Land2Sea

Aquatic Ecosystem Services in a Changing World

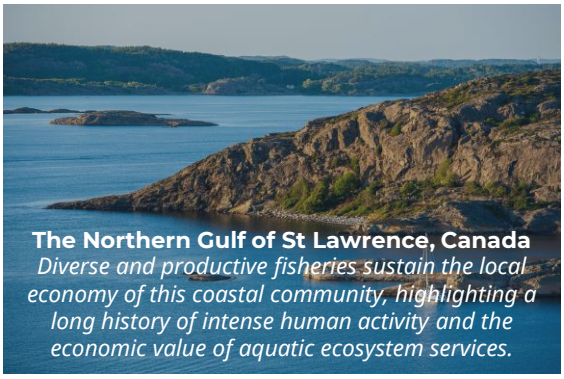
Newsletter #2, Winter 2022

Land2Sea (2019-2022) aimed to (a) clarify impacts of multiple climatic and terrestrial stressors on freshwater and marine ecosystems and their economic, societal and cultural contributions to people and (b) produce models and tools to inform policy and management. It involves researchers and stakeholders from Ireland, Germany, Sweden, Canada and the USA and work in four case study areas.

This Newsletter complements Newsletter #1 with a summary of some other key activities in the project. Contact the project coordinator Prof Tasman Crowe or visit land2sea.ucd.ie for more information or view our Decision Support Tool https://esdecide.shinyapps.io/Land2sea_DST/.

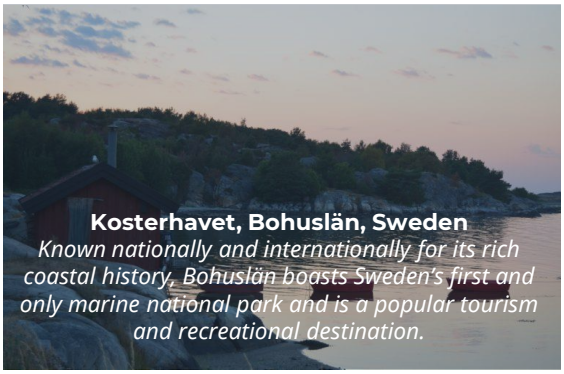
CASE STUDY AREAS

The River Liffey and Dublin Bay, Ireland
Set in the heart of the densely inhabited Irish capital city, Dublin Bay is the centre point for a wide range of recreational, commercial and cultural activities.

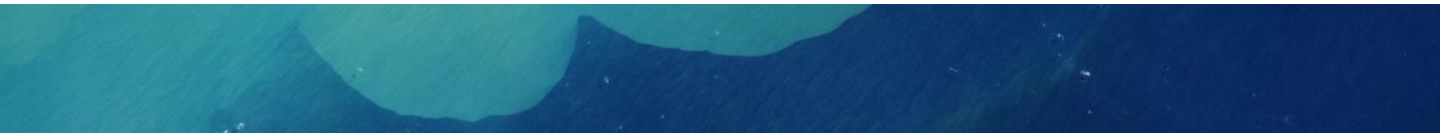


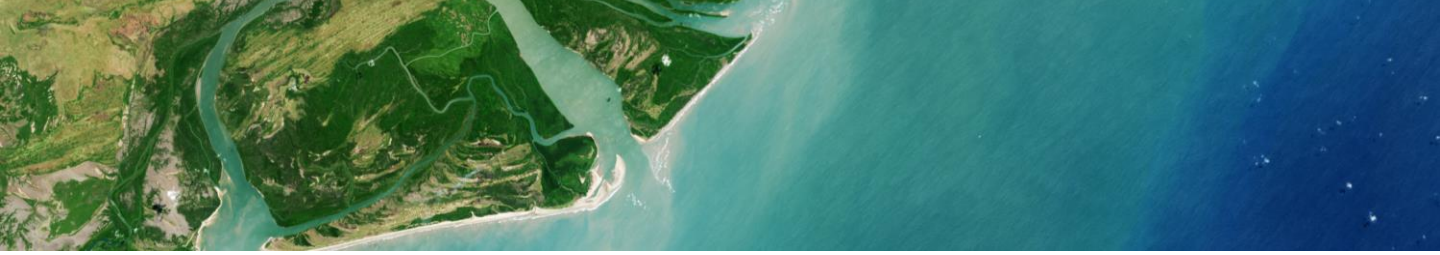
The Northern Gulf of St Lawrence, Canada
Diverse and productive fisheries sustain the local economy of this coastal community, highlighting a long history of intense human activity and the economic value of aquatic ecosystem services.

