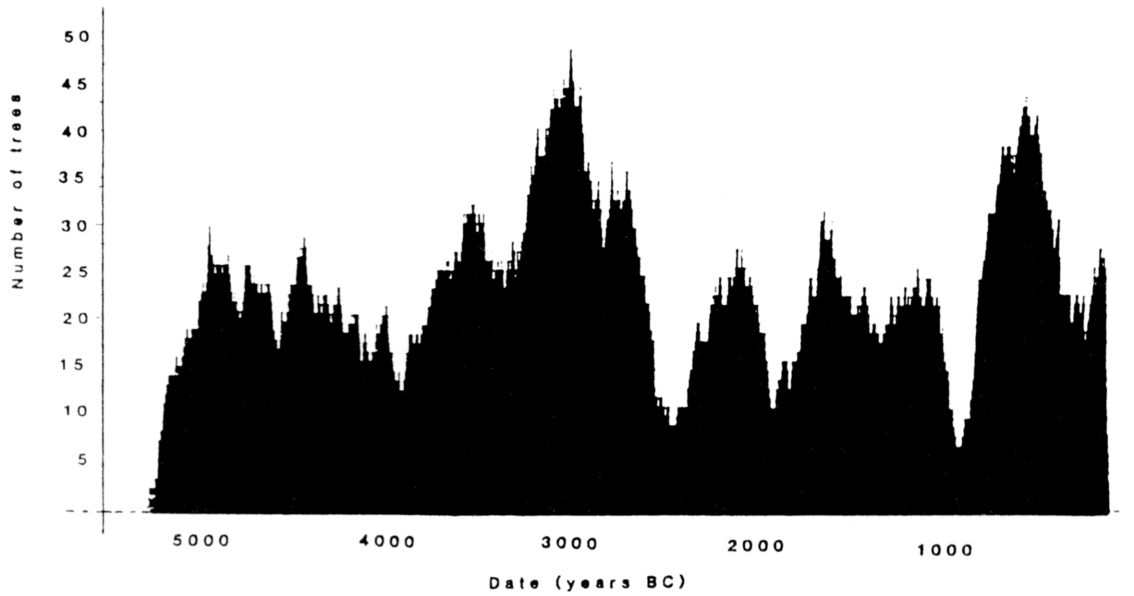


Figure 14.3: Phases of oak growth on the bogs of Ireland, derived from study of the annual rings of bog oaks. Note the peaks in growth at 3100 BC and 300 BC, with lesser peaks at 4900, 3600, 2200 and 1700 BC. The major dips in abundance occurred at 3900 BC, 2500 BC, 1900 BC and 900 BC. 3900 BC was the time of the elm decline, and the decline in oak at the same time suggests that the elm decline was due to a general environmental deterioration rather than elm disease alone. 2500 BC is at the mid-point of a period that saw widespread reduction in the growth of pine on bogs. The simultaneous reduction in oak suggests that all bogs were becoming wetter at this time. 1900 BC and 900 BC were periods which saw an acceleration of blanket bog in many upland areas.
(From Pilcher, 1990: by kind permission of the Royal Irish Academy and the author).

The trees were growing in nearly 2m of peat which had developed *over* a time interval of perhaps 1,250 years, during the lower and middle part of the 'Sub-boreal' (Zone VIII), getting drier as the ecological succession progressed from cottongrass heath to woodland. The presence in the peat of pollen belonging to plantain and weeds of the goosefoot family (Chenopodiaceae) is a reflection of early farming in the neighbourhood.

The average age of the several hundred trees studied was 132 years. Their diameters ranged between 5 and 40cm; they were quite widely spaced, with around 500 trees to the hectare. Growth in this forest was slow by comparison with modern pines growing on peat. Birch grew as an understory to the pine, and there was a dense ground layer of heather, with clumps of *Polytrichum commune* similar to those seen on drier bogs today. The forest seems to have been *very* similar to the modern native pinewoods of western Scotland, and the pine bog forests of Fennoscandia.

All the trees in the forest died at approximately the same time as the water table rose in response to increased precipitation, preventing germination and regeneration, and eventually leading to the death of the trees themselves, due to waterlogging which was probably accentuated by disease. This occurred between around 2800 and 2500 B.C. when climatic conditions became considerably wetter throughout northern Europe. But even though it was climatic deterioration which brought about the slow decline of these woods, it may not have been climatic improvement as such which allowed them to develop in the first place: pine woodland may simply have been the natural climax in the vegetational succession under the climatic conditions prevailing at this earlier time. Had it not got so much wetter, the woods would have retained their dominance.

During the 'Sub-boreal' period, from around 2480-2550 B.C., there was widespread initiation of blanket bog growth at the expense of pine woodland, but there were drier intervals (e.g. around 2000 B.C.) which allowed trees – pine especially – to invade habitats previously outside their ecological reach. Trees also colonised the new shorelines where lake levels dropped. Trees were able to grow at altitudes of up to 500m on mountain slopes. On Slieve Bloom oak reached 250m, and near the barren and now desolate summits of the Mourne Mountains, the remains of oaks over a metre in diameter have been found. The pinewoods which had flourished at sea level all along the west coast, where today no tree can survive the winds blowing in from the ocean, had been overtaken by bog much earlier – during the Atlantic period at the latest.

The early forests of the Wicklow Mountains, dominated by pine, birch and hazel, along with oak, alder, elm, and other species, had reached as high as 600m. Wood-peat with pine stumps can still be seen at this height today near Lough Firrib for instance. Birch had extended even higher. Above this the vegetation was probably montane grassland, but in time this too *gave* way to blanket bog, and the Arctic-Alpine plants that grew here were forced to retreat until today only a few resistant survivors remain in odd pockets. Blanket bog was probably beginning to form on most of the mountain ranges from around 6000 B.C. onwards.

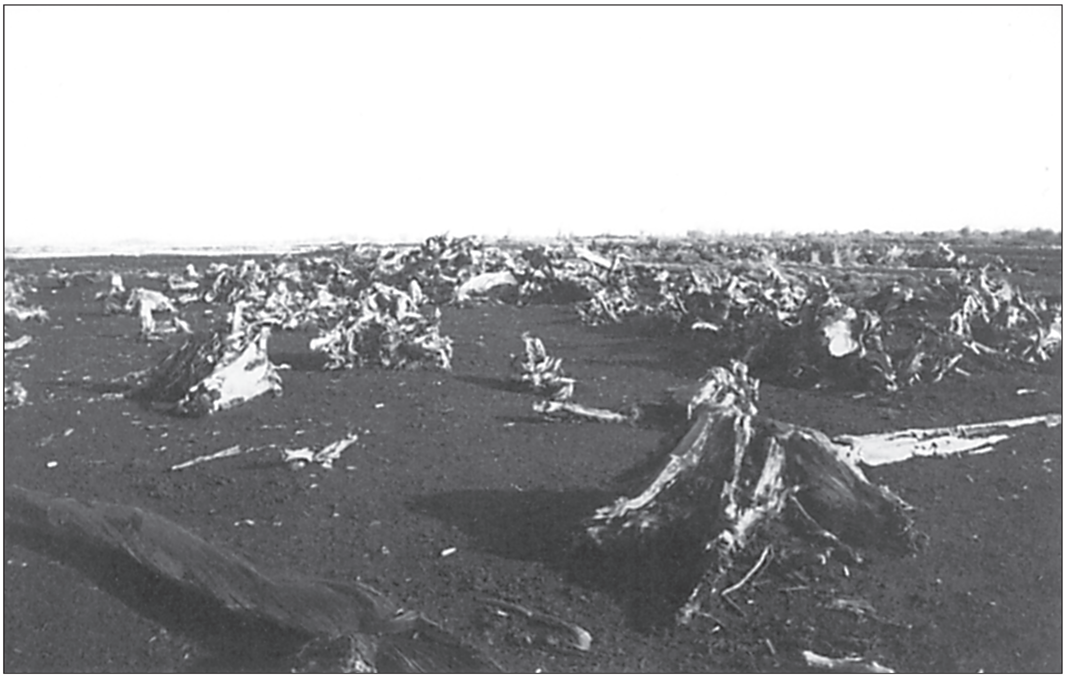


Figure 14.4: The remains of a pine forest under the bog at Drinagh, County Offaly.

Bog wood

During the centuries when people lived entirely off the land, depending upon its resources to supply all their needs, the bog was a resource of the greatest importance. It provided fuel, and it acted as a land bank that could sustain the disastrous growth in population that took place in the early 19th century. It so contained buried treasure. Occasionally this was real treasure, but such finds are rare sensations (Chapter 15). A much more valuable treasure was the buried storehouse of timber sealed deep in the vaults of preservative peat, buried since the time the growing bog had engulfed the ancient forests which once covered the land. This ancient deposit had increased in quality and value over long centuries since it was laid down, becoming seasoned and impregnated by the preservative alchemy of the bog. It as greatly prized for its durability and in some cases for its beauty, especially since it was often the only timber to which people had access in the early 19th century. An elaborate and specialised vocabulary grew up around bog timber, its many uses and the crafts associated with them.

Bog wood was being used throughout Ireland wherever bogs were extensive, certainly by the 17th century, especially as standing timber became scarce. Thomas Dineley wrote in 1681 how

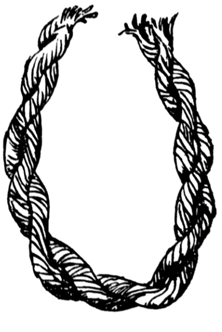
> In Boggs here, as in most parts of Ireland, in digging for Turf, are found large firr Trees, and particularly in the Bishoprick of Cloyne, in the county of Corke, and Province of Munster; in the Boggs are found such quantities of Firr timber trees that they make benches, tables, wainscoat, and floor Roomes therewith; they use it also so much for fewell that the air smells of Turpentine.

As Dineley's early account suggests, bog wood had many uses, but one of the most important was as structural timber for houses; for centuries the roof timbers of tenant farmhouses were made almost entirely of bog oak and bog pine, because timber of the size required for roof timbers could be got nowhere outside the estate woods of the landed gentry in the 18th and early 19th centuries. It was used not only in the vernacular thatched cottages of the poor, but sometimes also in larger buildings such as churches. Bog wood was also used in other ways in house building - as scallops for pinning thatch for instance – and bog wood rope had many roles in house construction.

Bog wood was used all over Ireland to make ropes, a craft which goes back for thousands of years. The wood was shredded into 1-2mm thick slivers, which were then beaten to increase their flexibility, before being woven together either by hand or with a rope twister to produce two-ply ropes (usually) that were about 1.5 to 2cm thick [**Figure 14.5**]. They were used mainly for cording wooden beds to support the tick or mattress. These bed cords sold in lengths of around 20 yards for 10d (in 1802). Deal ropes were also sometimes used in thatching and roof making, and to rope down thatch along the wild Atlantic coastal fringe where roped thatch was the practice. Less commonly, bog wood rope was used for burden ropes, halters and tethers, boat cables, ropes for tying hay and corn stacks, and for chair seats.

Bog timber was also in great demand for furniture. Yew in particular was especially prized in this regard; it was extremely durable, and was used for the making of high-class furniture and cabinet work, being similar to rosewood, but 'superior to it in beauty of colour and firmness of texture'. But there are occasional instances of more extravagant uses; we have earlier seen below in Ballyfin in County Laois it was sometimes used for gate posts as well as for roof timbers. There is one record at least of the use of bog timber for harp making; a harp made for the famous northern harpist Hempson (O Hampsey) in County Derry at the beginning of the 18th century is believed to be made of bog alder, and carries the inscription

Figure 14.5: Part of a rope made from bog pine, from an old roof in the Mourne Mountains.



> In the time of Noah I was green,
> Since his flood I have not been seen,
> Until Seventeen hundred and two I was found
> By Cormac O Kelly underground:
> He raised me up to that degree
> That Queen of Musick you may call me.

Bog oak is often black, extremely hard and durable; however, it tended to decay after long exposure to the air, so it was used mainly in damp situations - underground or for water works. Bog pine - usually called fir - is much more abundant than the other trees, and it was used for building and in the making of furniture of all sorts. When it was first dug out it was sometimes quite soft, but as it dried it became as hard as iron. Bog wood' was also widely used to make wooden vessels: tubs, piggins and noggins (milk pails), butter churns, feeding troughs, milk tubs, cileire (keelers) for settling milk, pails for water. Black bog oak was especially favoured for butter vessels and piggins, and pine for churns; black oak skimmers were used to skim cream from milk and butter from the churn.

One of the most widespread uses of bog deal was for lighting and firing, for which its high resin content made it ideally suited. The wood was cloven into splints usually between 1-1.5 ft. long. These were placed in a convenient crack in a wall or on the hob, though rushlight holders, or special iron holders of other kinds, were occasionally used for smaller splints. But if a clear and steady light were required they had to be held by hand and the charred wood tapped away as it built up - usually a job for the children. An old man of 90 living in Ballymacelligott parish in County Kerry recalled in 1938 how, as a boy

> 'Tis often I lighted a splinter when my mother was darning socks or sewing a patch in clothes. While we were eating our supper, also, some one of the family should hold a splinter until they had finished, and it was the same everywhere.

Deal torches were still being used in a few places right down to our own time. There were parts of the country, mainly where bog deal was plentiful, where they were at one time the only source of light after dark. They *gave* much better light, and required much less preparation than rush lights, the making of which was a slow and tedious process and few poor people had ready access to a supply of tallow. People occasionally made a living from the preparation and sale of bog wood splints, selling them in bundles at 2d a bundle. Bundles of *five* or six splints were often bound together with straw rope to make larger candles, especially for outdoor use. In a few places, the splints were dipped in tallow in the manner of rush lights, to form *caisníni* or *sciotacháin.*

One of the most dramatic uses of bog deal torches was in salmon spearing by night, a practice which was widespread wherever salmon streams and bogs occurred together, especially in the 19th century, and perhaps most commonly in County Galway. The fish were lured and dazzled by the blazing light and then speared. We *have* a vivid description of the practice from Erris in County Mayo:

> ... by holding lights over the pools of the river [Owenmorel at night, the fish are attracted, and a handy spearsman soon deposits in his bag the bleeding spoil. These lights are torches made of dried bog-wood, split into small slices which produce a most brilliant blaze: and the act itself is called 'burning the river'. The hundreds of them scattered through the mountain region at night in the fishing season, to the uninformed traveller, might appear as so many fay lights or 'Will 0' the wisps', with all their accompanying horrors.

Blocks or stumps of bog pine *(crompán)* were greatly valued for firing wherever they occurred. A pile of pieces of crompan would be kept beside the fire and used whenever there was need for extra light in the kitchen. They make a really *lovely* fire, bright and fragrant. Little *cipíní* of bog wood were also used as firelighters.

In our own day the use of bog wood is mainly confined to the making of artistic pieces, a use which goes back for at least 150 years. The best of this modern art includes some of the work of Michael Casey and his apprentices in Celtic Roots, a recent company set up under the aegis of Bord na Mona; some are *very* fine pieces, which owe their character to the inherent qualities of wood, tree and time, and the skill of the artist in allowing these qualities to dominate the piece [**Figure 14.6**]. The extensive bogs of the Galway-Clare region provide the oak and pine timbers that the artist Ronnie Graham uses for his inspiring wood sculptures.

Bog timber, of course, usually lies buried deep in the bog, and the method everywhere used to locate it is of great interest, especially as nobody has yet come up with a satisfactory explanation of why it works. This method was described by many intrigued visitors to Ireland in the 18th and 19th centuries. A visit would be made to the bog early in the morning, when the dew still lay on the ground. A place where the dew evaporated quickly suggested buried timber, and once such a place was located the nature of the buried timber was explored with a long metal probe *(bior);* the experienced hand could tell not only whether the wood was sound or not, but its dimensions and orientation, and even what species of tree it was. Buried trees could also be detected by noting places where frost or snow quickly disappeared:

During a heavy frost the bog is traversed, and the buried log staked out. In the spring a bog hole is opened along the site of the log. This answers two purposes: the turf cut out lets the operator get at the log to raise it, while a clamp of turf on a wild mountain in a distillation district is very handy if a still is to be ran at a neighbouring coom or lough.

Figure 14.6: Michael Casey's altar in Pollagh Church, carved from a trunk of bog yew.

Getting the tree out was an extremely laborious process, often requiring deep squelshy excavation, followed by an exhausting session of levering and hauling. Cutting bog timber required a very special axe, which had a long, narrow blade 2-2.5' long and 3-4" at the cutting edge, and with a handle 3' long **[Figure 14.7]**. These were made by the local blacksmith and were much in demand, especially in very wet summers when the turf supply failed, and bog deal might be the only fuel available.

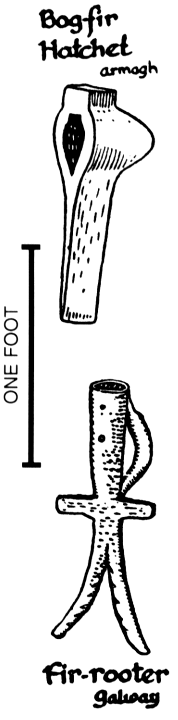


Figure 14.7: A 'fir' hatchet. This had to be big and heavy; it could weigh anything up to 14 lbs. A special 'lifter' was used to root up the timber, which was often held tenaciously in the wet peat. (From Evans, 1942).

Drowned bogs

For several thousand years after Ireland's bogs began to develop, sea level was much lower than it is today. Because of this, the bogs along the coast extended much further out than they do today, only to be overwhelmed as the ocean began its inexorable recovery, at about the same time as the more warmth-loving trees were beginning to invade the woods of pine and birch. These drowned bogs can still be seen in many places along the west coast [**Figure 14.8**], particularly in the area of Roundstone and Renvyle in County Galway and along the estuary at the north end of Tullaghan Bay in Mayo, where a submerged pine forest has been exhumed by the complete erosion of the bog. Submerged bogs are also known off the coasts of Antrim, Down and Donegal. Off the peatless Aran Islands (and elsewhere in Galway Bay) bogs can be seen below the low water of spring tides. They also occur at several locations off the south coast, especially in Cork and Waterford. In Dunworly Bay near Clonakilty there is at least 50 feet of peat below sea level.

This attack by the sea only began after the full development of the peat, and yet there is also a post-glacial raised beach in this *very* area, showing that at one stage sea-level was considerably higher than it is today. This rise in sea-level is most pronounced on the north-east coast, which had a thriving human population in Mesolithic times. As long as sea-level continued to rise, Mesolithic implements were washed into beach deposits at Cushendun, Larne and elsewhere, derived from long-abandoned homes or workplaces along the shore.

These sea level changes, *however,* take place at different times in different parts of the country. It appears to *have* taken place during the last 2,000 years in Connemara. Rises in sea level submerged the famous dolmen at Rostellan in County Cork, the crannog at Ardmore in County Waterford, and the fascinating inundated cultural landscape of the southern shores of Clew Bay. They also swamped many other crannogs, because one of the most important effects of a marine transgression of this kind is to cause backing-up of fresh water in lakes and rivers. Most crannogs only come to light following the lowering of water level as a consequence of land drainage. Many of them are entombed in peat, so that they would have been more accurately described as bog or marsh dwellings rather than lake dwellings.

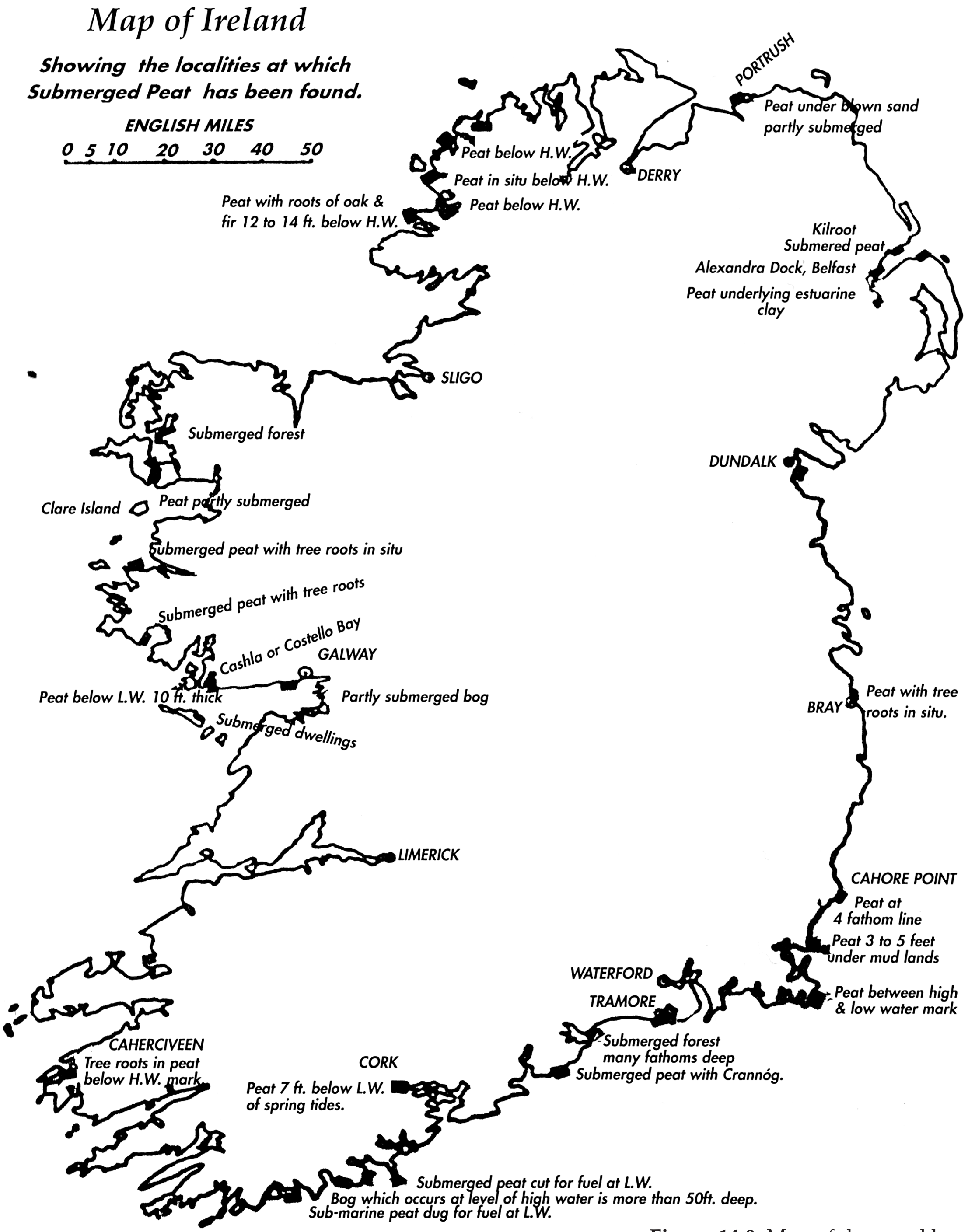


Figure 14.8: Map of drowned bogs (From Hallissy in Cole *et al.* 1913).

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Chapter Fifteen

Archives In the peat 3: A treasury of archaeology

It hath very much Red bog in the west part of it which occasioned the making of Sevll long Taghers or Causies to unite the lands and in these Red boggs there are spacious parcells of good and profitable Lands and Woods.

Nicholas Dowdall Esqr. (1682). ***Description of County Longford.***

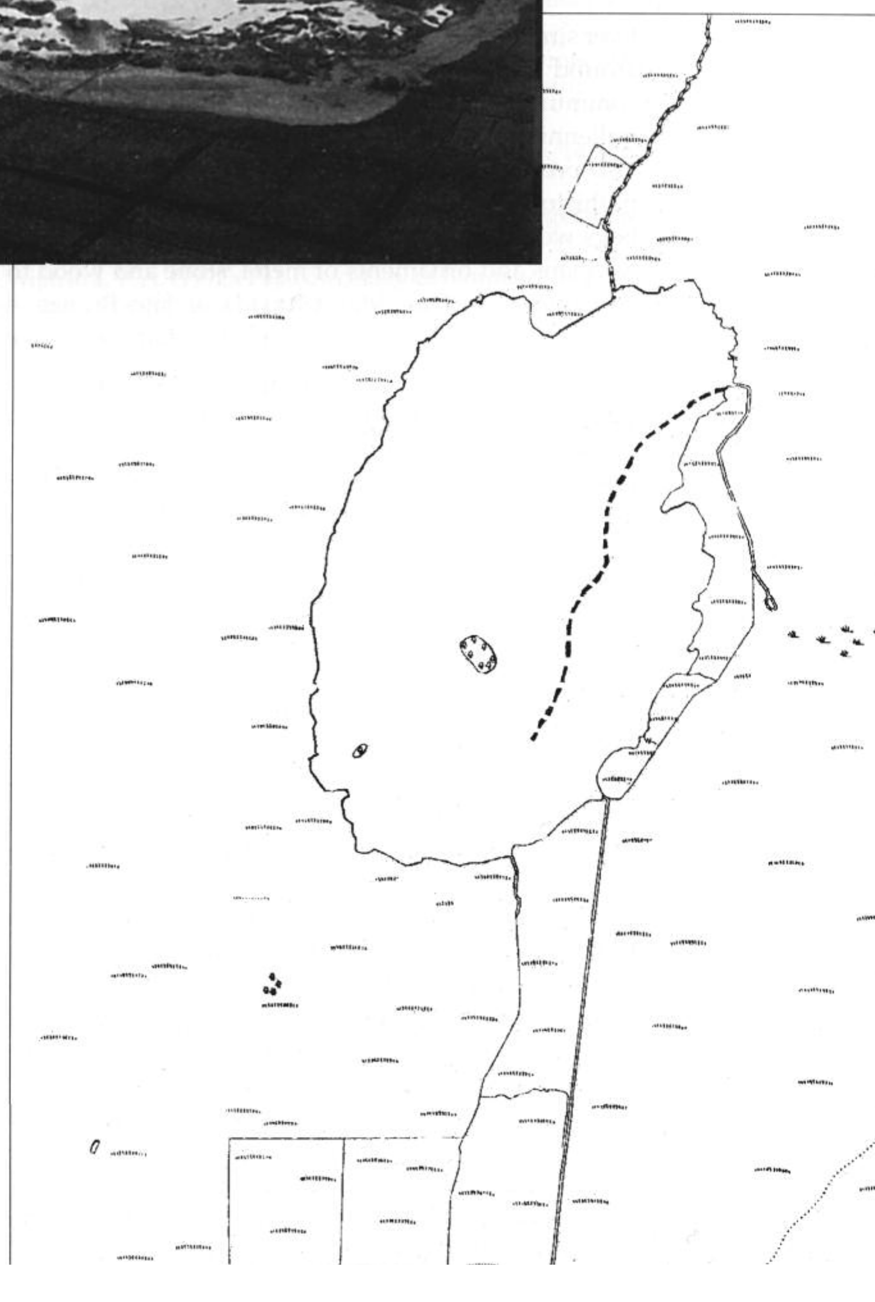
Ever since bogs first started to grow and expand in the landscape, people have been living around them. Much of what we know about the environment in which the earliest Irish communities lived comes from the pollen chronicle which the bogs have kept over the millennia, recording the history of vegetation change since the Ice Age. But the bogs have also preserved a wealth of other material which sheds much light on Irish history and prehistory. An account of the wealth of archaeological objects which have been found in bogs would require a book all to itself. There are thousands of them, ranging from tools, weapons and ornaments of metal, stone and wood to articles of clothing, blocks of butter and human bodies. Many hoards of late Bronze Age objects occur in bogs, strongly suggesting that they were deliberately left there as ritual deposits (See below).

Boora, north of Kilcormac in County Offaly, is part of one of the largest and at one time most undisturbed areas of raised bog in the Midlands. It was one of the first bogs to be developed by Bord na Mona, and it is now almost cut away. In the early 1950s a small peat-floored lake in the middle of the bog, Lough Boora, was drained to facilitate production [Figure 15.1]; the lake bed dried out and was colonised by grassland and trees, and by the mid 1970s the crumbly fen peat towards the eastern edge of the drained lake was beginning to erode. As it did so, a ridge of cobbles and small boulders began to appear, becoming more prominent with the passing of the years. It became known as the 'stony corner', and had the reputation among local sportsmen of being a place where geese gathered in the winter. The ridge had attracted the attention of Joe Craven, an observant field worker with Bord na Móna, over the years; he was impressed by the regular form of the cobble ridge and brought it to the attention of others, believing it might be an ancient causeway of some kind. But when the experts looked at it, this cobble ridge was identified as part of a storm beach: nothing to do with the modern lake on the map, but part of a rocky beach that had stretched north-south along the eastern shore of the much greater lake that existed here following the Ice Age, before the raised bogs had started to form [Figure 15.2]. The beach ridge consisted of bouldery moraine from which finer material had been washed out by the waves, and was situated at a fairly constant level of 52m above sea level; in the pre-bog landscape, a lake with its surface at this level would have covered an area of at least 320 ha - large enough to have allowed the build-up of the waves which were responsible for the storm beach. Near Crancreagh Bridge, 8km to the west, a single wave-eroded mushroom stone marks the position of what must have been the north-western shore of the lake. This extraordinary relic records two levels: the higher level corresponds to that recorded by the mushroom stones along the Shannon on the shores of Lough Ree and below Clonmacnois and records the highest level of the ancient Lough Boora, and the lower level corresponds perhaps to the water table which prevailed for a time after the drop in the level of the Shannon which these stones record.

Other wave-eroded stones are found at Drinagh, Lumcloon and Derrinlough, at other points along the same ancient shore [Figure 15.3, Plate 1]. In time this Greater Lough Boora disappeared, going through the usual process of natural succession to fen and eventually bog. In the process a much smaller lake, the modern Lough Boora, covering an area of 40ha, was impounded at a level 2m above the surface of the ancient lake. This was the lake which was drained as Bord na Móna prepared to harvest the bog in 1951.

(a)

Figure 15.1: (a) An aerial photograph taken in the early 1950s showing Lough Boora shortly after it was drained to allow peat production. (b) Outline of Lough Boora before Bord na Móna drained it. The broken line shows the ancient shore line.



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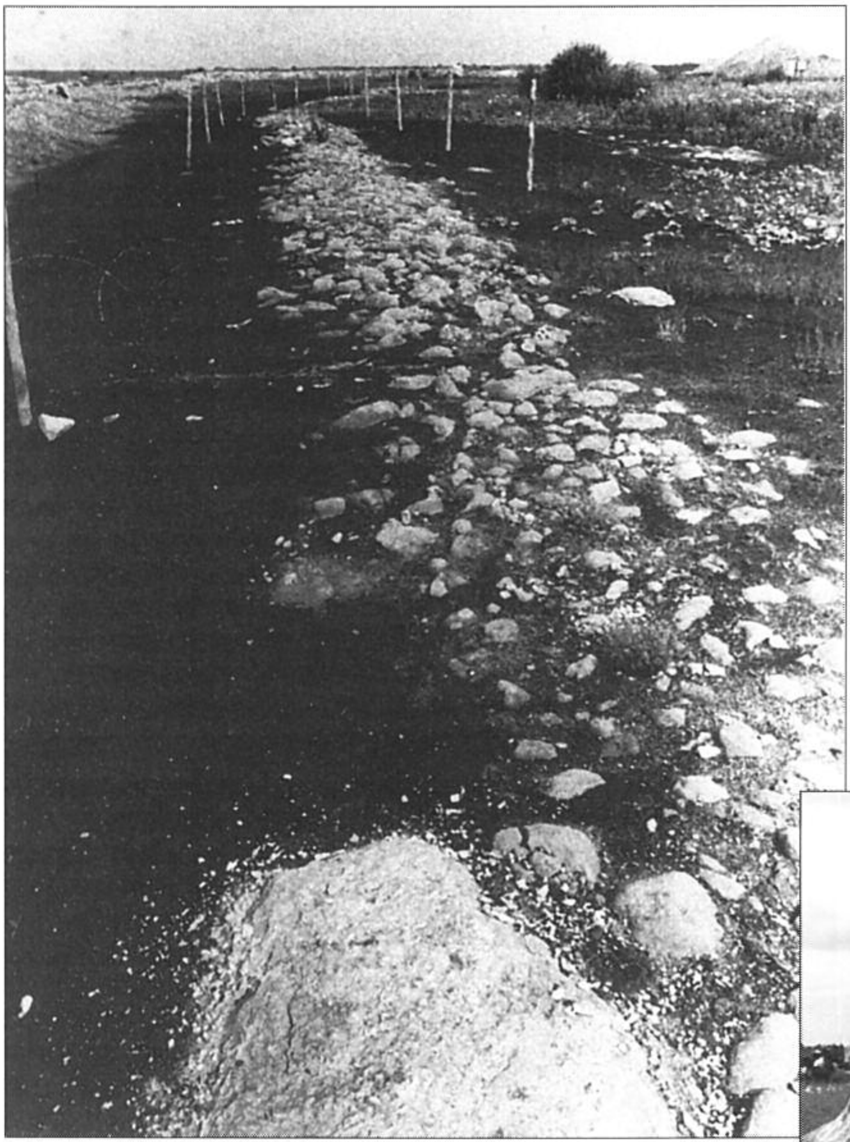
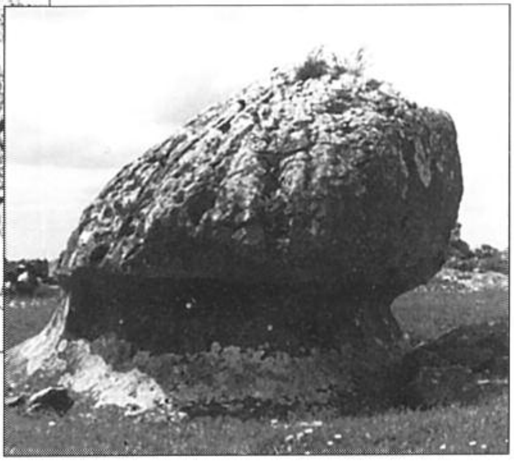


Figure 15.2: The stony beach on the ancient shore of the post-glacial Shannon Lake at Boora, exposed for the first time in eight and a half millennia. In mid-winter it is possible to walk this fossil shore when the air is full of the chiming of whooper swans, just as it was for the mesolithic people who camped here: and in whose diet it must surely have featured.

(c)



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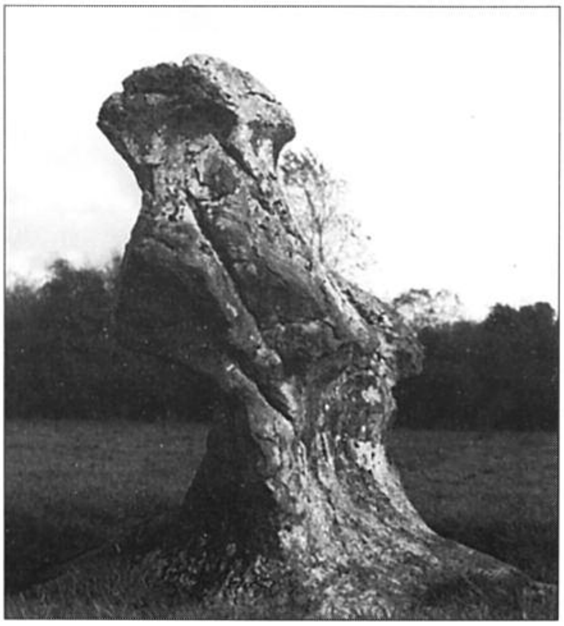
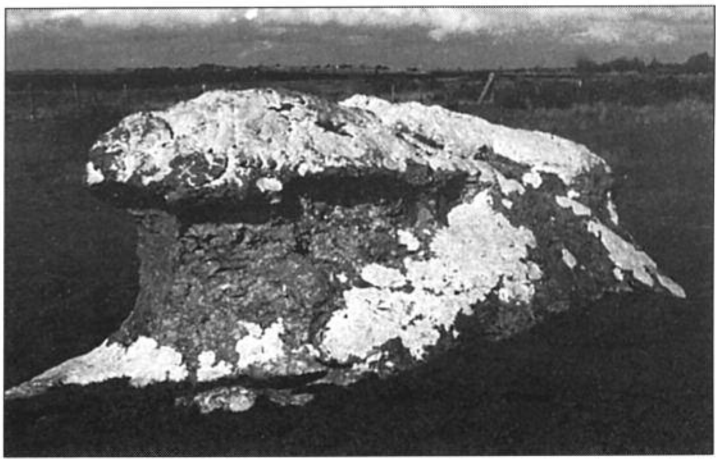
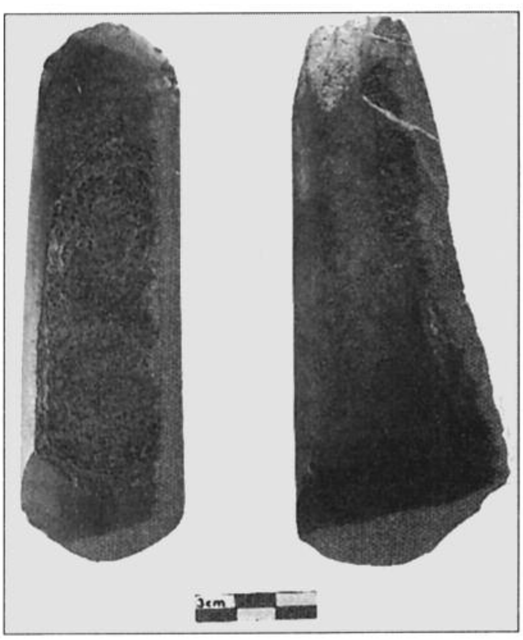


Figure 15.3: Wave-worn lake-edge marker stones around the bogs near Boora. (a) The Crancreagh stone; (b) stone at Drinagh; (c) Nuskroom Stone at Creevagh, close to the Shannon south west of Clonmacnois.

(b)



All this is of great interest because of what it tells us about the way the landscape looked after the Ice Age, and how it has evolved since. But what was utterly startling was the discovery, on what had been a promontory jutting into the ancient lake, of the remains of over 14 hearths, together with abundant evidence of the people who had used them. This occupation layer rested on a thin, uneven deposit of silty clay; this could be lake clay, in which case the occupation of the lake edge may have followed a lowering of water level which might have made the lake margins more attractive to water fowl. Why this discovery should be so startling in archaeological terms was that the charcoal from the hearths gave radiocarbon dates equivalent to between 8,400 and 9,000 years before the present, establishing the presence of human communities here in the very heart of Ireland in the Early Mesolithic. Around the hearths were artefacts: the tell-tale microliths of the Mesolithic - more than 200 of them - with over 400 blades of chert and flint, chert scrapers, a small number of polished stone axes and the debris of chert tool-making, including 200 or so cores [Figure 15.4]. Together with these were the remains of the meals eaten by the toolmakers: the burnt bones of red deer, wild pigs, hares, birds and small fish; the only plant remains were hazel shells. There was a lot of pine in the pollen profile, and oak and elm were consistently present. The small amount of ericaceous (heather and heath) pollen shows that bogs had not yet spread widely; on the other hand, the marsh fern *(Thelypteris palustris*), which is characteristic of fen and fen carr habitats, was very abundant. All of this points to a date late in Mitchell's Zone VIc [Table 13.2]. The mesolithic culture in the north-east of Ireland also pre-dates the development of bog - and it is from beneath the bogs around Lough Neagh that much of what we know of this period has come.



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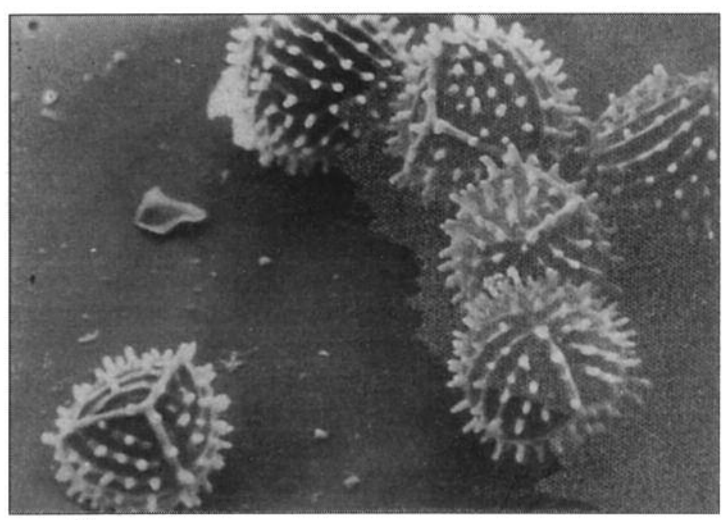
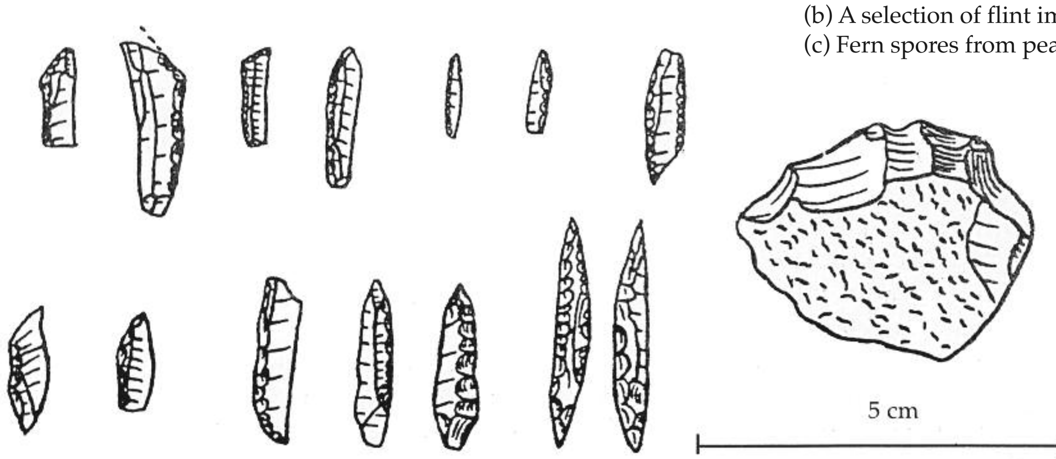


(c)

Figure 15.4: Evidence of the mesolithic past of Boora.
(a) Stone axe.
(b) A selection of flint implements.
(c) Fern spores from peat profile.



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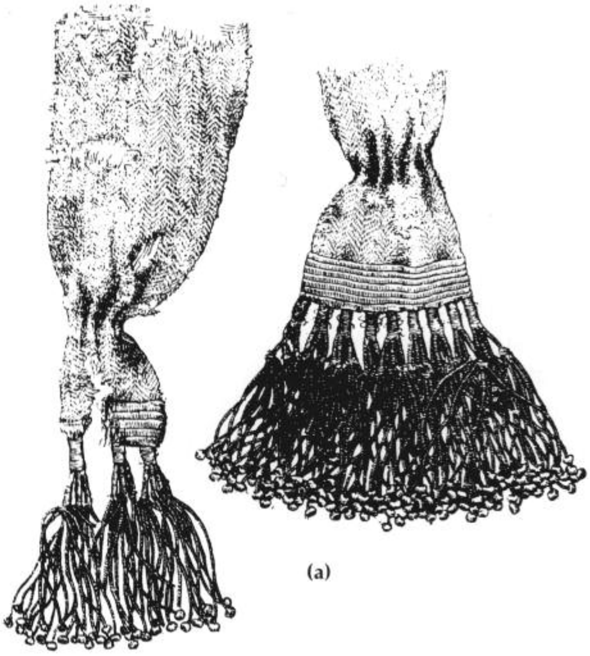


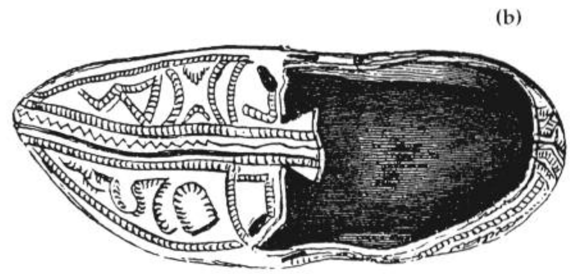


Figure 15.5: Objects of leather and cloth preserved in bogs.

(a) This beautifully-made horsehair fabric with exquisitely braided ornaments of the same material at the end is part of a cache of objects found just above the sub-peat gravel at Cromaghs bog near Armoy in County Armagh in 1904. It has recently been suggested that the object belonged to a 'crane bag': an assortment of miscellaneous items of sacred or magical significance.
(b) Leather sandal found in a bog (Joyce).

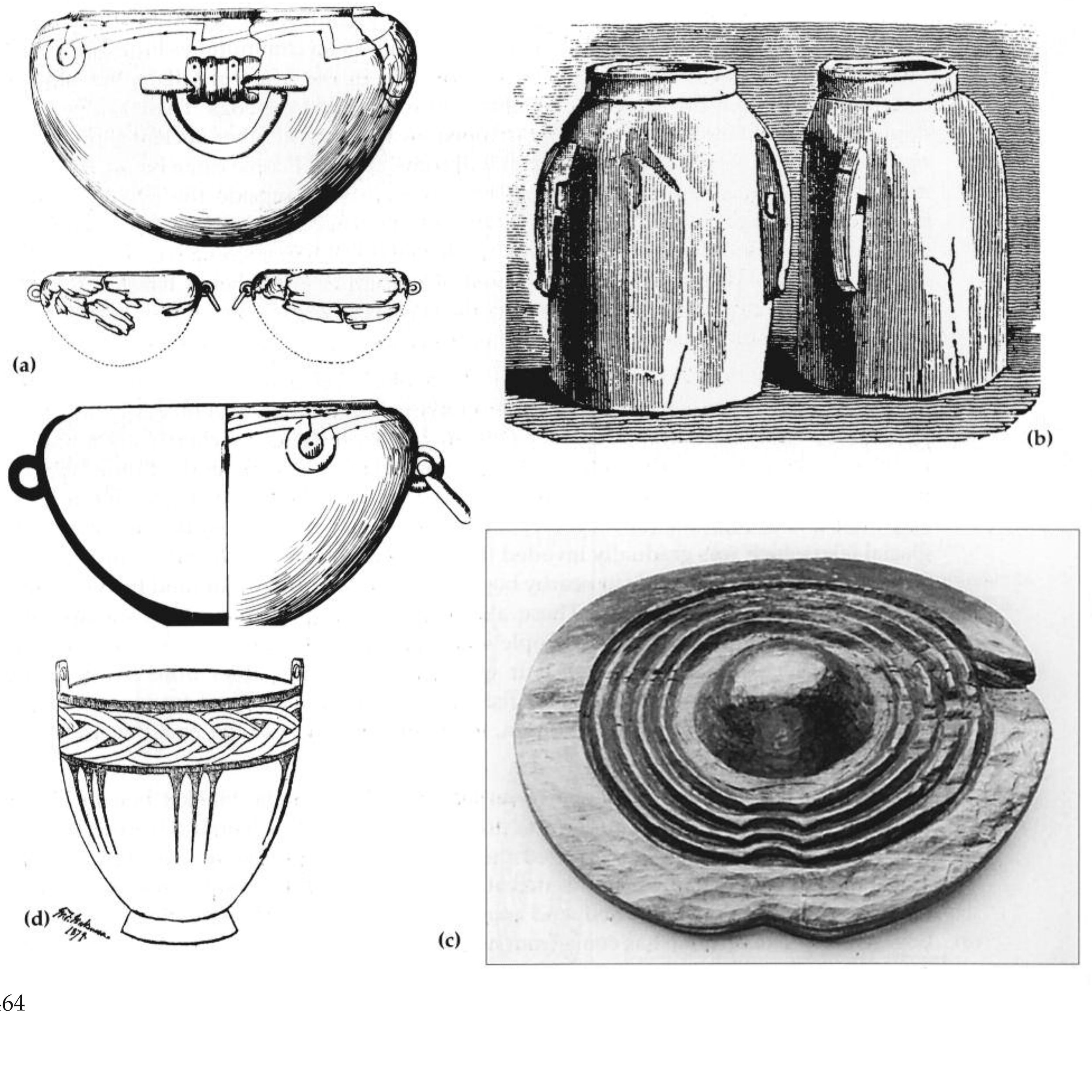
The implications of the Lough Boora discoveries for an understanding of the relationship between people and bogs in Ireland are profound. This discovery pushed the accepted date for the colonisation of the Irish Midlands back by more than three millennia, establishing beyond doubt the presence of human communities little more than 500 years after the ending of the Ice Age not only in the heart of Offaly, but almost certainly throughout the landscape of lakes which preceded the bogs. There can be little doubt that as the large raised bogs are stripped away to reveal other ancient shore lines, more evidence of early human settlement will come to light. People came before the bogs in Ireland, and their cultural evolution has taken place alongside the evolution of a bogland landscape which has always played an important role in Irish cultural development. One older find which hints at what lies in store is a strange discovery made in 1862 in Heathlawn bog 6.5km north-west of Portumna. A bushel of hazel nuts were found lying on the gravel under 4m of peat; the kernels were corroded, but the shells were perfectly sound: the remains of a cache of nuts gathered for a Stone Age winter?

Spreads of charcoal and the burnt stone of abandoned hearths, together with associated tools, have been found under a number of other bogs. Several stone axes, and pottery of neolithic tradition, together with fragments of flint and chert were found at Rockbarton bog (fen) near Lough Gur, suggesting a date very early in the Bronze Age, if not in the Neolithic itself. In and around the ash spreads were found charred hazel nuts, and the fruits of bramble (or raspberry) and elder. This bog occupies the site of a post-glacial lake which was gradually invaded from the margins by marsh and eventually fen. Similar finds have been made in nearby bogs at Ballycullane and Cahir (and further afield in Kealanine bog near Bantry). These also presumably mark the sites of temporary settlements or campsites made by people who came here from areas of more permanent settlement, such as nearby Lough Gur or Cush, to fish or gather other wild foods. Although food-gathering of this kind - fishing, hunting, harvesting of fruits - was more central to the earlier Mesolithic tradition, it continued as part of the neolithic and later cultures.

Javelin heads of neolithic age have been found under the blanket bog in Slieve Bloom and in the Wicklow Gap, lost no doubt by early hunters roaming the undulating parklands of pine which then covered the hills. The neolithic axe-making industry on Tievebulliagh is principally concentrated at the base of the peat, though some implements have been found in the peat itself, and associated with pine stumps growing in the early bog. Another axe of stone has come from near the base of the bog at Derrycassan, Cavan.

Bogs are one of the few situations in which wooden artefacts from early times can be preserved [Figure 15.6]. These include such things as shields, coffins, spades, animal traps and containers. The first archaeological object to be dated by pollen analysis was a wooden cauldron from a bog at Altartate in County Monaghan. The only known Bronze Age wooden shields come from bogs; among the most impressive is the wonderful shield of alder wood found in 1934 less than 1m from the bottom of a deep raised bog at Cloonlara in County Mayo, between the highly humified sub-boreal peat and the fresh brown sub-Atlantic peat above. Another was found at Annandale in County Leitrim in 1863. Bog finds of later date include the enigmatic wooden statue or idol found in the bog at Ralaghan, near Shercock in County Cavan. It is somewhat less than life size, and has a hole which some archaeologists believe had some ritual phallic significance. Among the numerous wooden vessels recovered from bogs is one which was hollowed out of a single piece of yew, and with an oak bottom, discovered in a bog in Offaly some time before 1833. Numerous simple vessels made for the most part of willow wood were found during the course of the Ballinderry crannóg excavations.

Figure 15.6: Objects of wood preserved in bogs.
(a) Wooden cauldron made from poplar: from Altartate, County Monaghan (NMI).
(b) A wooden vessel hollowed out of a single piece of yew, with an oak bottom, discovered in the last century in an Offaly bog *(Dublin Penny Journal,* 1833, p.328).
(c) Wooden shield of alder from Cloonlara, County Mayo (NMI).
(d) Wooden vessel from Cavancarragh bog, County Fermanagh. The body of the vessel is made of oak, the base of alder. About 15” high, cover missing.



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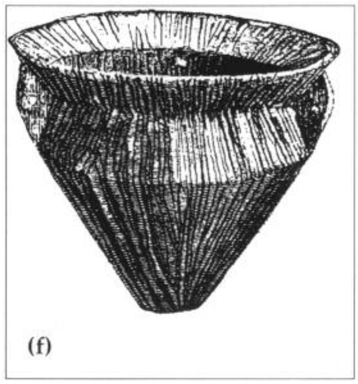

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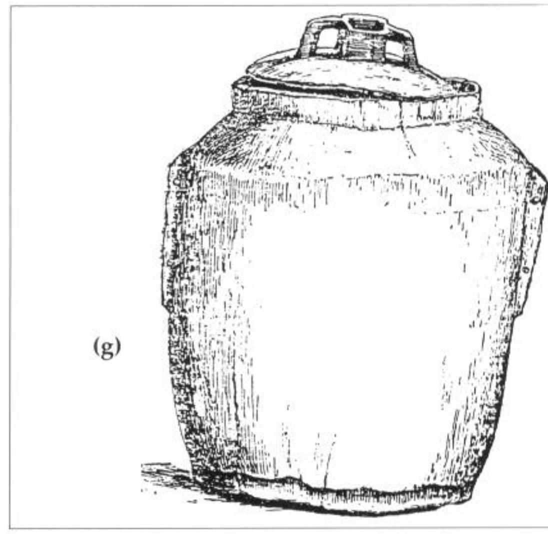


(g)

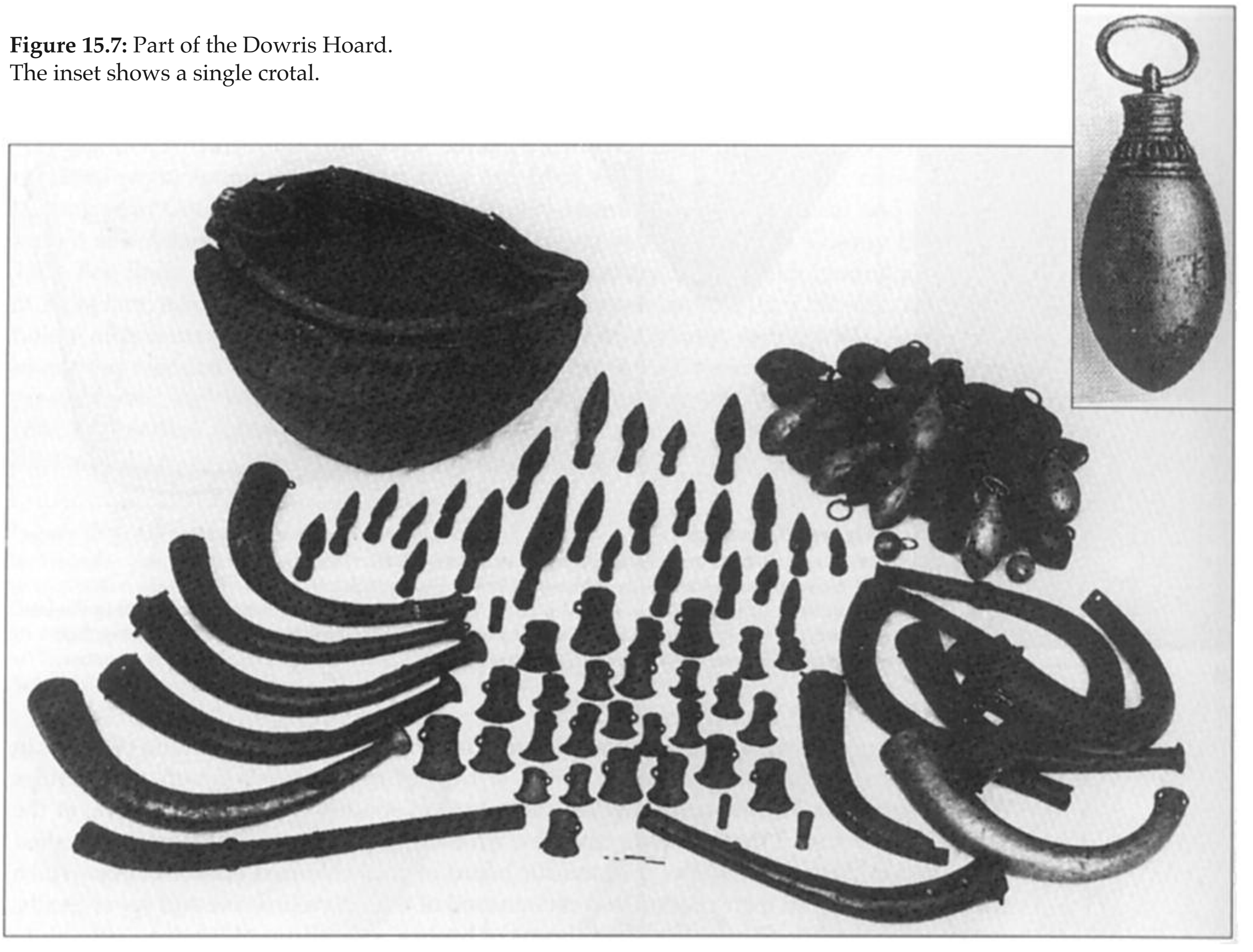
Figure 15.6 (cont.):
(e) Wooden statue from Ralaghan, County Cavan (NMI).
(f) Wooden vessel from Ballydoolough, County Fermanagh.
(g) Butter churn made from a solid piece of pine, found in a bog (probably in Derry) in the last century; it is only about 30cm high, so it was probably used for churning cream rather than fresh milk (Frazer, 1890-91).

One day in early summer around the year 1825, two men were trenching potatoes in the Derreens on the shore of Lough Coura at Dowris near Whigsborough, a few miles north-east of Birr in County Offaly. This is only 8km south-west of Lough Boora, at the very southern end of the same bog complex. All thought of potatoes must have vanished from their minds at the sight of the fantastic hoard of gold-coloured bronze objects which they unearthed with their spades: several hundred of them, javelins, axe and spear-heads, mysterious pendulous ovoid bronzes, horns of bronze, a cauldron of bronze - enough to fill a horse's cart [Figure 15.7]. At the time of the find, Lough Coura covered about 100 acres of open water, and was 172 feet deep; in the later Bronze Age it will have been much more extensive. The hoard which Edward Hennessy and his friend came upon that summer had been given up to the clear water at the edge of the shrinking lake in the 8th century B.C.

The hoard from Dowris would be astonishing enough if it were unique, but more than 50 other Bronze Age hoards have been found in similar or related contexts — laid to rest in bog lakes all over the country during the Late Bronze Age. The earlier hoards tend to occur in peat which is highly humified, and was accumulating slowly at the time the hoards were deposited; the later ones by contrast occur in peat which is only slightly humified. The majority are Late Bronze Age; there are only five Middle Bronze Age hoards.

Nobody has yet provided a satisfactory explanation of why such valuable objects were thrown into lakes and pools on the bog in the first place. One strong possibility is that these lonely bodies of water were regarded as sacred and looked upon with veneration in these early times: and that the collections represent not a single act of *hoarding* but the accumulation over many years, and perhaps centuries, of an *annual* or seasonal votive offering. There is the tantalising possibility that the 19th-Century veneration of Holy Wells on the opposite edge of the bog, at Crancreagh 4km to the north-west, and at Lug 4.25km to the north, developed from an echo or survival of the Bronze Age tradition so spectacularly demonstrated by the Dowris Hoard. To return to Lough Coura itself: by the end of the century the lake had been reduced to reed marsh, and in 1934 R. L. Praeger described it as 'an extensive limy marsh'. Even that has almost vanished today, and much of this once fascinating area of fen and lake has been smothered under coniferous woodland.

Figure 15.7: Part of the Dowris Hoard.
The inset shows a single crotal.



Most of the archaeological finds in Zone VI belong to the Early or Middle Bronze Age. The finds include pottery, daggers, rapiers, lances, halberds. In late Zone VI peat at Cordal in Kerry, a hoard of three copper axes of the Early Bronze Age was discovered. A flint lance head of Early Bronze Age was found at Derrytagh North in County Antrim, very close to Lough Neagh. It lay some 16′ below the surface of the bog, at the roots of a massive fallen oak which was part of an ancient forest growing in a metre of compact, dark peat; the pollen profile paints a picture of an isolated patch of woodland surrounded by open bogs.

Many of these objects were probably things lost in the normal daily course of events, but other finds are less casual. Where hoards of objects are found together they are believed to be the stock of itinerant traders, and it is difficult to imagine these being casually lost or misplaced. But these 'traders' hoards' have turned up fairly often, and they nearly always occur in bogs. A good example is the hoard of 259 flint flakes which were found 2.3m below the surface of a blanket bog at Raheelin in County Leitrim, near the top of Sub-zone VIIb. At the time these were lost or left behind, birch was growing on the bog.

Some of the earliest metal objects found in bogs come from Knockasarnet bog 4km north-west of Killarney: here a flat axe of copper or bronze, and a cake of the same material were found just a foot above the mineral soil beneath the bog, at a level in an early stage of Sub-boreal time. A point of special interest about the cake of copper is that here we are not far from the early Bronze Age mines at Ross Island near Killarney. In the same area, and at about the same level, a flint lance-head was found at Derrytagh North. At this time pine was common in the Killarney woods, but as the Sub-boreal advanced it lost its dominance to oak, which in the wetter climate of the Sub-Atlantic which followed gave way before birch.

Two looped spear heads of Middle Bronze Age date were found in bogs at Dernaskeagh and Cloonacool in County Sligo, one at and the other just below the major recurrence surface. A rapier with a bone handle of the Middle Bronze Age was found in the bog at Shower, County Tipperary, 12km north-east of Limerick, in the plain of the Lower Shannon. This is at a level 70cm below the major recurrence surface, a level similar to the finds at Glanalappa East and Emlaghlea. At Glenalappa, in the north-west Kerry bogs, a dagger of the late Early Bronze Age was found considerably below the VII-VIII junction. But in the same area, at Togherbane, a bronze rapier of early Middle Bronze Age occurred considerably nearer to the junction. An axe of the Middle Bronze Age turned up somewhat below the VII-VIII transition, in Emlaghlea Bog near Waterville in south-west Kerry. When it was lost the bog was drier and covered with pine, as were the Killarney bogs.

Stone moulds of Middle Bronze Age, one for a spear-head and another for a spear-head and a knife, were found beneath the peat near Belmullet. Two bronze axes with stop ridges, made during the Middle Bronze Age, were found lying together 15cm above the base of the bog and below the VII-VIII transition, at Derryfadda Lower in County Mayo. When tools like this were lost in Middle Bronze Age times, the bogs were a good deal drier and shallower, and covered with trees. They were presumably good areas for hunting, and the spears and javelins found in bogs were very likely lost while hunting; the axes may have mislaid by woodcutters in search of good timbers for their houses or farm buildings. This part of Mayo is today one of the most desolate places in Ireland, but when the people of the Bronze Age were living here it was largely open woodland. The forests of pine stumps which occur beneath 1 and 2m of peat are usually rooted in the mineral soil beneath. Here, as elsewhere, the woodland vegetation gave way to blanket bog in Sub-boreal time.

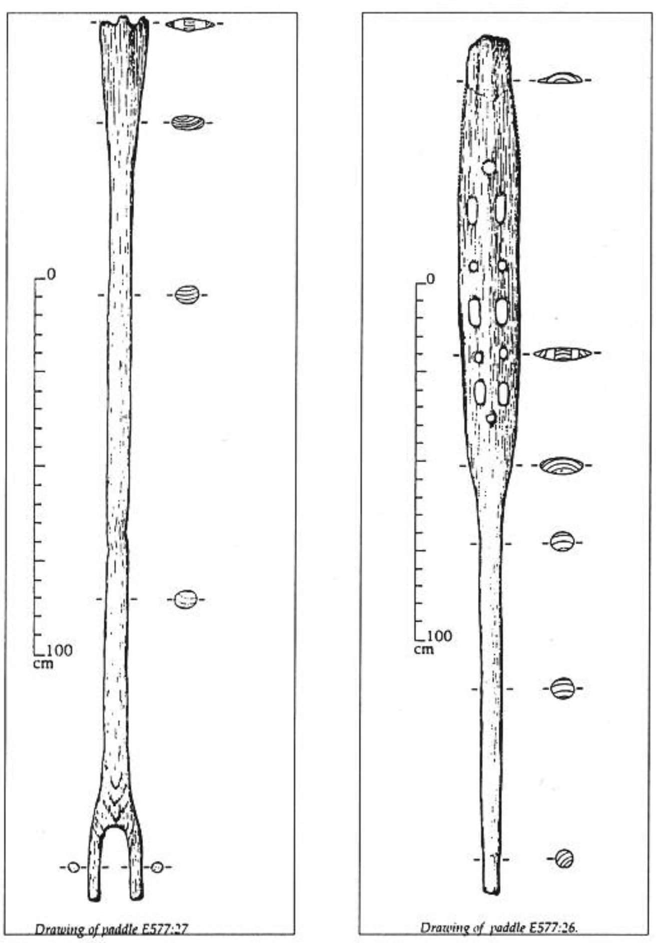
Virtually all finds of *Middle* Bronze Age objects have been made at levels below the recurrence surface - at least where the bog-horizons from which the objects came are reliably known - whereas *Late* Bronze Age objects always occur above the surface. The Late Bronze Age socketed axe found on the bog at Castlelackan Demesne near Killala in Mayo was found in fresh sphagnum peat in the lower part of Zone VIII, a short distance above a level taken to be the equivalent of the major recurrence surface. In the blanket bog at Aughrim in north-west Kerry, a Late Bronze Age sword found more than 3.5m deep in the bog somewhere near the base of Zone VIII. A Late Bronze Age sword was found lying in the bog at Canbo, and a looped spearhead in Carrowreagh Bog, both in Roscommon, both date to late in Sub-Zone VIIIa.

Among the most remarkable archaeological discoveries from a bog comes from deep in the Bog of Cullen, on the Tipperary-Limerick border, where not only vessels and ornaments of gold were found, but the various crucibles, ladles and other instruments used in the working of the metal along with them. These objects were part of one of the largest late Bronze Age hoards: altogether at least a hundred objects of gold and bronze.

One of the most exciting archaeological discoveries of recent years was made by Pat Dooley in 1992 at Blackwater Bog in Clonfinlough. This was a small Bronze Age settlement of three circular wooden houses surrounded by a stockade. Of particular interest is the fact that the little ‘village’, which dates to about 900 B.C., was built on wooden platforms on the bog itself. A number of important artefacts were discovered on the site: bits of pottery from cooking and storage jars, amber beads, and a pair of paddles. These last are of particular interest, because they are of unique design, and are among the earliest evidence of boating activity - although there can be little doubt that they are in the direct line of a tradition that goes back to the Mesolithic fisher people on the shores of the postglacial lakes [Figure 15.8].

Iron Age finds are relatively rare from bogs, partly because iron is less likely to survive, but also because the bogs were becoming so much wetter. People were less likely to be wandering across them. Among the many important archaeological finds from the Early Christian Period is the 11th-century Lemanaghan Crozier, believed to be the shrine for the staff of Saint Manchan who founded Lemanaghan Abbey, and which was found by two Bord na Móna workmen on the nearby bog in 1977 [Figure 15.9]. This may be an example of a valuable object hidden in the bog rather than simply lost.

But bogs also played another role in the story of Early Christian Ireland. Many early monasteries were founded by men seeking to escape from the world, to find God in the wilderness. In Central Ireland the seclusion of the bogs offered such a wilderness, as the desert had done for the early hermits in Egypt, whose lives and deeds greatly influenced the Irish anchorites of the Céli Dé movement. Bog island monasteries are among the most interesting of these 'desert' sites. They include Derrynaflan, Monaincha, Clonown and Lullymore. The name *cluain* was often used for sites of this kind, since one of its earliest meanings is a fertile clearing surrounded by an expanse of bog, and the word *derry (doire)* sometimes refers to bog islands. An understanding of the role of bogs in the medieval landscape is a pre-requisite to an understanding of the origins of particular monastic settlements in Ireland [Figure 15.10]



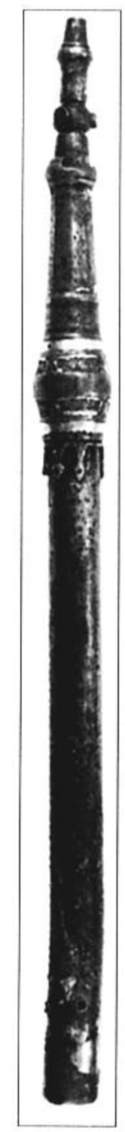


Figure 15.9: The Lemanaghan crozier (NMI), with a group of figures from Saint Manchan's shrine (Joyce).

Figure 15.8: Ancient wooden paddle from Blackwater bog, (Irish Archaeological Wetland Unit).

Figure 15.10: Lemanaghan (Offaly 6″ sheet 15).

In the Early Christian period Lemanaghan occupied a fertile island of mineral land surrounded on all sides by bog, a 'desert' which provided a retreat for the hermit monks who lived here, seeking communion with God and developing a sympathy with Nature almost unique in this age. It was here that an anonymous monk in the 9th century penned the famous lines which have come down to us under the title *The Song of Manchín of Líath,* describing his ideal of the hermit's place of retreat, and perhaps reflecting the Lemanaghan of his day:

> A very blue shallow well to be beside it,
> a clear pool for washing away sins through the grace of the Holy Ghost.
> A beautiful wood close by around it on every side
> for the nurture of many-voiced birds to shelter and hide it.
> Facing the south for warmth, a little stream across its ground,
> a choice plot with abundant bounties which would be good for every plant.

The monastic island (and the late medieval settlement which succeeded it) was of necessity reached by toghers; not surprisingly then, archaeologists have excavated an exceptional number of toghers in the surrounding bogs in recent years. In later times the island was extended on all sides by reclamation of the bog in the north-west, north-east and south-west quadrants, and of fen and callows on the banks of the Brosna to the south-east. New clachan-type settlements grew up in places such as Srah and Camwerth.

Bog bodies

We have remarked earlier on the likely presence of a ritual dimension to the Bronze Age hoards found in bogs. There is clear evidence of ritual also in another facet of bog archaeology: the human remains preserved in peat. *Bog bodies* are among the most fascinating of the archaeological 'objects' found in bogs. Around 80 bodies have been found in Irish bogs over the past two and a half centuries, most of them in raised bogs. Most of these bodies are relatively modern, and some no doubt represent the remains of people who died in the natural course of events and who were buried in the bog; others are very likely the bodies of people who were murdered and hidden in the bog to avoid discovery. But a small number may be people who suffered ritual execution in the Iron Age: a practice known right across Europe in Celtic times, but much better documented in Denmark, Germany and Great Britain, where Lindow Man, Tollund Man, Grauballe Man and many other victims have through their gruesome mode of execution won for themselves an unexpected posthumous immortality in the modern hall of fame. In 2003, a pair of individuals were discovered in separate bogs in the Irish midlands and an international team lead by the NMI showed that they had been subjected to ritual killings (one had been tortured and decapitated) and dumped in swampy graves along a tribal border some 2,000 years ago. Old Croghan Man was a giant at 6′ 6″ and his hands bore no signs of his ever having worked a day in his 20-odd years of life. Clonycavan Man was a relative man at 5′ 2″ but enough of a dandy to have acquired an Iron Age hair gel imported all the way from Gaul.

Many hundreds of bog bodies have been excavated from the peat bogs of north-west Europe; the great majority date to the period between 100 B.C. and 500 A.D., although some are much older than this - in some cases going back to the Mesolithic. One of the oldest in Ireland, and also the first properly documented account of a bog body, was the body of a woman found in 1781 at the very bottom of Drumkeragh bog in County Down. There was a large stone at each end of the skeleton, which was accompanied by numerous garments whose quality suggested a woman of high rank.

Figure 15.11: The body of a woman aged between 25 and 35 years found by turf-cutters in May 1978 under a metre or so of peat in an extensive area of upland blanket bog at Meenybradden, Inver, County Donegal. Radiocarbon dating indicates a date somewhere between 1050 and 1410 AD. There is no obvious evidence of the cause of death. (Photograph NMI).

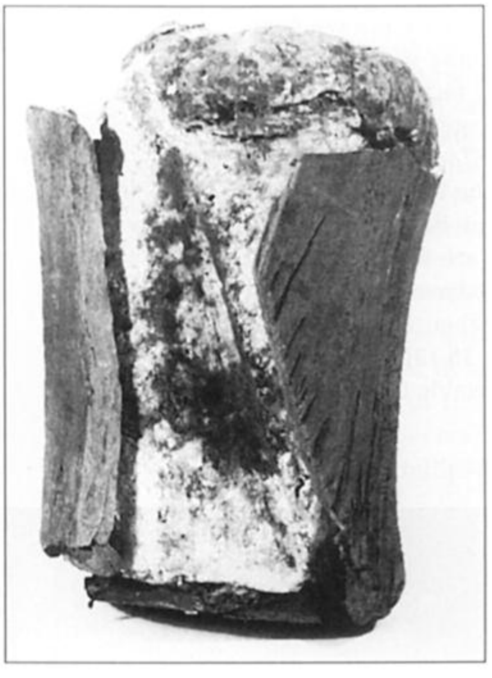
Bog butter

One of the most widespread archaeological items found in bogs is butter, because the bog was the nearest functional equivalent to a refrigerator in early Ireland. In order to preserve butter in earlier times, 5% or more salt was added to it; before the butter could be eaten, slices of it had first to be soaked in water to reduce the salt content. If salt was scarce or unaffordable, the cold, anaerobic, antiseptic peat offered an alternative way to preserve butter through the autumn and winter. It also provided a way to preserve garlic butter, a special kind of butter made specially for use during Lent. Salt could not be used to preserve garlic butter because soaking in water before use would remove the garlic as well as the salt. Unfortunately, there are very few accounts of bog butter *in situ* which might give an accurate picture of how it was actually buried in a way that would ensure preservation.

The butter was wrapped in cloth or skin containers, in baskets or hampers made of wicker, in wooden casks hollowed from a single piece of wood (and able to hold half a hundredweight), or in barrels made of staves (able to hold twice that amount) [Figure 15.12]. Among many descriptions of finds of bog butter is the following:

> Mr Crowley, of Whitehill Cottage, found in the bog immediately S.W. of his house, *a cow's skull in undisturbed bog.* It had five feet of turf between it and the marl, and fifteen feet over it. He also found in the bog on the W. of his cottage in *undisturbed bog,* a roll of butter, eighteen inches long and five wide, at a depth of ten feet, and having ten feet between it and the marl. When found it was quite like butter, and when seen by us it was dry and light, but if applied to a flame it burned with a bright light, and had the smell of rancid butter or oil. Through the mass were brown rootlets of plants which gave it the appearance of the white peat of Valencia Island.
>
> *Memoirs of the Geological Survey of Ireland* 134, *p.36.*

Figure 15.12: Bog butter enclosed in wooden container. (Photograph NMI).



Butter was buried in bogs until the end of the 17th century, reflecting the fact that milk and its products were the main food of the Gaelic Irish until the collapse of the Gaelic order around this time. The practice continued much later in Scotland, and it may well have survived longer in some parts of Ireland as well. However, it is generally accepted that storing butter in bogs in this way is a Gaelic adaptation of a farm practice that was widespread throughout northern Europe. Bog butter deteriorates in appearance and flavour with time as the fat in the butter is altered by microbial action to adipocere. It is usually a hard, yellowish-white substance, a bit like cream cheese in texture and flavour. William Frazer described it as 'tasting like old spermaceti'. Hygiene being of a different nature in those days, it usually contains plenty of cows' hairs. Bog butter was offered for sale in Tralee as late as 1853; the taste was described as 'an-ghoirt', a taste said to appeal to the early Irish. Other types of fat (such as sheep tallow) may also have been buried in bogs from time to time; when this is left for a long time, the fat also alters to adipocere and acquires a cheesy flavour.

Roads in the peat

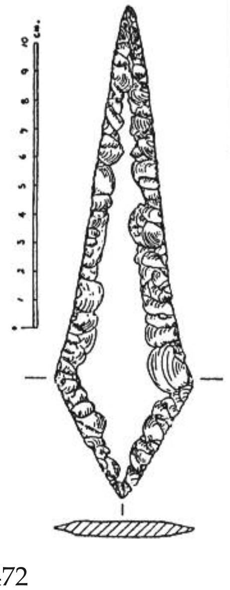
Three thousand years ago Ireland was enjoying what was perhaps one of the most prosperous and peaceful epochs in its history. Late Bronze Age technology was making better and more efficient tools and techniques available to the farmer so that ever-increasing amounts of productive land were being reclaimed from the wild. But by this time extensive areas of the country were covered by bogs which were a major obstacle to communication, especially in Central Ireland, where the farming landscape was an intimate patchwork of fields, bogland and callow, with an ever-decreasing area of woodland.

In the centuries after 1000 B.C. there was profound cultural change in Ireland. For one thing, the country was becoming a focus of avaricious interest to the bands of aggressive iron-using Celtic warriors who were infiltrating Bronze Age cultures everywhere on the fringes of Europe, and would in a short time take over the framework of Bronze Age Irish Society and refashion it in a new mould. But this was not the only disruptive force, because in the middle of the last millennium B.C., perhaps at about the time the Celtic language of the new Iron Age rulers was replacing the languages of the Bronze Age, the climate began to become even wetter. Sphagnum established a more complete dominance on the raised bogs, which began to grow more rapidly as a result. The disruption caused by the great climatic deterioration of the last millennium B.C. may have been a catalyst in the waning of the Bronze Age, as the iron sword-bearers swept across Europe.

To provide more direct communication between the farmstead and distant fields, or between settlements separated by bog, trackways were often laid down on the surface, but with the passage of time these were swamped and swallowed up by the growing sphagnum. In our own day, as exploitation of the slowly-accumulated harvest of peat rewinds in a few decades through the several millennia during which the upper sphagnum peat accumulated, we come upon these roads, which were all sooner or later abandoned to the bog. Their discovery puts us in touch with the everyday problems of the past in a way which few other aspects of archaeology do so poignantly and sharply.

Bog trackways are also very well known from many other parts of Northern Europe, most notably north-west Germany - where over 300 trackways ranging in age from Middle Neolithic to late medieval times are known, and where there is clear evidence for prehistoric traffic systems - Scandinavia, Holland, and the Somerset Levels in England, which were criss-crossed by a veritable web of trackways constructed between Early Neolithic and Early Bronze Age times. More than a thousand trackways are known from Ireland, dating from all periods back to the Neolithic but this is certainly only a fraction of the total. Toghers occur at different depths in the bog, reflecting the fact that they were built over a long period of time. The toghers in the Corlea complex range in date from the 4th millennium B.C. to the sixth century (Corlona 5 gave an age of 587+/- 9 A.D). In the days before modern dating techniques, G.H. Kinahan calculated on the basis of assumed growth rates of peat that a timber togher at Duncan's Flow Bog at Ballyalbanagh in County Antrim had been built around 1326 B.C. Associated finds are frequently very helpful in dating toghers. One example is the Late Bronze Age socketed axehead reported to have been found lying on one of the timbers in the Balligear togher. Another good example in the sword found with the Littleton togher [Figure 15.13]. The wetter conditions of the last half millennium B.C. made the bogs more intractable than they had been, but people continued to use them for travel and transport.

(a)



(b)

Figure 15.13: (a) The Littleton Sword.
(b) Flint javelin head from Camaderry, County Wicklow. Found on a heap of sand about 5m below the original bog surface, near Saint Kevin's road at the top of the Wicklow Gap.

These special roadways and tracks over the bogs were called *toghers*, a word which was also used for causeways across marshes, intertidal flats and other wet places. They were usually built in one of three landscape settings: (1) to connect areas of productive or settled land on opposite sides of a bog which could otherwise only be reached by making a wide detour through boggy scrub or woodland; (2) to provide - or maintain - access to islands of productive land, or settlements which were surrounded by bog; and (3) to provide access to areas of special interest in the bog itself. The lost togher which survives only in the name of Ballintogher in Geashill parish (County Offaly) reflects the first of these uses; in two poems in the Metrical Dindshenchas it is referred to as *Tochar Mor itir Da Mag* and *Bothur eter Oa Mag* - the trackway between two areas of farmland *(mag).*

In the barony of Dartry in County Monaghan, ringforts are often located upon drumlins which are sometimes separated from one another by bog. Sir Charles Coote in his survey of the barony describes what he regarded as portable toghers:

> In this barony are numerous Danish forts [ringforts], generally erected on a rising spot in a morass: and in turf cutting have frequently been found the wicker hurdles, which they carried, to make a pass through the bogs, when they went to forage or maraude through the country, and, according as they retreated home, took up; thus answering the like purpose as a drawbridge to a fortified place. At Freamount, the seat of William Mayne Esq., several of these hurdles were found near to one of the remarkable raths, which is the largest I have seen, and most capitally defended with well constructed works; its area is about an Irish acre, and commands a number of toghers or strong bog passes.

There are sixteen Togher townlands in various parts of Ireland, and the word occurs as an element in at least 30 other townlands, and dozens of others are referred to in the *Civil Survey* of 1654 and other early documents. Toghers are particularly common in the Midlands. Several are mentioned in Sir Charles Coote's account of the bounds of the Barony of Phillips town in County Offaly:

> ... from thence to the middle of the causeway called Toghercroghan ... and thence through the bogg of Loghnalover and thence to the end of Togherfadd (next Phillippstowne) thence to Toghermcffolly called Kishfennan mearing with the towne of Moynrath.

Here are two extracts from Coote's account of Coolestown barony in Offaly:

> A chain of moats extend through this country, and were strongly fortified; they all command toghers or bog passes, which were very numerous.

> It is soe interlaced and invironed with great boggs and low moorish grounds and rivers that there is noe passage from one part thereof to another; nor out of it to any other barony but through the straights of foords, causewayes or passes ...

Many modern roads often follow the line of the old toghers. The roads following Saint Fintan's road (See below), and that along the line of the Togher of Monahorn (both in Laois) are examples. Many of the early monasteries deliberately sought the solitude of these bog islands, but they were also selected for strategic reasons because they could so easily be defended - in Early Christian times against marauding Vikings and native Irish raiders, and in later times by the native Irish against English invaders. In the Registry of Clonmacnois there is a reference to a stone 'in the end of the toghar of the 3 Donalds' on which was carved 'what lands of right belonged to the Abbot of Cluain and the Nunns'. During the construction of the Grand Canal, workmen uncovered a togher connecting Clonfert to Clonmacnois under several feet of bog.

Some of the derries - islands of productive or wooded land surrounded by bog - to which toghers led could be quite small. In Clonfinane bog at the north-eastern corner of County Tipperary turf cutters came on rows of upright branches running in the direction of a tiny oasis in the middle of the bog. This little oasis was surrounded by birch trees, but in the middle was a dry area 10m across in which there was a small mound that was formerly sheltered by old whitethorns. This site was known as the Priest's Bush, and traditionally believed to have been a penal mass site.

The construction and uses of toghers

Although some toghers were wide and substantial enough to carry the weight of animals, few were adequate for wheeled vehicles. The great majority of toghers were probably only suitable for people on foot. Numerous examples of each kind have been partially excavated. Typical of the footpath togher is a Bronze Age track described from Corlona Bog in Leitrim, which consisted of sets of three planks laid end to end all the way across the bog. The central plank in each set was the widest, and the width of each set - and so the width of the track - was just over a metre. One end of each set was secured to the solid ground under the peat by a pair of pointed piles or stakes, whereas the opposite end was merely supported on a layer of brushwood. A footpath togher with a different structure was excavated at Monevullagh (perhaps *Móin a 'bhealaigh,* which means the bog of the road?) in County Kildare. In this case the togher was made from oak trunks of about 60cm diameter which had been split down the middle and then the halves laid end to end with the flat ends facing upwards. A third structure is exemplified by a togher at Robertstown in County Kildare which consisted of long planks about 60cm wide laid end to end; in this case the plank was flanked by two unhewn round trunks 15-23cm in diameter, and each set (comprising the central plank with trunks on either side) rested at either end on a cross timber laid beneath them at right angles.

Roadway toghers were of two kinds: those made entirely of timber and brushwood like the pathways, and those which incorporated stone or gravel on a brushwood foundation. The runners usually rest on a foundation of brushwood, and sometimes a drainage trench might be dug along either side. Brushwood tracks were usually made of hazel; where more substantial timbers were used they were of oak, ash, birch, alder, willow and yew; blackthorn and whitethorn are found occasionally. The timber roads were constructed in different ways. Planks were often laid side by side at right angles to the line of the road, resting on top of long timbers lying parallel to the road. In one road of this kind, the most northerly of the Littleton toghers, the oak planks were about 3m long (and the road was therefore about this width), and most had square holes at each end, through which long wooden pegs were driven to anchor the togher in the peat. Another example is the Danes Road at Lullymore which joined two of the mineral islands in the bog together. This ran for a distance of about a kilometre; it was made of oak sleepers 3m wide, laid side by side, and originally lay some 2m below the bog surface. The middle part of the road was removed in the winter of 1946-47, but the ends still lie in position beneath the peat.

Different kinds of wood were used for the pegs - willow, poplar and ash - and the runners were made of oak, cherry, alder and (oddly), blackthorn. Part of the central togher at Littleton consisted of round trunks of ash, oak or birch laid side by side, secured by long pegs driven between them near the edges. At one end the togher was supported on longitudinal runners of ash, whereas at the other it rested on hazel brushwood. In a roadway togher excavated at Derraghan Bog in County Longford, the togher consisted of planks laid side by side and resting on longitudinal runners. The planks were secured by pointed stakes up to a metre long, driven into v-shaped notches at the ends of the planks.

Probably the best-known and most intensively investigated bog trackways are those in the bog which lies to the west of Kenagh in County Longford. A togher in the townland of Corlea was brought to the attention of Barry Raftery of UCD in 1985, and what started as a short term rescue excavation blossomed into a fascinating multi-faceted research programme extending over many years. The Corlea togher complex is now by far the best known in Ireland; nearly 60 tracks had been investigated by 1990. The concentration of tracks here is remarkable; in the townland of Derryoghil five or six lay at the same level in the bog, separated from each other by no more than a few metres.

A number of the stem and brushwood tracks in Corlea date to the Neolithic (4th millennium B.C.), and several more have been dated to the 3rd millennium B.C., including one at Cloonbony near Lanesboro, dated to 2500 B.C. and made of 2m lengths of round stems of alder laid transversely on longitudinal runners of birch and ash, pinned in place by pegs of birch and alder. Corlea 6, a track made of a mixture of split oak and ash stems and round wood, has a construction date of 2259 +/- 9 B.C. This track is of special interest because the clear and crisp axemarks on some of its timbers were almost certainly made with a metal tool. Most of the excavated tracks belong to the 2nd millennium B.C., and they consist largely of longitudinally laid brushwood. Woven hurdle panels made from coppiced hazel were used in the construction of a number of late 2nd millennium tracks.

The most impressive of the toghers, in the townlands of Corlea and Cloonbreany, formed part of a road which ran for a distance of some 2km [Plate 11]. The oak trees used in its construction were felled in 148 B.C. It consists of close-fitting split oak sleepers 34m in length, and up to 60cm wide, supported on pairs of long, straight runners - more than 10m long sometimes. The sleepers were mortised and pegged down with long pegs of hazel, birch or oak. This togher ran in a north-westerly direction towards an island in the bog. The Derraghan More togher (mentioned earlier) was found in the bog to the west of the island - is made in exactly the same way, the oak trees used in its construction gave a radiocarbon date between 200 and 100 B.C., so they are almost certainly part of the same road system. This is by far the most impressive togher known from detailed excavation; thousands of heavy oak beams had to be transported for several kilometres to make it. It may be highly significant that this togher was built at a time of extensive civil engineering projects in Ireland: the great dykes of the Dorsey in south Armagh and the Black Pig's dyke in Monaghan and the wooden temple at Navan Fort were built at the same time.

Part of the Corlea trackway now forms the focal point at the Corlea Trackway Exhibition Centre, but this did not mean simply transferring it from the bog straight to the Centre! Bog timbers may look remarkably well preserved when they are first excavated, but in fact what keeps them together is the water they contain: much of the tissue in the wood has been destroyed. To preserve the timber and prevent its collapse, the water must gradually be replaced by a liquid wax solution known as PEG, a very time-consuming and costly process. Before they could be exhibited at the Centre, the timbers of the Corlea trackway were first soaked for seven months in a solution of warm wax at Lanesboro, and subsequently taken to Portsmouth in England to be freeze-dried. This sequence stabilised the internal structure of the timbers, and enabled them to be placed in the Centre in the exact position in which they lay beneath the peat.

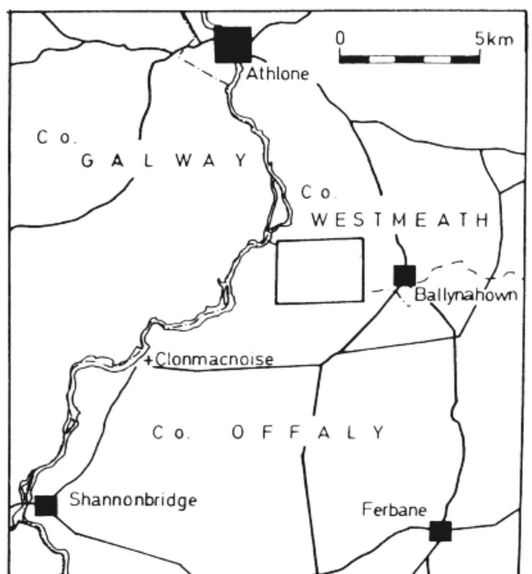
Though most toghers are made of wood, stone trackways and roads were constructed on occasion when flagstones were readily available. Flagged roads are known from raised bogs at Timoney in County Tipperary, and at Lemanaghan and Bloomhill in County Offaly; the flagged medieval pilgrim road to Glendalough ran for part of its course across the blanket bog of the Wicklow Mountains. The *Annals of the Four Masters* and the *Chronicon Scotorum* both record the building of stone roadways at Clonmacnois in 1026 and 1070 A.D.; the construction of the flagged ways across Bloomhill and Lemanaghan bogs may have been part of this enterprise.

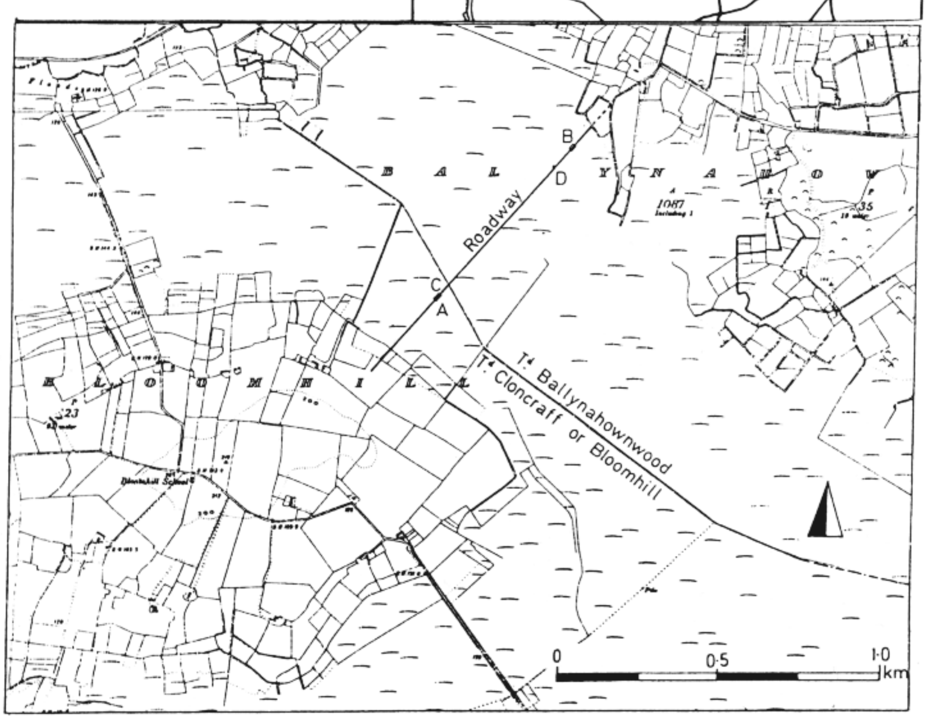
The Bloomhill road ran across the bog for a distance of 1km, linking the mineral ground in Ballynahownwood townland in County Westmeath on the north-east side with that of Bloomhill (Cloncraff) in County Offaly on the other [Figure 15.14]. The road was 4m wide, made of closely-fitting local flagstones, the gaps between them blocked with smaller stones. The discovery of numerous horseshoes (probably 13th century in age) along the road show that it was used by horses (and no doubt by other animals), and very likely by wheeled vehicles as well. The road had been laid down on a bed of inverted peat scraws 0.2m deep, resting on a layer of birch brushwood, which in turn overlay a mixture of clay and stony gravel. After some time in use the flagged road became waterlogged and overgrown, and was finally enveloped by bog. Later, after unsuccessful attempts to keep the surface passable by spreading gravel, a simple wooden trackway was constructed in the early 13th century. This lay at a depth of 1m in the bog when the road was excavated in the 1980s.

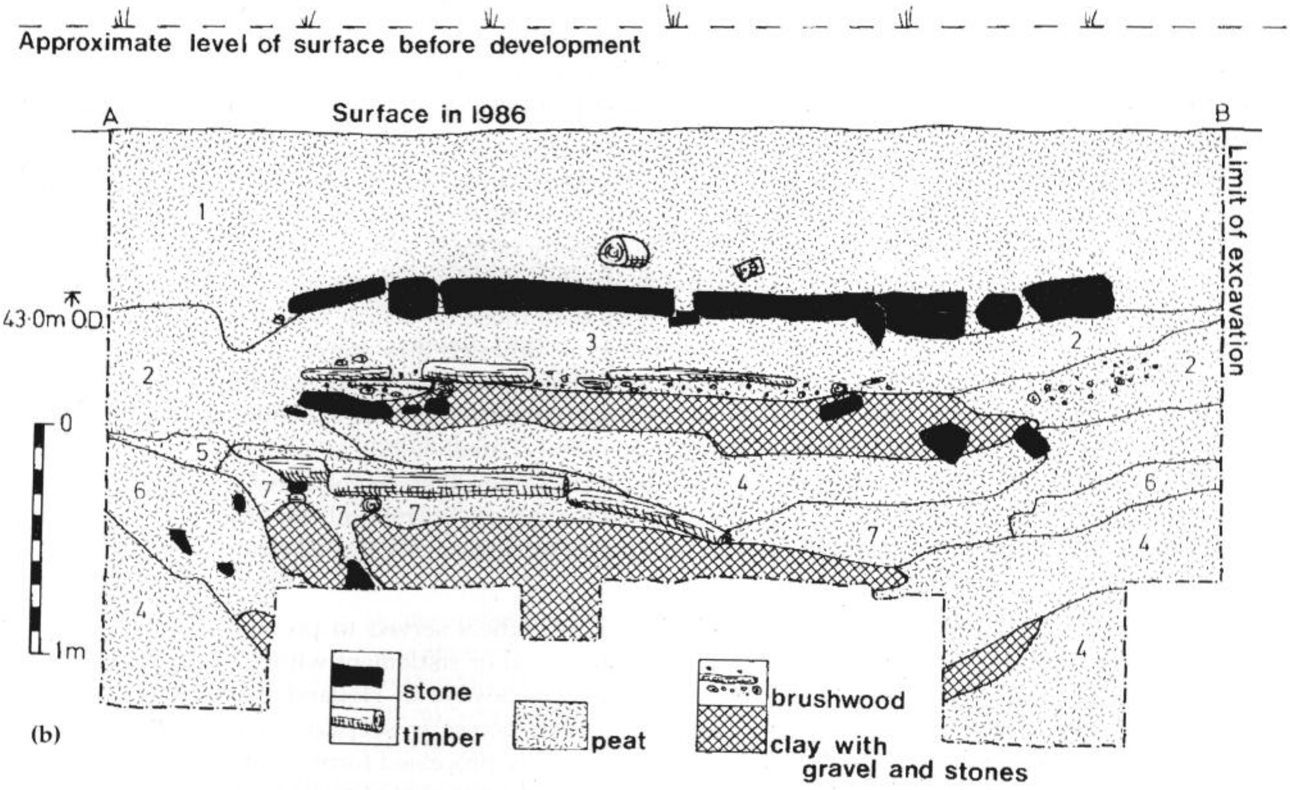
The flagged togher at Timoney near Roscrea in County Tipperary had a covering of sandstone slabs resting on top of brushwood, and a line of stakes driven into the peat at either side. This road ran southwards across the bog in the direction of dry land at Corbally, a kilometre away. The Timoney togher was built on a covering of fen peat, and was apparently overlain by unhumified sphagnum peat - probably because the weight of the togher depressed the underlying peat, making the togher the *wettest* spot, and highly favourable for the growth of fresh sphagnum. The wood from a yew stump directly under the togher gave a date of 1280-1520 A.D. A togher of pegged brushwood and sticks, covered with a layer of stones or gravel, seems to have connected the two old monastic sites at Clonsast in County Offaly, but was also probably used as a secular route connecting settlements on either side of the bog. Known as Saint Broghan's Road or Saint Kieran's Road, it joined the old graveyard of Clonsast on the eastern end of the bog to a *cillín* called Relic on the western side. The togher ran for about a mile, and was some 3m wide. It gave a date of 780+/-80 A.D ..

Other kinds of construction are also met with, and there is a considerable amount of variation in detail between different toghers. One of the most unusual is one which was

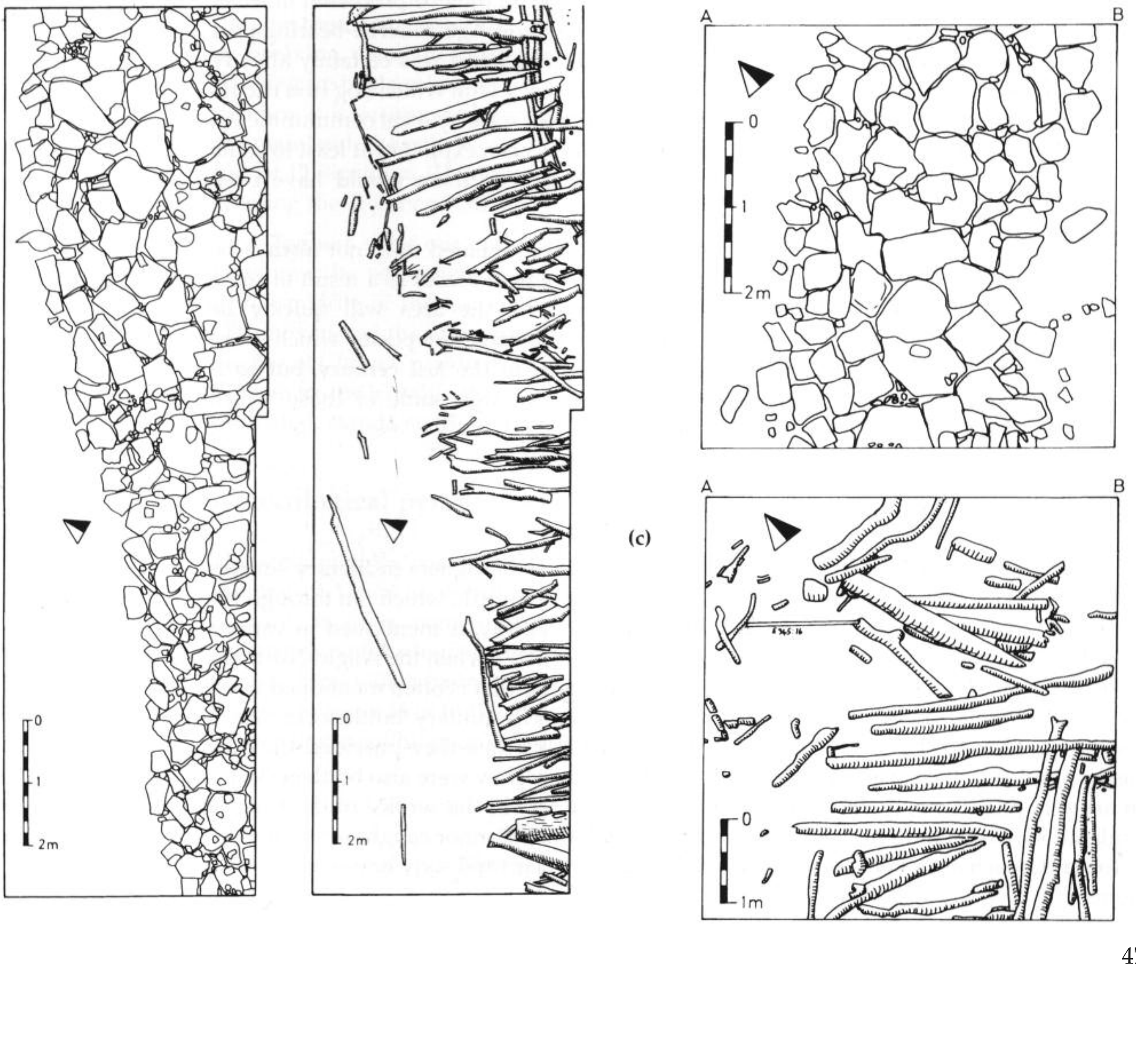
Figure 15.14: The roadway across the bog from Bloomhill to Ballynahown.
(a) Location of the site.
(b) A section showing the stone road at the top (at 43m OD), and the brushwood/timber tracks lower down, resting on gravel and clay. The numbers refer to the colour of the material.
1 mid-brown;
2 dark grey-brown;
3 dark grey-brown with sods;
4 dark brown;
5 black;
6 whitish silty;
7 light brown silty.
(c) Two sections of the road and track in plan view. (Breen, 1988).






Approximate level of surface before development
Surface in 1986
A
B
Limit of excavation
43·0m OD
1
2
3
4
5
6
7
0
1m
stone
timber
peat
brushwood
clay with gravel and stones

(b)


A
B
0
1
2m
1m

(c)

discovered 2.5m below the surface of a bog in the townland of Baltigear in County Meath in 1972, and which comprised no fewer than five superimposed layers of oak timbers, each more or less at right angles to the one underneath. On top of this heavy wooden foundation there was a layer of gravel and sand, and on top of that again a pavement of pegged birch rods 3.3-3.6m wide.

Numerous toghers have been discovered and reported during turf cutting, and subsequently investigated, but very many more must have existed. It may not be an exaggeration to suggest that toghers were built on the majority of bogs. Few areas have received the archaeological attention that Corlea and its neighbouring bogs have, and the finds here reinforce the probability that many more bogs than those for which we have formal records have or had toghers. Some bogs have several, although they were not all constructed at the same time. As we saw earlier, there were sixty or more in the Corlea complex. Three were discovered at Littleton bog in County Tipperary, and there were four in Derrybrat bog in the townland of Broughal in County Offaly. Timahoe bog in Kildare had nearly forty; recent work in Clonfert bog has discovered more than twenty, and a preliminary field survey of the bogs north and north-west of Derryoghil by the Archaeological Wetland Unit produced sightings of 120 new trackways, seventy of them in the townland of Annaghbeg.

From all that has been said it will be clear that most toghers served to provide passage across bogs or to give access to areas of productive land or settlement within a bog. However, we know from the extensive study of bog trackways in Holland that toghers were also constructed for another reason: to provide access to seepage areas within the bog where deposits of bog iron - a very rich and easily processed form of iron are - accumulated. We now know that in Holland bog iron are was exploited as far back as the Middle Bronze Age, even though at that period it could only be processed in small quantities; processing techniques improved greatly in the Iron Age. Siderite-bearing peat was recognised as such in Dutch bogs even in the Neolithic, and was certainly already being exploited there by around 500 B.C. Given the frequency with which bog iron occurs in Ireland and that the metal was widely worked on a small scale by local communities in the Iron Age, it appears likely that these deposits will have been exploited at least to some extent in the past in many bog districts, and that access to them would have been provided by toghers.

Areas of seepage where bog iron deposits have accumulated may not always be evident at the surface today, because if active water movement ceases as a result of some hydrological adjustment in the bog's circulatory system, the area will quickly be swallowed up by the hungry sphagnum. Many of the larger deposits which were apparent at the surface were exploited and worked out in the last century, but turf-winning enterprises frequently provide good sections through some of those which remain (e.g. Bangor Erris, Derrygreenagh, Monaincha).

Toghers in history

There are abundant references to the construction and use of toghers in literary sources from the seventh century on. The Togher of the Bog of Coinneadh, which ran through the parish of Templetogher *(teampall tochair)* in north-east Galway, is mentioned in various Irish Annals at least half a dozen times, the earliest being 1177 when the Anglo-Normans under Miles de Cogan invaded Connaught. Another togher that is often mentioned is the Togher of Croghan, *Tochar Cruachán Bri Éle.* Toghers were military bottlenecks which could be held against an advancing enemy - particularly when they provided the only means of ready access to a settlement, castle or monastery. They were also bottlenecks for an army in retreat. So, in 1395 when a party of marauders in the service of the King of England were retreating from Offaly, the Offaly chieftain O'Connor caught up with them at Tochar Cruachan, 'where great numbers of them were slain and sixty horses taken from them'.

Most of the historical references concern the use of toghers by the Irish against an invading enemy, especially during the wars of the sixteenth and seventeenth centuries. A Commonwealth document of 1652 describes raised bog terrain in the following terms:

> The country, being almost everywhere, in the counties mentioned [Galway, Sligo, Roscommon and Longford], interlaced with vast bogs, in the midst of which are firm woody grounds like islands, into which they have passes or causeways, where no more than one horse can go abreast, and can be easily maintained or suddenly broken up, and they themselves inured to wade through them, they can easily pass to and fro, and prosecute their designs of robbing and burning those places, which yield our forces subsistence.

In the sixteenth century, the areas of bogland, swamp and marshy ground in the basins of such rivers as the Shannon and Erne, and across the Midlands generally, was so extensive that the only suitable military route into Ulster was through the Pass of Moyry north of Dundak, which it took Mountjoy two years to capture in his war with Hugh O'Neill. On hearing that William of Orange was about to land in Ulster in 1690 the troops of James II assembled at Dundalk to resist the advancing enemy, whereas (observes the author of the Jacobite *Narrative of tile War in Ireland),* if they had advanced another four miles

> to the nigher end of the long causeway, that runs through the middle of a great bog, at a place called Four-mile-house, as being within four miles to Newry and as many to Dundalk, the moiety of his army, with good management, could have stopped the enemy, whereby he would have been forced to take a fatiguing march to cither of the two passes in the county of Armagh.

In the seventeenth century the only way to get to Lanesborough was across a togher. In 1690 the Jacobite army attempted to hold back the advancing Williamite soldiers by digging trenches across this togher at intervals. The digging of trenches across the toghers, or breaking them up altogether, was a method widely used to stall the enemy - like blowing up bridges in later times. Ross Island near Killarney also relied on a togher for its defence. It is surrounded by water on all sides except one, where a bog separated it from the mainland, the only access being over a togher. In the late sixteenth century the isolated fort of Philipstown (Daingean) in County Offaly could only be reached from Dublin by crossing the Togher of Offaly.

Toghers went out of use after the seventeenth century, when their functions were taken over by permanent roads, but they were not entirely forgotten. It is significant that in the middle of the last century a number of them could still be pointed out to John O'Donovan and the other antiquarian field workers of the Ordnance Survey - such as the Togher of Cluyn Cruaidh of Failte, 'which still exists and runs across the bog from Cloon-Burren to the *cruaidh* (hard ground) of Failte, and the Cross of Cairbre Cr0111, now mutilated, stands nearly in the middle of it'.

An ecological perspective

The account of the construction of the togher over Main Lamraige in *Tochmarc Etaine* (The Wooing of Etain) is worth looking at *verbatim,* because even though it is a mythical account, it gives some impression of the amount of disturbance involved in the construction of the togher, and reminds us that the undisturbed atmosphere of many bogs is something which has enveloped them only in recent centuries. The silence of the bogs is perhaps more akin to the 'true Silence' of Thomas Hood's poem: it is not the silence of a place unvisited by people, but that of an *abandoned* place:

> where Man hath been,
> Though the dun fox or wild hyaena calls,
> And owls, that flit continually between,
> Shriek to the echo, and the low winds moan
> There the true Silence is, self-conscious and alone.

The task laid upon the other worldly Midir for losing a game of chess with Eochaid Airem king of Tara was that he should lay a causeway over Móin Lamraige, 'a bog which no one had ever trodden before'. Eochaid's steward was told to spy on the work, which was carried out while everyone else slept, and this is what he saw:

> It seemed to him that all the men in the world from sunrise to sunset had come into the bog. They all made one mound of their clothes, and Midir went up on that mound. Into the bottom of the causeway they kept putting a forest with its trunks and its roots, Midir standing and urging on the host on every side. One would think that below him all the men of the world were raising a tumult.
>
> After that, clay and gravel and stones are placed upon the bog. Now until that night the men of Ireland used to put the strain on the foreheads of oxen, but it was seen that the folk of the elfmounds [who were doing the work] were putting it on their shoulders. Eochaid did the same, hence he is called Eochaid Airem [i.e. ploughman], for he was the first of the men of Ireland to put a yoke on the necks of oxen. And these were the words that were put on the lips of the host as they were making the causeway: 'Put in hand, throw in hand, excellent oxen, in the hours after sundown; overhard is the exaction; none knoweth whose is the gain, whose the loss, from the causeway over Móin Lamraige.

The ecology of bogs which were crossed by strategic toghers must have been considerably disturbed on occasion, particularly perhaps in the seventeenth century wars, which is the last time they functioned in this way. Consider for example the bog near Lanesborough, in County Longford, referred to earlier:

> The Enemy appeared on the Bog on this side of the Town, being, as they say, nigh Three Thousand, and had cut several Trenches cross the Causeys that go through the Bog towards the Town; these they disputed for some time, but losing some of their Men, they retired into the Town and from thence to beyond the Shannon ....

Apart from disturbance of the bog surface, the construction of toghers meant some destruction of natural woodland. In the *Lives of the Irish Saints* there is an account of how the son of the King of Corco Baiscinn came with 30 warriors to Saint Mochuda, seeking admission to his community of monks. Mochuda received them, but gave them a tongueless bell and sent them away to find somewhere they were more urgently needed. After seven years of wandering the faithful band reached Lann Ela, where the silent bell rang of its own accord, whereupon the warrior monks cut down a wood, and with the timber they built a togher across the Bog of Lann to Tech Laisren. However, many toghers were made of brushwood, and this was probably the product of normal agricultural woodland management. Other toghers were probably constructed - in part at least - from timber left over from such activities as house building.

Pilgrim roads and miracle roads

Toghers feature in several other miracles in that endless storehouse of wondrous deeds: the legends of the saints of early Christian Ireland. When Saint Ruadhan of Lorrha lived at Derrynaflan in the middle of Littleton Bog, a neighbouring bishop sent him a very large vessel of butter as a gift, so large that it took a cart drawn by two oxen to transport it, and big enough to provide for Ruadhan and his monks and all their guests from the beginning of spring until Pentecost; when Pentecost came the container was miraculously replenished. But Derrynaflan (as the name suggests) was on a bog island, and there was no way to get the cartload of butter across - apart from which a murderous beast lived in the bog. However, when the party got to the bog (the beast having been duly despatched) they found a wide, firm road which hadn't been there before, and was never seen afterwards. In reality, we know that there were several toghers across Littleton Bog, and there will certainly have been one or more going to Derrynaflan.

An equally miraculous explanation was advanced to account for the construction of the stone causeway which formerly ran across bogland to link the Early Christian sites of

Clonenagh and Cremogue in County Laois, now largely obliterated by the modern road which follows its course. Legend tells how Saint Fintan of Clonenagh arrived at Cremogue, weary and footsore after a long journey away from his abbey. It was night, and neither moon nor stars shone to light his way across the bog that stood between him and home. At the saint's word the clouds parted to reveal the moon, which shone down on a newly-laid track running straight to the abbey.

Two interesting bog roads of a different kind are pilgrim roads: Saint Kevin's Road to Glendalough, and *Tochar Phádraig* to Croagh Patrick. Saint Kevin's road was a paved road built on the mineral soil under the shallow bog running from Hollywood to Glendalough. A small section of the road was excavated during the construction of the ESB's hydroelectric scheme on Turlough Hill; most of it was overgrown by bog, or broken up over the long centuries following the destruction of Glendalough at the end of the fourteenth century, and its subsequent decline as a place of pilgrimage. *Tochar Phádraig* ran all the way from Ballintober to Croagh Patrick, a distance of fifteen miles, some of it across blanket bog. Sections of the road can still be seen and followed.

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Chapter Sixteen

A new landscape in prospect: the bogs of the future

Where would the world be, once bereft
Of wet and of wildness? Let them be left,
O let them be left, wildness and wet,
Long live the weeds and the wilderness yet.

Gerard Manley Hopkins

A few decades from now most of the large raised bogs will be exhausted of their peat reserves. The great state organisation that is Bord na Móna can count the remaining years of peat production on its fingers. Milled peat will be declining in the years leading up to 2030; the manufacture of briquettes has already reached its peak and is now declining, and machine turf production by Bord na Móna has ceased. In due course the great machines will fall silent, and take their place in the iron graveyards and museums where earlier models already rust. In time, the burning of turf may be little more than a ritual, a link with the past like the May Bush outside the door celebrating the fertility of the first fields, or the driving of cattle through the fires on Saint John's Day: except that in those cases the link is broken and the origins forgotten.

The removal of the larger bogs will give us as much as 100,000ha of cutaway bog by 2030; its subsequent development will be one of the great reclamation ventures of Europe, on a scale comparable to that of the English fenlands or the polders of Holland. Although the larger raised bogs will all have gone within a generation, we are still in time to make sure that – as happened when the prehistoric fields replaced the wildwood – the exchange has a rich ecological dimension. The economic return of a large acreage of expensive reclaimed cutaway is not enough. The new landscape must be an adequate exchange for the old in terms of richness of experience: not just for the visitor, but primarily for those of us who will continue to live here when the bogs have yielded their harvest.

Revaluing the functions of cutaway bogs

The value of cutaway bog means different things to different people. Some will think the most profitable way to use it is to plant trees, others to lay it down to grass. In the view of others it is most valuable when used for recreation and amenity, or allowed to run wild in order to recover something of lost biodiversity.

An adequate accounting of the value of peatlands needs to take account of the full range of ecosystem functions they serve. The various ways in which cutaway bog might be made productive in the narrow monetary sense have always been considered the most important and attracted most attention. The potential *carrier function* of cutaway can also easily be quantified in monetary terms: in certain circumstances cutaway bog is able to carry infrastructural development such as dwellings, windfarms or landfills; but whether such developments are acceptable in terms of their overall environmental impact requires careful assessment on a case-by-case basis. Though many cutaway bogs continue to be important for their contribution to the regulation of hydrological and atmospheric balance, many of the important *regulation functions* of peatland are lost when the peat is removed (see Chapters 5 and 10).

In recent years there has been a growing and increasingly articulate awareness of the *information functions* of bog: their capacity to be places of recreation, educational experience and inspiration. The economic quantification of ecological functions is something in urgent need of attention. While information functions and the values we attach to them are different in kind from those that underpin productive and carrier functions, it is important to be able to attach *proxy values* to them – a task at which economists have become increasingly adroit – when decisions are being taken about the best use option for any particular area. This is one of the most important variables to be considered, alongside the more familiar physical, chemical and geomorphological variables, when decisions are being taken on the future direction of particular areas of cutaway.

Productive functions

The need for a government body with representatives from the many groups with an interest in or concern for peatlands in order to design and implement a land use policy or act as a best use option forum for peatlands has long been felt and the need is more critical than ever today. What is essential is that the future patterns of land use be those that best serve the social and economic well-being of the people as a whole, rather than sectional or short-term interests. Bord na Móna is committed to this principle. Gerry McNally, who is its Land Development Manager, has pledged that 'every acre of Bord na Móna cutaway bogland will be utilised in the national interest; there will be no derelict, waste, or unproductive land left – and what is left will blend back environmentally into the landscape'. It may not be so easy however to decide what the national interest in this regard actually is, and there is a real danger of accepting short-sighted answers. Part of that oversight is the assumption that wild landscape is *less productive* in the long term than such options as coniferous forest.

Bord na Móna has considered the after-use of the cutaway from its early days, hand in hand with An Foras Talúntais (now subsumed in Teagasc, the agricultural advisory body). Experimentation on potential after-use options began as soon as the first cutaway became available at Clonsast (See Chapter 2). It soon became apparent that it was unsuitable for commercial arable farming. Of the many possible agricultural uses the only two that were considered to be viable options were grassland and forestry. The critical factor in determining the production possibilities of cutaway is the depth of peat remaining when a bog has been worked out, and the *nature* of this peat. It may be recalled from earlier chapters that because of the way the raised bogs developed in the first place several different kinds of peat can occur at the same ordnance level in the lower strata of the bog: fen peat, woody fen peat, reed peat, sphagnum peat and so on. In 1989 it was estimated that as much as 50% would become coniferous forest, 30-40% grassland and the remainder would be available for wetland and the development of natural landscapes.

To get the best agricultural use from new soils developed on residual peat, good management is essential: careful attention to drainage, taking precautions to prevent soil compaction and to ensure an open soil structure. These new soils are often very low both in macronutrients (potassium, phosphorus, calcium) and micronutrients (cobalt, copper and magnesium: the copper deficiency often induced by high soil molybdenum levels) – so attention to crop nutrition is important. Weed control is more difficult on these soils because the organic material in them tends to inactivate herbicides.

Beef and lamb producing enterprises are doing very well on grassland developed on cutaway at Clonsast, Boora and Derrygreenagh, and there is evidence that good grassland can be established even on impervious sub-peat soils. Although grassland was seen as the most profitable commercial after-use in the early years, the changing agricultural context has made it very much less so at the present time, when so much better land is being taken out of production. Bord na Móna no longer considers it an economically viable option for cutaway bogs.

The industrial cutaway raised bogs found in the midlands were perceived as offering great potential for forestry, and back in the late 1980s, it was assumed that Coillte (the state forestry board) would take up whatever cutaway raised bogs was made available to them for planting. However, the failure rate in the early plantings has been high, and faced with the particular challenges and difficulties of this new medium, Coillte suspended further afforestation of cutaway peatlands until further research was carried out.

Recent research under the recent BOGFOR project of peatland research (funded by Coford, Coillte and Bord na Móna) has shown that conventional forest establishment techniques have limited application on cutaway peatlands, and that no single reclamation measure is appropriate for all areas. This does not mean that trees will not grow successfully on cutaway bog: but cutaway does not present large areas where a single species will grow at a uniform rate and be sufficiently productive in silvicultural terms to be economically profitable. The variation in site conditions encountered in any given cutaway peatland means it is better suited to a mosaic of different species, and even if the result is not economical in the narrow monetary sense, these diverse woodlands have much greater aesthetic and ecological value and may provide the raw materials for a variety of wood-based manufactures. Research from the BOGFOR project has shown that Norway spruce, Scots pine, downy and silver birch and common alder can perform particularly well on specific cutaway site types. Careful site assessment before species selection, and the appropriate mosaic of site preparation and management practices subsequently are therefore essential.

The new cutaway offers a unique opportunity to create new forests in which native trees displaced by the encroaching bog can again become dominant. This possibility of developing an extensive network of new woodlands in the areas particularly suited to them is one of the most exciting longer term possibilities, and one that would enhance the recreational, educational and ecological value of the new landscapes enormously. When considering the nature and value of cutaway afforestation it is also important to keep in mind the certainty that our perspective on woodland in 50 years time may be very different from today: just as our perspective is different from what it was 50 years ago (see below, page xxx).

Study of the feasibility of cultivating other crops that – in theory at least – might substitute for peat in power plants when peat is no longer available, should be a continuing priority, though experience to date with willow and poplar has not been encouraging in this regard. This is especially relevant in view of the current drive to develop renewable energy sources. At the same time it must be remembered that many of the power stations are approaching the end of their normal working life; for this reason an argument for the production of biomass on cutaway cannot be based on a simplistic claim that they will extend the working life of the power station. Another area of investigation where promising developments are currently taking place is the production of wood fuel pellets without chipping, either for household or industrial use.

Early experimental work on the use of cutaway bog for the growing of crops other than grass, spruce and pine was not encouraging. This should not however discourage the search for alternatives, especially with groups of plants that are naturally more at home on peat (such as cranberry and blueberry), and particularly those whose cultivation is compatible with other uses such as wildlife conservation and recreation. (However, an experimental cranberry plantation established at considerable expense in the 1990s by Bord na Móna presented insuperable difficulties to commercial success and was abandoned). David Bellamy has argued enthusiastically for the cultivation of reeds, but that idea has not yet attracted the sort of serious investigation it merits. One important possibility that has not been looked at is the cultivation of varieties of willows suitable for the manufacture of cane furniture. A key disadvantage with ideas such as these is that they are novel, and not obviously viable. Although most of these options may only supply niche markets even when they are successful, there are real possibilities for such novel alternative crops, and perhaps as the economic climate evolves, and with it the social concern with such issues as sustainability, they will be more seriously investigated. The more remote possibilities include the cultivation of sphagnum, the mention of which ten years ago caused raised eyebrows in many a sceptical ecologist – especially in view of climate change – but this is an idea that is now attracting considerable research interest. At the beginning of the Neolithic revolution the same ecological eyebrows would no doubt have been raised even higher at the suggestion that modern cereals might some day be developed from such unpromising wild grass ancestors.

Other concepts that have scarcely been explored at any level in the Irish context include the development of constructed wetlands, which exploit the filtering and purifying capacities of aquatic ecosystems in the treatment of such waste products as town sewage, while at the same time developing naturally diverse habitats. This will require us to apply our ecological intelligence to the field of environmental engineering: but at least we have reached the stage of asking what such artificial wetlands might *look like* in the Irish peatland after-use context, and what would be required in order to apply ecological intelligence in this way.

Ecological functions

The other major option for industrial cutaway is to allow it to colonise naturally, and develop a new mosaic of natural ecosystems that are adapted to the changed conditions (see below), and this is now coming to be seen as the most significant option. In a very forthright address to the 13th International Peat Congress in Tullamore in June 2008, Gerry McNally summed up Bord na Móna's long experience of trying to find commercial uses for cutaway bog with the view that "research effort should now concentrate on enhancing the natural rehabilitation processes which will maximise the sustainability of the diverse ecosystem that will evolve." Some parts of this mosaic could be taken advantage of for purposes of amenity and recreation. The lowest-lying areas in the hollows among the moraines, which were occupied by lakes in the early post-glacial period, will flood naturally – or can be flooded artificially – when Bord na Móna withdraws, giving back to the landscape something of the aspect and atmosphere it had when the first people fished and camped here 8,500 years ago. More than 10,000ha of the Bord na Móna bogs in the Shannon catchment presently require, or will eventually require pumped drainage in order to allow peat extraction. This adds very significantly to costs; but once extraction has ceased in these areas they could add considerably to the area of semi-natural wetland in the Shannon basin. They would also add to the water storage capacity of the floodplain, which may help to alleviate the affects of winter flooding on farmland.

Bord na Móna has been vigorously engaged in the development of strategies to maximise the ecological value of the cutaway landscape in recent years (partly because it is now required by the Environmental Protection Agency to prepare and submit a plan for the after-use of the areas on which it is at work; it currently operates under nine such licences).

Peatland conservation: a retrospect of growing concern

Little more than a century ago, the great boglands which covered 17% of the area of Ireland were regarded by most people as a wet desert, a tragic waste of land which under different circumstances Providence might have endowed with fertile farmland instead of bestowing these 'useless and unsightly excrescences' growing over and covering up three million acres of good land. In time the wasteland came to be viewed differently: as one of the country's most valuable and underdeveloped natural resources, whose commercial exploitation has contributed greatly to Ireland's welfare. There have been economists who thought the bogs were little short of worthless, or, like Boate, blamed their very existence on the 'retchlessness' of the Irish, who might have prevented them from growing in the first place had they been more industrious. But for most they were a valued resource to be utilised as fuel and to provide new land; we have seen earlier how Sir Charles Coote believed the eskers had been bestowed on the Midlands by God in order to make the reclamation of the bogs possible.

Over the centuries, the bog has played a crucial role in the economy of the traditional farm. But the annual cycle of the peat harvest was more than the laborious round of activities necessary to lay up an adequate supply of turf for the winter. The days on the bog were days of hard work, but they were enjoyed, because there was something more here. There was the reassurance, working on the bog, that winter was over at last and another summer at hand. Part of the unique atmosphere was a sensuous awareness of summer, and later the fruitfulness of harvest, and underlying this the excitement of contact with the natural world. Here nature was sensed perhaps more richly than anywhere else, and even if the experience was not articulated as such, the time spent 'on the bog' was much more than an economic exercise: contact with the bog was an aesthetic experience, a cultural ritual which added richness and meaning to the fabric of life. But this was taken so much for granted, was at such a deep level a part of everyday living, that it was never expressed. So much of the natural wonder of the bog was unseen, unheard by those who worked on the bog in the early years, preoccupied as we were with the exhausting exhilaration of harvesting the turf. It only began to come into focus on subsequent visits years later, when the now abandoned spread-ground had taken on the feel of a school playground during the summer holidays … except that here there would never again be a return to life and laughter in a coming September.

People might complain about the sheer physical drudgery of the work – though for those engaged in the daily labour of farming it was no more exhausting than many other farm tasks, but that was at the surface. Like Jimin Mháire Thadhg, who felt that if everybody who worked on the bog *meitheal* was as tired as he after his day's work, *'ní foláir nó táid siad mí-bhuidheach don té cheap móin ar dtúis'* (there's no chance of them being too grateful to whoever it was invented turf in the first place). The deeper meaning of the bog has been articulated by many artists in word and paint, most memorably in the work of Seamus Heaney, who comes from the farmland of County Derry, where the bog is a primary colour in the tapestry of the rural year. Several of his early poems (especially in the collection *North*) show his absorption in the imagery of the bog, and in a particular way with bog bodies, with their dark secrets and potential for metaphor, myth and allegory. The magic of the bog has also been widely articulated in the verse of folk poets.

It is only sixty years or so since a new perspective on the value of bogs began to emerge, focused on the belief that some at least of Ireland's peatlands should not be developed, but preserved as the last wild places: because of their natural diversity, because of the record they contain of how the landscape has changed in the millennia since the Ice Age, and as living museums and libraries of our own human past. Conservation was not part of the outlook of a community living with the bog in its blood. It didn't need to be, because the bog was infinite: it went on forever and it would last forever. The great expansion in bogland development of the mid-twentieth century took place too quickly for this perception to change in parallel with change in the scale and rate of exploitation. Now, as we enter a new millennium, the perception has begun to alter, just in time perhaps if we are to preserve access to the experience of one of the few corners of the natural world that remain to us in Ireland.

This changed perception was inspired by the new perspectives that the birth of ecology and the growth of Quaternary stratigraphy brought about. Botanists in northern Europe were beginning to speak of the magic of the bogs with a new excitement, and stratigraphers were beginning to see that the bog was more than northern Europe's last great, undisturbed wilderness: that in its deep peat, steadily accumulating over all the centuries since people had first settled in Ireland, and for many millennia before, there was an incomparable and almost inexhaustible archive of information about how the landscape had changed and evolved after the Ice Age, and about the successive communities who had played a role in directing that evolution.

At a time when the country was largely preoccupied with structuring the economy for Europe's first post-colonial independent state, and one of its poorest, this new and exciting vision had little influence beyond a few privileged focal points. A milestone in the spread of the new ideas about bogs was the establishment in 1934 of the Committee for Quaternary Research in Ireland, the brainchild of R. Lloyd Praeger and the archaeologist Adolf Mahr. Praeger's great works on the flora of Ireland, *Irish Topographical Botany* (1901) and *The Botanist in Ireland* (1934) were beginning to open up a new era of plant ecology in Ireland, but they were less influential than his more personal and anecdotal masterpiece, *The Way that I Went*, published in 1937, which has probably had a greater influence on Irish naturalists than any other book ever published. The Committee's remit was the investigation of the record of Ireland's fauna and flora as it was preserved in the bogs and other post-glacial organic deposits, and one of its first initiatives was to invite Knud Jessen to Ireland. Jessen was one of the foremost authorities on bog stratigraphy in Europe, with an unparalleled record of research into the palaeobotany and geology of the bogs, late-glacial and post-glacial deposits of his native Denmark. Along with an assistant, Hans Jonassen, he spent the summers of 1934 and 1935 in Ireland, accompanied by a number of young Irish researchers, among them G. F. Mitchell, whose subsequent research and writings were one of the most powerful influences in spreading an awareness and understanding of the heritage of Ireland's landscape. Another important event in that magic summer of 1935, unforgettably recorded by Praeger, was the meeting of this group with Hugo Osvald, the great Swedish bog scientist who loved and understood the nature and importance of bogs perhaps more than anyone else living at the time, together with A. G. Tansley, Harry Godwin and Margaret Dunlop. Praeger's description of their visit to Roundstone bog deserves (yet again!) to be quoted at some length:

> We stood in a ring in that shelterless expanse while discussion raged on the application of the terms soligenous, topogenous and ombrogenous; the rain and wind, like the discussion, waxed in intensity, and under the unusual superincumbent weight, whether of mere flesh and bone or of intellect, the floating surface of the bog slowly sank till we were all half-way up to our knees in brown water. The only pause in the flow of argument was when Jessen or

> Osvald, in an endeavour to solve the question of the origin of the peat, would chew some of the mud brought up by the boring tool from the bottom of the bog, to test the presence or absence of gritty material in the vegetable mass. But out of such occasions does knowledge come, and I think that that aqueous discussion has borne and will bear fruit. For the bogs and what they can teach us of the past history of our country are yet to a great extent a sealed book, though they will not remain so much longer.

But 1935 was also the year in which the Turf Development Board was set up, likewise with much continental inspiration. In 1949 Jessen's inspirational masterpiece on Irish bog stratigraphy was published with the assistance of Bord na Móna, which had been established three years before.

An indication of how quickly the new way of thinking about bogs evolved is the total absence of any mention of conservation or ecology in the important review paper on bog development in Ireland by Walsh, O'Hare and Quinn published in 1958 in *Advancement of Science.* Indeed, this review warns us that the reclamation of cutaway bog should take place immediately after harvesting has ceased 'so that reversion to a scrub-like condition can be avoided', whereas 'particular stress is being laid on the rehabilitation of old cut-away, a category of land which, if it could be brought into production on an economic basis, would mean much in terms of increased productivity and more efficient farming'. However, a more conservation-conscious attitude to bogs was apparent in some areas. At the First International Peat Congress in 1954 Pierce Purcell – for so long at the forefront in peatland resource exploitation – called for a halt to the wasteful use of peat for low efficiency firing; more of it should be used for soil improvement, and some bogs should be conserved as nature reserves.

The new awareness that the bogs represent something more than a source of fuel and soil conditioner, coupled with the growth of environmental consciousness everywhere at the time, flowered in the Universities during the 60s and 70s, greatly influenced by the writings of Praeger, and providing the impetus for a movement among the new generation of young naturalists to conserve what remained of Ireland's bogs before it was too late. Two key figures in the development of this new consciousness of the importance of bogs were J. J. Moore of UCD and Tom Barry in Bord na Móna. Father Moore pioneered the study of peatland phytosociology in Ireland; his students over the years – led by Gerry Doyle – have been to the forefront in the study of peatland ecology and in conservation. Tom Barry brought a new environmental awareness to Bord na Móna, beginning with his paper on bog conservation presented to the Fifth International Peat Congress in 1975. Another key figure in awakening awareness of the importance of Ireland's bogs was David Bellamy, who fell deeply in love with them in the late 1950s, and has campaigned passionately for their conservation ever since.

One of the weaknesses in the case being made for the preservation of Irish bogs in its early days was that it was spearheaded by scientists and naturalists, conveying the impression that the only people who *really* understand the importance of bogs were botanists and palynologists. On the opposite side are those who appreciate peat as a natural resource, and who (equally on their own terms) claim to be the people who really *do* understand the importance of bogs. The war between development and conservation was waged with increasing intensity as the largest of the raised bogs disappeared. If developers have been narrow-minded during this half-century in their grasp of values beyond the purely commercial in Ireland's boglands, many conservationists have been correspondingly short-sighted, failing to appreciate whole spectrum of the ecosystem functions of peatland, and failing to articulate a policy that was adequately grounded in reality.

Those who valued the bogs in other ways and on different terms – the silent turf-cutting majority whose lives the bog had enriched for centuries – did not really figure in this battle between the Goliath of development and the David of conservation. But at much the same time as the scientific studies upon which the conservationists would build their case

Final year botany class at UCD in the late 1960s, with lecturers and demonstrators. Fr J. J. Moore S.J. is on the left of the picture, Gerry Doyle in the centre. Also included are Hubert Fuller (back left), Jim White (back right) and Professor Phyllis Clinch (front right).

Born in Mayo in 1927, Fr Moore was the key figure behind the development of the modern peatland conservation movement in Ireland. Fr Moore described himself as 'a simple University teacher who has tried since 1960 [when he began to lecture in UCD] to convey to my students an appreciation of the beauty of the Irish landscape as well as a scientific understanding of the ecological inter-relationships responsible for its existence … I tried to pass on what I myself had received, first, as a young student, from Dr Helen O'Reilly who had studied with Lüdi at Zürich, and later from Reinhold Tüxen whose deep insight and feeling for all the elements making up the landscape – its soils, its vegetation cover, its people and their local cultures, was so inspiring'. During the 1960s the students listened politely, but in 1970 Fr Moore began to experience a different reaction: the desire to take concrete action to ensure the conservation of the bogs of Ireland. This culminated in 1982 with the setting up of the National Peatland Conservation Committee, made up mainly of dedicated students, with himself (in his own words!) as an 'éminence grise' among them. In the same year Fr Moore was awarded the Europa-Preis Für Landespflege (the European Prize for the Protection of Nature and the Development of Landscape) 'to honour his achievement for environmental education and for the conservation of nature and landscape in his country'. He donated the money which came with the prize to start a fund for the conservation of Irish bogs.

> *'When I wandered over the raised bogs of the midlands as a student in the 1950s, I enjoyed an experience which it is impossible to have anymore – the experience of being isolated in a vast brown ocean of bog, extending to the horizon on all sides, where the only landmarks were church steeples. One always needed to carry a compass in these vast areas. This experience can no longer be enjoyed since all these larger bogs of up to 10 km diameter have now been cut. At present we have no undrained raised bog left which is more than 300 ha in extent'.* (J. J. Moore's address on receipt of the Europa-Preis Für Landespflege).

were being carried out, the ethnology of that vernacular cultural perspective was being recorded and gathered and stored away, as was its material expression, to an extent. But it was being done quite separately. Had the natural and cultural studies been brought together and allowed to influence each other in the way they did in Scandinavia, a new spirit might have been breathed into the whole approach, and we might have harvested the bogs without losing the wilderness. We need to pay a lot more attention to the philosophical, social and educational context the science of bogs is, or should be, serving.

The National Peatland Conservation Committee (NPCC) grew out of this growing awareness among the academic community and in conservation circles of the rate of disapperance of intact peatlands and the ecological loss this represented. The Committee was established in 1981 and published its first catalogue of outstanding Irish peatlands in 1982, updating the Foras Forbartha catalogue of the previous year. This catalogue was further updated in 1986 when the NPCC became a formally constituted limited company with charitable status, changing its name to the Irish Peatland Conservation Council (IPCC). The council is a voluntary body whose aim is the preservation of a representative sample of undisturbed peatlands; it works towards this aim through educational activities and publicity, the lobbying of political and other relevant interests, site monitoring and active conservation. Its influence is boosted through the support of such bodies as the Worldwide Fund for Nature, the Dutch Foundation for the Conservation of Irish Bogs and the International Mire Conservation Group (IMCG); the IMCG (established in 1984) is an international umbrella group for a number of national peatland conservation organisations such as the IPCC. From the early 1980s Mathijs Schouten, who was the first to bring the Dutch experience and perspective to bear on the Irish situation, has been an influential advocate of bog conservation. In 1996 the Council published its Fifth Conservation Plan, outlining its objectives to the end of the century. One of the key objectives of the plan was securing Special Areas for Conservation (SAC) status for as many peatlands as possible, so that they would be incorporated in the EU Natura 2000 Network, resulting in substantial EU assistance with the purchase of these sites. The main aim of the IPCC in the early days was the preservation of as many intact bogs as possible from the ravages of the machines, but its recent plans show a considerable widening of scope, with a much greater focus on disturbed sites. The campaign for the conservation of peatlands of special ecological value has been highly successful over the last few decades, increasing from a few thousand hectares in the early 1980s to some 20,000 hectares today.

The conventional scenario for bogland conservation for long assumed the continuation of environmental conditions under which the living bog of today is in equilibrium. Should the conditions change, the fauna and flora would also change to establish a new equilibrium, and as we have seen in earlier pages this has often happened before. In Ireland we are close to the maximum mean annual temperature at which bog formation can occur (11ºC). In earlier periods of warmer climate, the higher temperatures may have slowed down or even stopped peat growth altogether. While it is difficult to predict the detailed effects of future climate change resulting from global warming with any degree of certainty, many scientists anticipate that doubling of carbon dioxide levels will result in a mean annual temperature rise for the European coastal region of perhaps 3°C and a concomitant rise in evapotranspiration of c. 250mm/yr without a compensating increase in summer rainfall. Winters may be wetter and windier, and summers warmer and wetter.

These changes will have profound implications for peatlands. Under the new conditions of the late 21st century the system-linked discharge of raised bogs might find it difficult to function, and the natural topographical differentiation of the bog surface into the hummock-hollow-lawn complex is certain to be severely disrupted. The fall in summer groundwater level would increase moisture stress, especially in the hummocks, resulting in an increase in hummock disintegration. These changes would affect all other members of the flora and fauna. In summary, the 'natural' raised bogs of the future will be different from those of the present. The surface will be drier, and the vegetation more dominated perhaps by heather and encouraging a new invasion by pine.

The conservation of uncut peatlands has been the priority of government and voluntary conservation groups, and continues to be the prime objective. But in land use terms the area concerned represents a tiny percentage of the area originally covered by bog. In no sense can these preserved bogs take the place of the lost peat wilderness, especially as they become increasingly isolated from each other, and come under increasingly stringent management to maintain their character in the face of climate change and other human impacts. The cutaway on the other hand has the potential to become the new midland wilderness if the ecological opportunities it presents are taken full advantage of. Industrial cutaway bogs may not comprise priority habitat under the conservation criteria conventionally used, but they are more important from another perspective. They cover a very extensive, diffuse, largely interconnected area. Only they can provide the experience of nature in the midland landscape of a future time when the reserves will be museums, and largely off-limits. And they include on their fringes nuclei of ecological vitality which are growing in biodiversity while many reserves are under strain as a consequence of ecological isolation and the pressures resulting from climate change.

Under these circumstances it is all the more important that we should not confine our conservation efforts to the preservation of the isolated wet bogs that survive, but should pay more attention to those modified peatlands and adjacent seminatural ecosystems that are evolving through their own ecological dynamism, and which under drier climatic conditions may be the future reservoirs of ecological diversity in those parts of Ireland where bog now plays an important role in the landscape. In recent years, as awareness of its ecological potential has grown, much of the effort of the IPCC, as well as the after-use concern of Bord na Móna, have been devoted to maintaining and enhancing the ecological value of cutaway. The increased importance of these areas in a drier world makes it all the more important that they be identified and mapped today. The challenge is the creation of a new landscape, developed in those ways from which the community as a whole will most benefit in the long term: dominated indeed by land reclaimed for farming and forestry, but interwoven with a tapestry of other areas where a mosaic of wild secondary bogland habitats has been allowed to remain and evolve and continue to change.

The conservation movement developed too late to stem or deflect the impetus of Bord na Móna, whose enterprise was the culmination of a century and a half of evolution. This enterprise was the long-awaited achievement of an objective that had always been seen as essential to the well-being of the country and more particularly of the communities who lived among the bogs. The growth of the conservation movement had taken place outside of that context, predominantly among a highly-educated group of people whose way of living did not involve them directly in a choice between their personal economic welfare and 'environmental' considerations, and there was little attempt in the beginning to share the vision and philosophy of conservation with those who were most directly involved in the process of change. Not all of those who came to represent the conservation perspective had the wisdom or experience of Osvald or Jessen, whose deep appreciation of bogland heritage was framed in the context of an awareness of the economic and social dimensions ranged on one side, and the natural and cultural heritage values on the other, in the conflict between conservation and development.

We need to arrive at a point where the debate about the bogs is not a debate between two opposed sides, but one that takes place in the mind and heart of each concerned individual in the community. This underlines the need for increased environmental sensitivity among people in general, but what we often forget is that just as surely as *they* may need to attend lectures and courses on natural and cultural heritage, *we* need to attend courses and lectures on the realities of living on the land without heartbreak, and surviving the sharp winds that blow through the modern agricultural economy. The elaboration by Donal Clarke and Hans Joosten of the Wise Use approach in recent years has gone a long way towards forging a *rapprochement* between the two sides.

We should return briefly to a consideration of the basic questions. Why should we bother to conserve bogs at all? What areas should we be preserving? Who are we to conserve them for? There are scientific reasons first of all. All of the plants and animals that grow on the bogs of Ireland occur elsewhere, but the Irish populations are genetically different, subtly adapted after all these thousands of years to Irish conditions. They are therefore a small but significant part of the total pool of genetic resources of Europe as a whole. Bogs are hydrologically important, although we do not really understand how they affect the regional hydrology – or more specifically, how their removal will affect it. They constitute a continuing record of climate and environment. They are the main reserve for ecological diversity in many landscapes. They are important as a carbon sink.

But even in the minds of those who argue for bogland conservation most ardently, other reasons may run deeper. One of the most important reasons is the fact that bogs are just wonderful places, the last Irish wilderness. This experience is not confined to bogs that have special conservation status: it is to be found in all bogs that are still in a semi-natural condition. At a fundamental level there is the simple reason that bogs are a unique part of Ireland's landscape; in a way they are part of ourselves. In a very true sense, we are in the process of selling our birthright for urgent economic reasons, just as in an earlier time our ancestors sold the birthright of the ancient forests, so that today it is no longer possible to walk through the wildwood, experiencing the natural world as it was in an earlier time. In exchange for the forests our ancestors got a new landscape: the landscape of traditional farming, which was in its different way as valuable as that which was exchanged – not an adequate exchange in terms of ecological diversity perhaps, but a rich, beautiful, exciting and culturally stimulating landscape, a wonderful place to live and work in.

What bogs to conserve

Since the publication in 1981 of the first national report on Peatland Sites of Scientific Interest in Ireland by an Foras Forbartha at the request of the Wildlife Advisory Council, attention has focused on the preservation of the small number of larger bogs which are considered to be relatively intact and undisturbed, and which constitute some sort of representative cross-section of the range of Ireland's peatlands. The original official government conservation target has been 40,000ha for blanket bogs and 10,000ha for raised bogs (out of a total original peatland area of around 1,177,670ha). So far a total of 18,424ha of raised bog and 184,000 of blanket bog, together with 20,000ha of fen, are classified as Special Areas of Conservation (SACs) or Natural Heritage Areas (NHAs). This total of approximately 220,000ha is however less than 20% of the original peatland area. Turf-cutting has been continuing along the edges of many of these bogs, which also impacts on hydrological and carbon exchange functioning within the main body of the bog, but this should cease after 2008.

The county surveys of An Foras Forbartha (1968-74) were the first attempt to identify the surviving bogs of key conservation status. This has been built upon and amended over the ensuing quarter of a century by the Wildlife Service and the IPCC in the light of more detailed knowledge on the one hand and the continuing deterioration or disappearance of these bogs as the years went by on the other. The Wildlife Service began its systematic bog surveys in 1980, and published its first report in 1984. One indication of the rate of destruction of ecologically outstanding bogs at this time is the fact that all except one of the 25 raised bogs listed as being of international scientific importance in the Foras Forbartha report of 1981 had been damaged in the intervening years. In September 1990 Bord na Móna published its Policy Statement on Conservation, undertaking to transfer all twenty bogs of high scientific interest in its ownership (totalling some 2,500ha) to the Wildlife Service, thereby ensuring that the intact bogs of high conservation status in its control will be preserved. But Bord na Móna only owns a percentage of the total peatland area of high conservation value: most of the rest is in private hands.

Bogland conservation policy was in the early years directed towards the preservation of a representative sample of relatively intact bogs of different kinds for future generations to enjoy. Because they were so very few, and because of their natural and historical integrity, these bogs rightly claimed prior attention. But this scattering of bogs of international or national importance is only a tiny fraction of what needs to be preserved. For the communities who live around them, the smaller bogs that are scattered throughout the country are as important as bogs of higher conservation status: only the *measure* of their importance is different. And with the increase in the number of small turf-cutting machines operated by private developers, the majority of the intact small bogs that might have seemed safe for posterity twenty years ago, are safe no longer. Taken collectively the smaller bogs comprise an extensive network, constituting the most important mosaic of semi-natural landscape in the lowlands. Its maintenance is vital if the new bogland landscape that is now beginning to take shape is to develop the natural richness it can and should have. The most immediate problem is that there is very little information available on the ecology, extent and distribution of such special places. They are small and scattered, they have not caught the attention of the botanical surveyors who have seldom looked on landscapes with the broader perspective and more local focus that are required. These peatlands need – urgently – to be mapped by systematic survey at local level, which can be done quickly with the assistance of satellite imagery, aerial photography and local knowledge. Then at least we will know what we have and can take the necessary steps to build its ecological potential into planning guidelines. We need a broader and richer perspective, and a series of different scales against which to measure diversity.

The conservation of bogland heritage also needs to be supported by a much more active community awareness of the importance of the issue. The gallant pioneering efforts of An Taisce and the IPCC are only a first spark here: they need to kindle a responding flame in more community-based groups – at school and on the farm, in towns, everywhere. A possible solution advocated in the earlier version of this chapter was the appointment in each County Council of a Natural Heritage Conservation Officer, whose core task would be to draw up a County Plan for natural heritage. Such a plan would look at nature from the perspective of the local community, albeit within the context of national objectives and international obligations, and would present a cost-effective and realistic agenda for its implementation with maximum long-term community involvement. This is not far removed from the thrust of Harry Godwin's comments on conservation of the East Anglian fens:

> Successful and esteemed as the Nature Conservancy and its successor, the Nature Conservancy Council, have been, it would be mistaken to suppose that they could be responsible for more than a carefully chosen group of reserves of the highest national priority. There remain great numbers of sites throughout the country, generally of smaller size and of more immediately local and specialised interest (though often of high scientific and educational value) that are more appropriately cared for by local organisations, who are better placed to see the need, to anticipate the threat and secure continuous and watchful oversight of them.

Most Councils do now have Heritage Officers, but their responsibilities cover the entire spectrum of natural and cultural heritage. In accordance with their obligations under the UN Biodiversity Convention local authorities are obliged to draw up and implement local area Biodiversity Action Plans; these present an opportunity to focus anew, and at an appropriately local scale, on the biodiversity potential of peatlands.

The identification of areas of ecological importance is only the first step. It needs to be followed up by a campaign of information aimed at schools, farms, industry, the community in general. This would also provide a specific local geographical focus to a bogland educational programme: e.g. a map of local bog-edge birchwoods shows where best to see mycorrhizal fungi in action, a map of local purple moor-grass fen brings life and immediacy to a discussion of the ecological adaptations of the plant or of our brief 18th century fling with its agricultural prospects.

Peatland areas of ecological importance are either private or corporate property, or in commonage. In the case of privately-owned bog, self-interest, directed towards the maximum individual well-being, will prevail. The more closely the maintenance of the maximum of ecological diversity can be made to coincide with this, the better the chance that nature will survive. The financial incentives for the conservation of areas of ecological importance on farms offered by the Rural Environment Protection Scheme (REPS) and other EU countryside management programmes are potentially of great importance in this regard, and offer a golden opportunity for farmer involvement in the conservation and rehabilitation of peatlands. The main peatland focus in REPS has been on halting the destruction of blanket bog brought about by overstocking. The potential of the scheme would be much enhanced by building into it a specific measure dealing with peatland conservation and ecological rehabilitation, with separate guidelines for areas of raised and blanket bogs.

The initiative taken by St Brendan's Community School in Birr, with the enthusiastic co-operation of Bord na Móna, is one example of what can be done where there is sufficient community interest and support. Here an area of cutover of much ecological interest, together with a section of adjacent uncut bog, has been handed over by Bord na Móna to the local community for conservation. The reserve (Killaun Bog Reserve) is managed on behalf of the local people by the school, which provides access and guidance, and is co-ordinating an ongoing programme of study.

From the viewpoint of the local community, conservation areas of local importance are more important than areas of international importance. For historical reasons we did not in Ireland develop the network of genuinely community-based local conservation and natural history groups that grew up in Britain. But there has never been a better time to start than now, though time is running out. Surely we don't have to make the mistakes that others have made? Surely we are not entirely focused on a selfish, narrow-minded, short-sighted present? And surely we can formulate our own imaginative priorities at community level, and implement them? As a new millennium opens, the bogs are undergoing their greatest transformation. The vast brown expanses are disappearing as the green wildernesses of the primeval forests disappeared, but very much faster, so fast that we are in danger of making short-sighted decisions that time may show to have been wrong.

The increase in the number of small harvesting machines, and the growing annual output mean that not only does the exploitation of active turbary continue to expand, but also that older, abandoned turbary areas are being re-developed. The increase of turf cutting on bogs of ecological importance has been of particular concern, especially those without statutory protection. The continuation of development without consideration of the extent to which we are diminishing our endowment to the future needs to be halted. Urgent consideration should be given to putting in place a legal requirement that *all* peatland development should be preceded by an environmental impact assessment and the submission and approval of a specific and professional plan for rehabilitation. This should not be seen as a plan to prevent exploitation of the resource, but as an attempt to introduce a serious and intelligent concern for the ecological diversity of the future landscape. At the very least, environmental impact legislation should have the potential to ensure that further peatland exploitation does not further encroach on areas of high conservation value. However, with a threshold for afforestation of 50ha and of 50ha for the extension of peat extraction schemes, the meshes of the EIA net are so large that most developments can slip through.

Restoring damaged bogs

Peat-forming conditions often develop locally in cutaway and especially cutover situations: at community level that is, but not at ecosystem level, although abandoned turbary can sometimes come close. Over the last two decades there have however been numerous attempts to restore or enhance peat-forming conditions on damaged bogs that are in or close to SACs or NHAs.

Several new research initiatives in peatland restoration have got under way in recent years. The Irish Raised Bog Restoration Project has carried out highly-detailed studies at Clara and Raheenmore bogs, and used these as the basis on which to develop a methodology for their rehabilitation, which is now being implemented. The IPCC has followed the same approach in its restoration of Lodge Bog in County Kildare. With financial assistance provided under the LIFE-Nature programme, Coillte has undertaken several ambitious restoration projects on bogs planted with conifers in the 1980s. Twenty of these (a total area of over 1200 ha) are in or adjacent to areas of blanket bog of high conservation status, and a further fourteen in raised bogs (totalling over 570ha). The main methods used are the removal of conifers and blocking of drains, as well as enclosure to prevent grazing or poaching.

The growth of new bogs

It is widely supposed that once the bogs have been cut away for fuel and peat moss, that will be the end of their ecological value. The astonishing enrichment that has taken place in such a short time at places like Turraun, Killaun and Boora shows that this need not be so: but most of the ecosystems that replace the harvested bogs, although rich and diverse in their various ways, will not be peatlands. However, observations of ecological development in areas of abandoned turbary show that bog regeneration as well as broader ecological rehabilitation are possible. In most parts of the cutover, when conditions have become drier or more nutrient-rich, heather or birch or fen grassland may become established, but where hydrological conditions are suitable, and most noticeably in old bogholes and drains, sphagnum begins to regenerate. The initial opportunist species that spearheads this re-advance by the sphagnum mosses is *Sphagnum cuspidatum,* but once the open water has been colonised other species take over to carry the invasion out of the water: species such as *Sphagnum fuscum, Sphagnum magellanicum* and *Sphagnum subnitens.* The success of sphagnum in establishing itself on cutover bog suggests that it should also be possible on the larger areas of cutaway where hydrological conditions are suitable. With large-scale industrial harvesting, sphagnum regeneration is most favoured in cutaway bogs harvested for sod peat and in peat moss bogs from which the upper sphagnum has been removed, leaving a considerable depth of fuel peat. Under the direction of Catherine Farrell Bord na Móna has restored much of the large tract of bogland that supplied peat to the power station at Bellacorick. Conditions for spontaneous sphagnum regeneration occur less naturally on cutaway milled peat bogs.

Several things are essential to facilitate the restoration of raised bog conditions. At least a metre and a half of fen peat must be left behind, and the flow of arterial water out of the system must be staunched by the blocking up of drains, but without preventing the surface run-off and system-linked discharge that maintain the oligotrophic status of the ecosystem. Where necessary, baulks of black peat may be erected to retain water. A further requirement is the provision of a seed bank; under natural conditions this would be provided by the adjacent intact bog. These requirements underline the importance of planning for regeneration from an early stage. In countries with a heightened consciousness of the ecological and landscape values of peatlands, the re-establishment of bog vegetation on cutover is seen as a priority. In Germany the granting of licences to extract peat is often conditional on the submission of a plan for restoration, and the law requires that the top metre must be restored on the cutaway and cannot be used for fuel. Much experience on peatland regeneration and ecological rehabilitation has been gained in Canada, the United States, Holland, Great Britain, Germany, Scandinavia Switzerland and elsewhere, and manuals that outline the practical principles of ecological engineering that underlie the restoration of bogs are now appearing in a number of countries.

The realistic prospect of peatland regrowth significantly expands the possible scenarios for the future of the cutaway in Ireland. It means that bogs can still be part of the future landscape in an extensive way, marked with 'nature's signature' as truly as anything that has gone before, and that we can continue to sustain many of the values they represent. They will not be the same bogs, but they will be living, ecologically vital and rich, growing alongside the remains of the ancient, mature bogs that will be struggling against climatic change like ancient oaks against the centuries beyond their maturity: revered and cared for but no longer compelled to bear the hope of the future alone.

Whether to utilise our peatlands, to leave them alone or to conserve and restore them or even attempt to grow new peatlands is a choice that calls for wisdom. Any decision should be made with the principle of sustainability in mind. This is currently being explored within the BOGLAND project (funded by the Environmental Protection Agency) which aim to develop a protocol for the future management of peatlands in Ireland. In effect, it will deliver to the government a list of appropriate measures to be put in place to promote the sustainable development of the remaining peatland resource, to ensure that adequate areas are high ecological values are identified and conserved and that cutaway peatlands are used in the best interests of society as a whole.

The changing bog

Of all the themes that run through these pages, one of the most persistent has been the notion that the bogs are never still. They evolve and change, and their development has always been intimately influenced by human action. Bogs are a stage in the development of landscape, a response to topography, changing climate and other natural influences. The human community is also part of the bog, and the direction the bog has taken at different periods in history and prehistory has been to a considerable extent determined by cultural influences. The first people arrived here before the bog, and lived alongside it as it grew and changed. Human activity had much to do with the growth and spread of the bogs in the first place, just as it is now responsible for their retreat.

For millennia the boundaries of the bogs that had overwhelmed the early farmlands of the Neolithic and Bronze Ages had to be respected; the borders between the brown lands of the bog and the green kingdoms of farm and forest were more or less static – the greater conflict was between the different shades of green of farm and forest. But even so, the brown wilderness was still part of the human world. Even as the bog continued to grow, trackways were being laid across it to carry the traffic of the human world, and its resources were being used for many purposes. The boundaries of the bog only began to retreat significantly after the 17th century, and we have traced its subsequent retreat in earlier chapters.

Change has often brought about an enrichment of the natural world. The blanket bogs for whose spread the activities of the early farmers acted as the catalyst brought a new and ecologically richer landscape into being. The wonderful flora of the Burren was able to spread over an area much wider than that designed for it by Nature because of the stripping from it of the agricultural wealth of soils by the activities of other early farmers, unaware of the consequences of taking away the protective cover of trees and other woodland vegetation from soils that were more vulnerable in the new climate developing at the time. This was wetter and harsher than the climate under which the soils had acquired their protective vegetation at an earlier period. So too, erosion of the bog's edges by countless thousands of slanes over the centuries brought about the virtual elimination of marginal lagg, the fringing areas of fen that once surrounded most raised bogs. But it also brought a new wilderness into being: the cutover with all its variety, which can often be richer than the bog it replaces.

This enrichment was an accidental spin-off of economic exploitation, nature's response to new opportunities. René Dubos elegantly summarised this *potentiality of damaged ecosystems:*

> Ecosystems possess several mechanisms for self-healing. Some of these are analogous to the homeostatic mechanisms of animal life; they enable ecosystems to overcome the effects of outside disturbances simply by

> reestablishing progressively the original state of ecological equilibrium. More frequently, however, ecosystems undergo adaptive changes of a creative nature that transcend the mere correction of damage; the ultimate result is then the activation of certain potentialities of the ecosystem that had not been expressed before the disturbance … We can improve on nature to the extent that we can identify these unexpressed potentialities and can make them come to life by modifying environments, thus increasing the diversity of the Earth and making it a more desirable place for human life.

The recognition of the categories of land use that are characterised by this quality of *ecological vitality,* and the identification of those tracts of land where they occur, and which offer the richest prospects for an increase in biodiversity, needs to be an important ecological priority, especially in the context of changing land use policies and patterns in the EU. Areas of turbary and old cutover are among the most important such areas. In the context of the reshaping of the entire landscape of the Midlands that will be the most dramatic land use change we will see in the first century of the new millennium, it is enormously important to appreciate the capacity of peatland for *regeneration,* and the ecological vitality of cutover bogs. As networked islands of ecological diversity, old turbaries are generally the most important areas in the Midlands. They comprise a complex mosaic of habitats: including large areas of birchwood, along with species-rich fen and various semi-natural grasslands, abandoned facebanks, extensive areas of luxuriant heather and a variety of other habitat types. The floristic poverty of the birchwoods has denied them the close interest of botanists, but this is a narrow perspective. Their mycological interest for instance – as earlier pages have shown – is great. The new fens are often a floristic paradise, their splendour most obviously reflected perhaps in the variety of their orchids and insects. The range of aquatic life is very great. Many areas that have regenerated naturally in a short time span would merit designation as NHAs if the criteria for selection were guided more by concern for biodiversity, landscape diversity and diversity of human experience.

A Landscape Dimly Seen: The Bogs In 2050

We find it difficult for all sorts of reasons to see more than a few years into the future. Think back to the Ireland of the 1950s – could we ever have imagined what the world of 2008 would be like! Global warming and the biodiversity crisis did not exist for us in 1946 (when Bord na Móna was set up) nor was there any awareness of the population explosion or the global water crisis and the challenge of feeding 10 billion in a water-challenged world. All of our attention was on the task of coaxing into flame the glowing embers of an economy that had very few natural resources at its disposal. The great hope was that the large-scale industrial strip mining of the raised bogs, the one resource that we had an abundance of – an unlimited abundance as it must have seemed in the beginning – might be the beginning of a more prosperous age. And indeed it did transform life in the Midlands by that significant increment through the late 1940s and 1950s: to the threshold of, and on into, the new era of EU prosperity, when the material well-being we now enjoy was as yet no more than a gleam in the eye of the cub that would grow up to become the Celtic Tiger.

In 1945 Todd Andrews visited Turraun: and in his autobiography he tells us that first visit was 'a kind of epiphany to me. I saw there *in parvo* what Bord na Móna was to become in time. The works were only accessible to a car driving along the towpath of the canal, and that was a perilous journey. In the nearby village of Pullough there was evident poverty and squalour on a scale much worse than I had ever seen, even in the Dublin slums of my youth. Pullough was so isolated as to be virtually an island isolated from the outside world.' The peat harvest changed all that.

Back in 1950 we gave little thought to how the bogs might be in 50-60 years time – any more than we give much thought now to how they will be 50-60 years hence, or what contribution they might make to our economy. The thinking was that in due course, when the harvest of the bogs was exhausted, an area of good Irish land the size of a new county would be at our disposal for conversion to agricultural land and for afforestation, with an undrainable residue for recreational and amenity use. We now know this optimistic scenario to have been inadequately informed about the physical and chemical nature of cutaway bog, and about how *the way we value land* would itself change over time. We have lost interest in converting cutaway bog into grassland for economic reasons, and find the commercial afforestation of cutaway on a large scale continues to be problematical. Although – true to their mission of making Bord na Móna a company that continues to be economically profitable – many within the Bord continue to seek alternatives that will turn a profit in the conventional sense, the most informed and grounded authorities both within and outside of Bord na Móna now accept that *the best we can do* with much of the cutaway is to allow and encourage the development of the mosaic of species-diverse ecosystems that will develop spontaneously. The point here is that this *is* the best thing we can do: not the second best, not the only thing we can do since other, more profitable options no longer appear viable. Sixty years ago we could not have foreseen that we would come to *value the other functions* of peatland in a way that might in certain circumstances outweigh what in conventional economics would be considered the more productive functions.

That is another thing that has changed since the early days of Bord na Móna: we understand and appreciate much better than we did 50 years ago the many ecosystem functions other than the productive function (in the narrow economic sense) that different dimensions and facets of natural ecosystems – including peatlands – perform in our lives. In the economy of the Midlands in the decades following the establishment of Bord na Móna the bogs were of greatest value to us as a source of the raw material from which we could make turf or briquettes, or burn to make electricity. We had little time or leisure to consider the recreational, aesthetic, ecological, cultural or spiritual functions they served.

Our children will still be here in 50 years, when there is no more turf and oil will be too precious to burn, long after the machines have started to rust, and the slane has joined the spade in agricultural museums. And although we cannot *see* into the future, and our capacity to *imagine* futures is limited by the conditioning of our psychological heritage, we can discern the challenge that reaches back to us from that future half a century and further hence, when the inevitable trends we can read today in human population growth and world farming will have *compelled* us into a new self-sufficiency we might have adopted with less pain if we humans had greater capacity and determination to use our knowledge and insight to plan for a time fifty years down the line. By this time land that we have taken out of production or allowed to decline in productive capacity will need to be reclaimed for a new kind of agriculture: in which new insights of ecology and genetics, and new technologies to facilitate sustainable land management, will be spliced with the techniques of maintaining inherent productivity learned during the several hundred years before they were consigned to a top shelf by the oil-dependent input-intensive model that has dominated the last short 50 years. Another factor with consequences we have scarcely begun to analyse as yet is the likelihood that by 2050 the population of the island of Ireland is likely to be somewhere in the region of eight million: what it was before the Great Famine of the 1840s.

The long-term prospect for farming is intimately bound up with the long-term prospect for forestry and the bog in general. Fifty years hence we may have come to depend upon timber for household fuel from the woods now taking hold on much marginal farmland. The forest management skills with which the new woodland resource is managed and the energy efficiency measures of everyday life will have come of age in 50 years: and in parallel with those developments we will see a continuing shift in the balance of the values we set on bogland.

In the changed circumstances of 40 years time it might appear that the afforestation of substantial areas of cutaway would acquire a new urgency. But even if we assume that continued research can overcome the silvicultural challenges that have hitherto balked economic forestry on cutaway bog, we also need to remember that in the warmer world of 2050, with biodiversity reduced and confined as never before – and by which time we will appreciate as never before the full spectrum of functions it serves in human life – cutaway will have come to be treasured as the last place on our doorstep to which we can retreat from an increasingly frenetic world in order to experience contact with nature. By this time there will be concern over the ecological change consequent on global warming in those bogs on which we have conferred a conservation status equivalent to 'hotspots.' The most recent analysis warns us of the possibility that unharvested peatlands may even be eliminated by climatic change predicted for the rest of this century. While we still await even a preliminary attempt at the economic quantification of ecosystem functions and services in relation to the cutaway of 2050, it is very clear from comparable studies that their total value to society, to the community, greatly outstrips the purely monetary return to be made by concentrating on any short-term profit. *There is greater value to society in facilitating its capacity to fulfil the other ecosystem functions it performs*, functions that productive land can less richly perform.

We need to concern ourselves *now* with this perspective if we are to ensure we don't do something else on our watch as the earth's custodians that our grandchildren will have cause to blame us for. History demonstrates our limited success in using our intelligence to foresee and shape our own future. As we try to peer prophetically through the misty curtain of time that stretches 50 or 100 years ahead of us into the future, we need to remind ourselves how poorly we saw that far ahead – to the present time – 60 years ago. When the great German philosopher Hegel cast his brilliant, encyclopaedic mind over the course of human history in the early 19th century, one of the things that struck him above all was that (as he wrote in the introduction to his magisterial *Philosophy of History*) 'What experience and history teach is this – that people and government never have learned anything from history, or acted upon principles deduced from it.' But at the same time our *capacity* to see ahead has never been greater, so we should be able to penetrate that temporal mist to some extent: as we need to do if we are to take the right actions now in order to ensure that we do not compromise the contribution of the bogs of the future to our grandchildren.

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APPENDIX: SCIENTIFIC NAMES OF VASCULAR PLANTS NAMED IN TEXT[1]

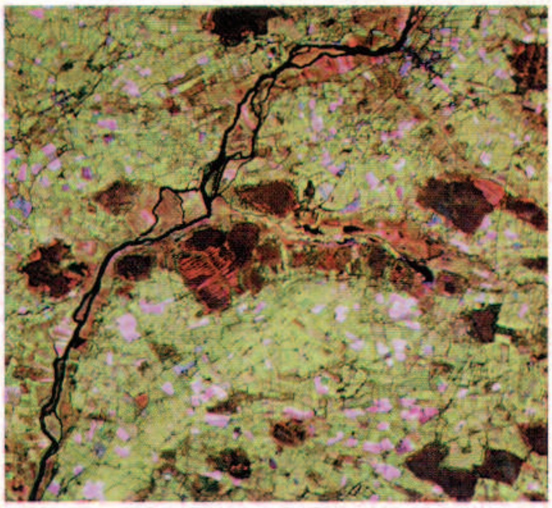
Angelica, Wild	*Angelica sylvestris*
Arrowgrass, Marsh	*Triglochin palustris*
Asphodel, Bog	*Narthecium ossifragum*
Avens, Mountain	*Dryas octopetala*
Avens, Water	*Geum rivum*
Beak-sedge, Brown	*Rhynchospora fusca*
Beak-sedge, White	*Rhynchospora alba*
Bearberry	*Arctostaphylos uva-ursi*
Bedstraw, Lady's	*Galium verum*
Bedstraw, Heath	*Galium saxatile*
Bent, Common	*Agrostis tenuis*
Bent, Creeping (Fiorin)	*Agrostis stolonifera*
Bent, Velvet	*Agrostis canina*
Bilberry	*Vaccinium oxycoccus*
Birch, Downy (Bog Birch)	*Betula pubescens*
Birch, Silver	*Betula pendula*
Bistort, Amphibious	*Polygonum amphibium*
Bladder-sedge	*Carex vesicaria*
Bladderwort, Common	*Utricularia australis*
Bladderwort, Greater	*Utricularia vulgaris*
Bladderwort, Intermediate	*Utricularia intermedia*
Bladderwort, Lesser	*Utricularia minor*
Blueberry, American	*Vaccinium corymbosum*
Bogbean	*Menyanthes trifoliata*
Bog-myrtle	*Myrica gale*
Bog-rosemary	*Andromeda polifolia*
Bog-rush, Black	*Schoenus nigricans*
Bog-sedge	*Carex limosa*
Bog-sedge, Tall	*Carex magellanica*
Bracken	*Pteridium aquilinum*
Bramble	*Rubus fruticosus* agg.
Brooklime	*Veronica beccabunga*
Broom	*Sarothamnus scoparius*
Broomrape, Greater	*Orobanche rapum-genistae*
Buckler-fern, Broad	*Dryopteris dilatata*
Buckler-fern, Narrow	*Dryopteris carthusiana*
Bulrush, Great	*Typha latifolia*
Bulrush, Lesser	*Typha angustifolia*
Bur-reed, Branched	*Sparganium erectum*
Bur-reed, Least	*Sparganium minimum*
Bur-marigold, Nodding	*Bidens cernua*
Bur-marigold, Trifid	*Bidens tripartita*
Butterfly-orchid, Greater	*Platanthera chlorantha*
Butterfly-orchid, Lesser	*Platanthera bifolia*
Butterwort, Common	*Pinguicula vulgaris (mothán)*
Butterwort, Large-flowered	*Pinguicula grandiflora.*
Butterwort, Pale	*Pinguicula lusitanica*
Cat's-foot	*Antennaria dioica*
Chickweed, Common	*Stellaria media*
Cinquefoil, Marsh (Bog)	*Potentilla palustris*
Clubmoss, Alpine	*Lycopodium alpinum*
Clubmoss, Fir	*Huperzia selago*
Clubmoss, Lesser	*Selaginella s.elaginoides*
Clubmoss, Marsh	*Lycopodium inundatum*
Clubmoss, Stag's-horn	*Lycopodium clavatum*
Columbine	*Aquilegia vulgaris*
Cottongrass, Broad-leaved	*Eriophorum latifolium*
Cotton grass, Common	*Eriophorum angustifolium*
Cottongrass, Hare's-tail	*Eriophorum vaginatum*
Cowberry	*Vaccinium vitis-idaea*
Cranberry	*Vaccinium oxycoccus*
Cranberry, American	*Vaccinium macrocarpum*
Crowberry	*Empetrum nigrum*
Cuckooflower	*Cardamine pratensis*
Deergrass	*Trichophorum caespitosum*
Duckweed, Common	*Lemna minor*
Eyebright	*Euphrasia officinalis*
Fen-sedge, Great	*Cladium mariscus*
Fern, Hard	*Blechnum spicant*
Fern, Marsh	*Thelypteris palustris*
Fern, Royal	*Osmunda regalis*
Fescue, Sheep's	*Festuca ovina*
Fiorin (Creeping Bent)	*Agrostis stolonifera*
Foxglove	*Digitalis purpurea*
Forget-me-not, Water	*Myosotis caespitosa*
Frog-bit	*Hydrocharis morsus-ranae*
Furze, Common (Gorse)	*Ulex europaeus*
Furze, Western	*Ulex gallii*
Gipsywort	*Lycopus europaeus*
Grass-of-Parnassus	*Parnassia palustris*
Groundsel, Heath	*Senecio sylvaticus*
Hair-grass. Early	*Aira praecox*
Heath, Cornish	*Erica vagans*
Heath, Cross-leaved	*Erica tetralix*
Heath, Dorset	*Erica ciliaris*
Heath, Irish	*Erica erigena*
Heath, Mackay's	*Erica mackaiana*
Heath, St Daboec's	*Daboecia cantabrica*
Heather (Ling)	*Calluna vulgaris*
Heather, Bell	*Erica cinerea*
Heath-grass	*Sieglingia decumbens*
Helleborine, Marsh	*Epipactis palustris*
Horsetail, Marsh	*Equisetum palustre*
Juniper, Dwarf	*Juniperus communis* ssp. *nana*
Lily, Cobra	*Darlingtonia californica*
Lobelia, Water	*Lobelia dortmanna*
Loosestrife, Purple	*Lythrum salicaria*
Lousewort	*Pedicularis sylvatica*
Lousewort, Marsh	*Pedicularis palustris*

[1] With few exceptions, these are the standard English names listed in Dony, Bury and Perring (1986). For Irish names see Scannel and Synnott (1987).

Mare's-tail	*Hippuris vulgaris*
Marigold, Marsh	*Caltha palustris*
Marsh-bedstraw	*Galium palustre*
Marsh-orchid, Broad-leaved	*Dactylorhiza majalis*
Marsh-orchid, Early	*Dactylorhiza incarnata*
Marsh-orchid, Northern	*Dactylorhiza purpurella*
Mat-grass	*Nardus stricta*
Meadow-sweet	*Spiraea ulmaria*
Milkwort, Common	*Polygala vulgaris*
Milkwort, Heath	*Polygala serpyllifolia*
Moor-grass, Purple	*Molinia caerulea*
Mouse-ear, Sticky	*Cerastium glomeratum*
Mustard, garlic	*Alliaria petiolata*
Mustard, hedge	*Sisymbrium officinale*
Najas, Holly-leaved	*Najas flexilis*
Orchid, Bog	*Hammarbya paludosa*
Orchid, Fly	*Ophrys insectifera*
Orchid, Fragrant	*Gymnadenia conopsea*
Orchid, Frog	*Coeloglossum viride*
Orchid, Small-white	*Pseudorchis albida*
Osier	*Salix viminalis*
Osier, Purple	*Salix purpurea* x *S. viminalis*
Pearlwort, Knotted	*Sagina nodosa*
Pearlwort, Procumbent	*Sagina procumbens*
Pimpernel, Bog	*Anagallis tenella*
Pine, Maritime	*Pinus pinaster*
Pine, Scots	*Pinus sylvestris*
Pine, Shore	*Pinus contorta*
Pipewort	*Eriocaulon aquaticum*
Pitcherplant	*Sarracenia purpurea*
Plantain, Lamb's-tongue	*Plantago lanceolata*
Pondweed, Bog	*Potamogeton polygonifolius*
Pondweed, Blunt-leaved	*Potamogeton obtusfolius*
Pondweed, Broad-leaved	*Potamogeton natans*
Pondweed, Fen	*Potamogeton coloratus*
Pondweed, Horned	*Zannichellia palustris*
Ragged-Robin	*Lychnis flos-cuculi*
Rape	*Brassica napus*
Rattle, Red	*Pedicularis palustris*
Redshank	*Polygonum persicaria*
Reed, Common	*Phragmites australis*
Rhododendron	*Rhodondendron ponticum*
Rush, Blunt-flowered	*Juncus subnodulosus*
Rush, Bulbous	*Juncus bulbosus*
Rush, Common	*Juncus effusus*
Rush, Compact	*Juncus conglomeratus*
Rush, Heath	*Juncus squarrosus,*
Rush, Jointed	*Juncus articulatus*
Rush, Rannock	*Scheuchzeria palustris*
Rush, Sharp-flowered	*Juncus acutiflorus*
Rush, Toad	*Juncus bufonius*
Sallow, Rusty	*Salix cinerea* ssp. *oleifolia*
Scabious, Devil's-bit	*Succisa pratensis*
Sedge, Black	*Carex nigra*
Sedge, Bottle	*Carex rostrata*
Sedge, Carnation	*Carex panicea*
Sedge, Few-flowered	*Carex pauciflora*
Sedge, Flea	*Carex pulicaris*
Sedge, Glaucous	*Carex flacca*
Sedge, Green-ribbed	*Carex binervis*
Sedge, Mud	*Carex limosa*
Sedge, Sand	*Carex arenaria*
Sedge, Slender	*Carex lasiocarpa*
Sedge, Stiff	*Carex bigelowii*
Sedge, Tawny	*Carex hostiana*
Sedge, White	*Carex curta*
Sheep's-fescue	*Festuca ovina*
Soft-grass, Creeping	*Holcus mollis*
Sorrel, Sheep's	*Rumex acetosella*
Speedwell, Marsh	*Veronica scutellata*
Speedwell, Water	*Veronica anagallis-aquatica*
Spike-rush, Many-stalked	*Eleocharis multicaulis*
Spotted-orchid, Common	*Dactylorhiza fuchsii*
Spotted-orchid, Heath	*Dactylorhiza maculata* subsp. *ericetorum*
Spruce, Sitka	*Picea sitchensis*
Spurrey, Corn	*Spergula arvensis*
Stitchwort, Bog	*Stellaria alsine*
St-John's-wort, Marsh	*Hypericum elodes*
St-John's-wort, Slender	*Hypericum pulchrum*
Stoneworts	*Chara* and *Nitella* species
Sundew, Great	*Drosera anglica*
Sundew, Oblong-leaved	*Drosera intermedia*
Sundew, Round-leaved	*Drosera rotundifolia*
Sweet-grass, Floating	*Glyceria fluitans*
Thistle, Bog (Meadow)	*Cirsium dissectum*
Tormentil	*Potentilla erecta*
Twayblade	*Listera ovata*
Twayblade, Lesser	*Listera cordata*
Valerian, Marsh	*Valeriana dioica*
Vernal-grass, Sweet	*Anthoxanthum odoratum*
Water-cress	*Nasturtium officinale*
Water-lily, White	*Nymphaea alba*
Water-lily, Yellow	*Nuphar lutea*
Water-milfoil, Spiked	*Myriophyllum spicatum*
Water-milfoil, Whorled	*Myriophyllum verticillatum*
Willow, Bay	*Salix pentandra*
Willow, Crack	*Salix fragilis*
Willow, Creeping	*Salix repens*
Willow, Dwarf	*Salix herbacea*
Willow, Eared	*Salix aurita*
Willow, Goat	*Salix capraea*
Willow, Purple	*Salix purpurea*
Willow, Rusty	*Salix cinerea* ssp. *oleifolia*
Willow-herb, Hoary	*Epilobium parviflorum*
Willow-herb, New Zealand	*Epilobium nerterioides*
Willow-herb, Rosebay	*Chamaenerion angustifolium*
Wintergreen, Common	*Pyrola minor*
Woodrush, Greater	*Luzula sylvatica*
Yellow-rattle	*Rhinanthus minor*

INDEX

References to figures are in italics. Figure references often include discussion in the text.



Satellite imagery of some raised bogs: in the floodplain of the Little Brosna river, Counties Offaly and Tipperary (above left); Clonfert bog on the west bank of the Shannon, County Galway (above right); Ardkill bog, County Kildare (below left).

Mushroom stone at Cornaseer on the shores of Lough Ree, County Roscommon.

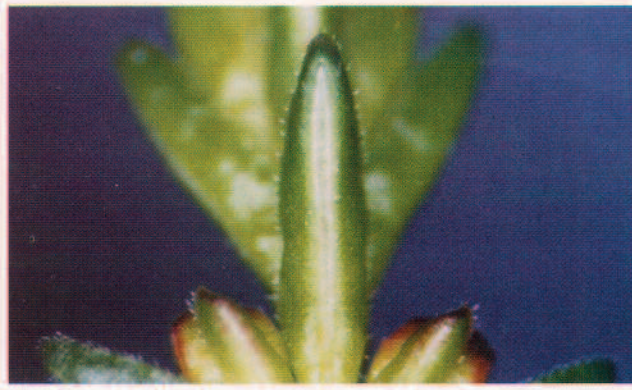
Peat silt settling pond with marl at Galros, near Birr, County Offaly; close-up of marl on right.

Plate 1


Heather (ling).


Bell heather.


Cross-leaved heath.


Single leaf of heather, viewed from below.


Common sundew.


Great sundew.


Cranberry.

Leaf rosette of common butterwort.

Leaf rosette of pale butterwort.

Carpet of bog asphodel at Clongawney bog.

Bladderwort flowers on the surface of a bog pool.

Bog asphodel.

Grass of Parnassus.

Furze in flower.

Plate 3


Pitcher plant.


William Maple's drawing of tormentil (1720-9).


Bog cinquefoil.


Bog thistle.


Lousewort.


Devil's-bit scabious.


Heather with bog lichens (*Cladonia coccifera*).


Bogbean.


Bog myrtle catkins.

Plate 4


Marsh helleborine (close-up).


Marsh helleborine.


Bog orchid.


Heath spotted-orchid.


Lesser twayblade.


Common twayblade.


Scented orchid.


Greater butterfly orchid.


Northern marsh-orchid.


Early marsh-orchid.


Early marsh-orchid.


Fly agaric (*Amanita muscaria*).


Violet cortinarius (*Cortinarius violaceus*).


Cordyceps ophioglossoides .


Mitrula paludosa .


Birch bolete (*Krombholziella scabra*).


Birch bracket fungus (*Piptoporus betulinus*).


Jelly babies (*Leotia lubrica*).


Bog lichens (*Cladonia coccifera*).

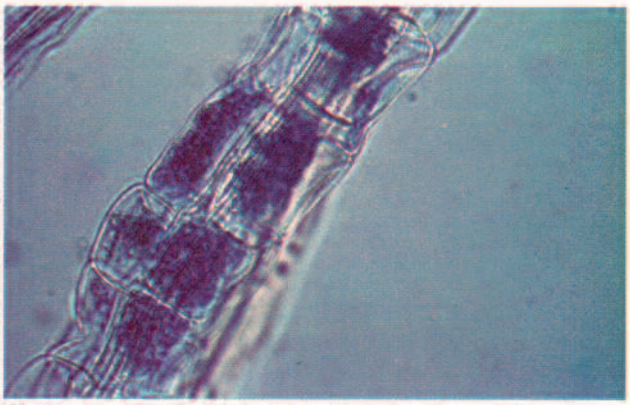

Hymenoscyphus ericae inside cells in heather root.

Plate 6

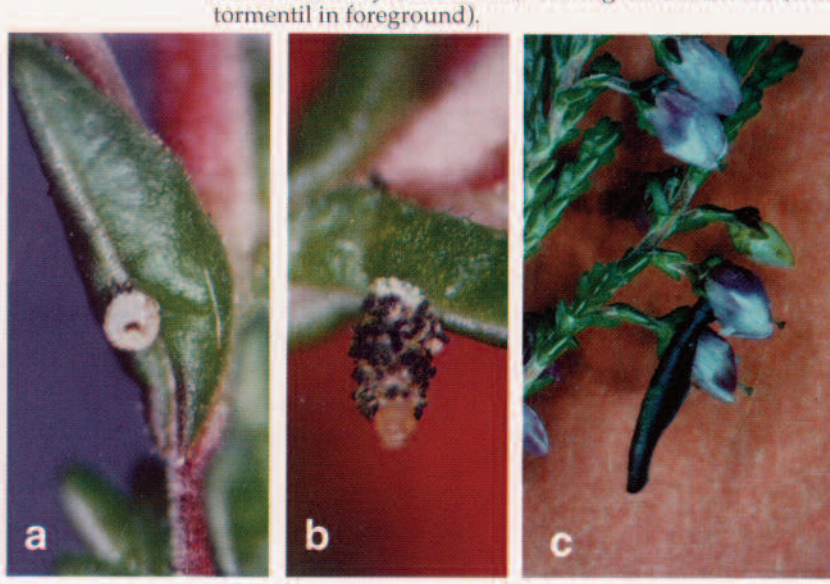
Large heath butterfly on cross-leaved heath.

Green hairstreak.

Marsh fritillary (upper side).

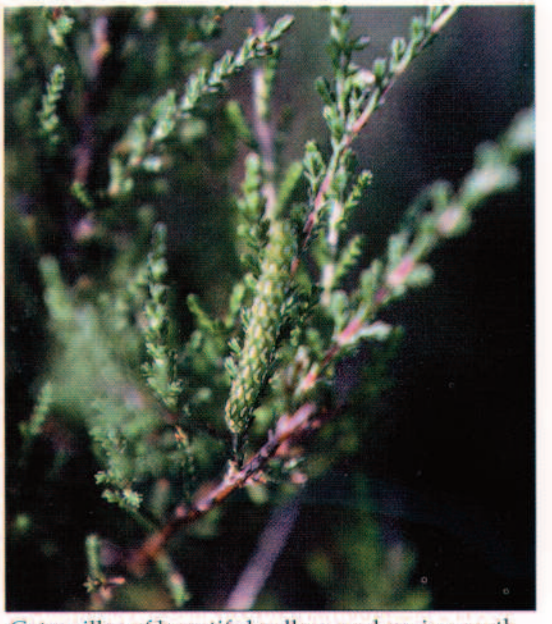
Marsh fritillary (underside): resting on lousewort (with tormentil in foreground).

Marsh fritillary: larval web.



Heather case-carrier: (a) egg on leaf join; (b) early stage on leaf, with rudimentary case; (c) feeding on flower.


Emperor moth.


Caterpillar of beautiful yellow underwing moth.


Eyed hawkmoth caterpillar, final instar.


Oak eggar caterpillar in heather.


Caterpillar of emperor moth.

Plate 8

Ground beetles: *Carabus problematicus.*

Carabus arvensis.

Tiger beetle.

Great diving beetle.

Water beetle (*Acilius sulcatus*).

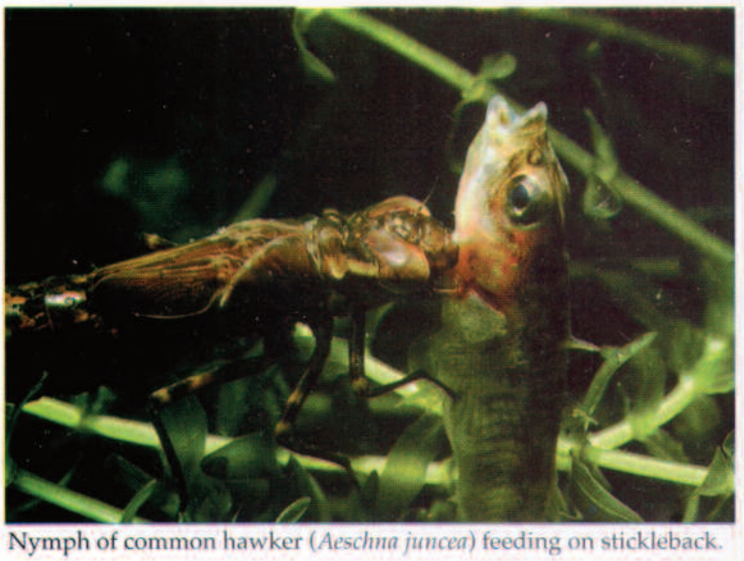
Larva of great diving beetle.

Plate 9

Common hawker male (*Aeschna juncea*).

Four-spotted chaser (*Libellula quadrimaculata*) resting on bogbean.

Large marsh or bog grasshopper (*Stenophyma grossum*).



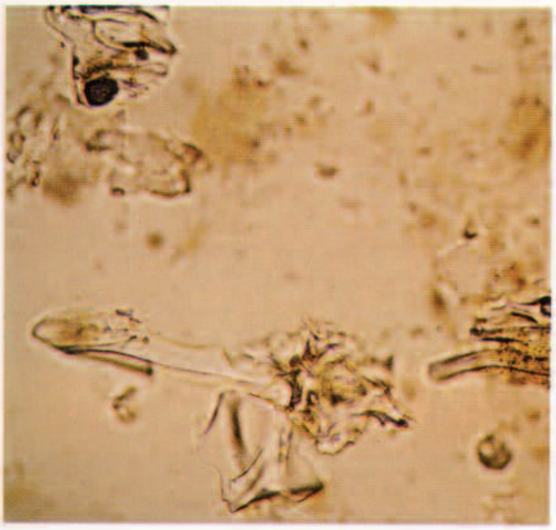
Nymph of common hawker (*Aeschna juncea*) feeding on stickleback.

Golden plover.

Bog spider*Dolomedes fimbriatus*, with nest.

A solitary wasp (*Ectemnius continuus*).

Plate 10



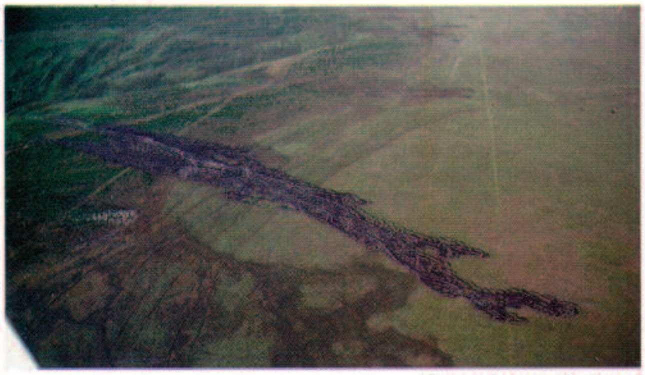
Shards of volcanic glass (tephra) in peat.
These shards, which were recovered from a layer 56cm below the surface of blanket bog in Croaghaun East, north-west Mayo, have been shown by geochemical analysis to come from an eruption of the Icelandic Volcano Hekla in 1104 A.D. The largest shard is 130μm; note the bubbles of trapped gas in the other shards. Rosaleen Dwyer has identified seven tephra horizons in this bog. One of them occurs at the level of the main humification change in the peat.

Chlamydophrys labyrinthuloides .
The drawing shows the creature shortly after it has woken from dormancy, breaking out of the protective multi-layered jacked surrounding its cyst, and showing the pulsating vacuoles and variously-coloured granules. Some of the granules can be seen travelling along the reticulated network of 'feelers'. When one of these encounters food, the protoplasmic thread will grow into a small amoeboid 'outlier' which will digest the particle. The outlier on the right has engulfed an *Oocystis*, and one of those at the top has swallowed a cell of *Spirotaenia*. The little ovoid body at bottom left is an outlier which broke away and encysted independently in an earlier period of activity.

Palaeosol profile.
Woody charcoal horizon under blanket bog, overlying a palaeosol with iron pan: near Bangor Erris, County Mayo.

The great oak trackway in Corlea bog, County Longford.

Plate 11



Two views of a bog burst on Slieve Bloom.

Erosion of blanket peat due to overstocking and overgrazing:
fenced commonage in the Erriff Valley, near Leenane, County Mayo, spring 1993 (left); on Mount Brandon (right).

Regeneration surface in Ardee bog, County Louth.

Natural grassland on the site of Lough Boora, County Offaly.

Birchwood on cutover bog at Lackan Bog SSSI, Ballyroney, County Down. This site is home to the marsh fritillary and more than a dozen species of dragonflies.

Old turbary at the Ridge bog near Birr, County Offaly.

Plate 12