The Tidal Elbe, Germany
Characterized by a rich cultural landscape and strong place attachment in local communities, the River Elbe comprises many valuable habitats for protected species as well as being heavily managed as an essential shipping route.



Kosterhavet, Bohuslän, Sweden
Known nationally and internationally for its rich coastal history, Bohuslän boasts Sweden's first and only marine national park and is a popular tourism and recreational destination.





COMBINED IMPACT OF CLIMATIC AND LAND-USE STRESSORS ON STREAM ECOSYSTEMS – PRELIMINARY FINDINGS FROM A FIELD MESOCOSM EXPERIMENT

Marcin Penk[1], Aishaani Sharma[1], Ann-Marie Kelly[2], Mary Kelly-Quinn[2] and Jeremy Piggott[1]
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Ecosystems are increasingly challenged by the multiple facets of climate change, coupled with intensifying land-use pressures. These co-occurring stressors can potentially interact in complex ways yielding 'ecological surprises', but we lack an empirical understanding and predictive framework for individual and interactive effects.

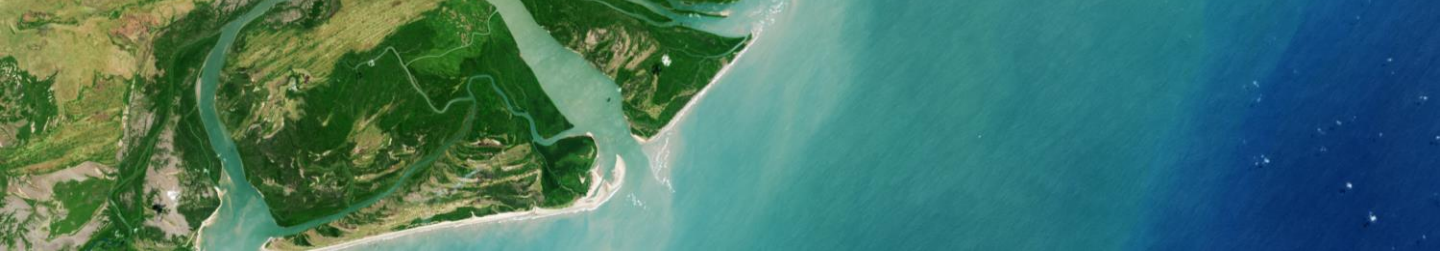
We conducted a field experiment to investigate the individual and combined effects of climatic stressors (including CO_2 enrichment and variation in flow regime) and land-use stressors (including removal of shading, simulating clearance of bankside vegetation, and siltation) on microbial, algal and invertebrate communities, and ecosystem processes. We used 128 flow-through circular stream mesocosms (ExStream system[1]) deployed in Co. Wicklow, Ireland.

Sample processing is still underway, but data on algal biomass collected using a fluorescent field probe have been analysed. Our preliminary findings show that CO_2 enrichment to levels 2–3 × present day tended to increase algal biomass, although this effect was transitional, and was dependent on the flow regime: it was more readily manifested under a stable compared to a variable flow regime. Increase in light intensity from the absence of shading (100% vs 60% incident light) affected algal biomass more consistently, particularly for cyanobacteria and green algae.

However, these two algal groups responded in the opposite directions; cyanobacteria increased, whereas green algae decreased without shading. The effect of light showed some dependence on siltation and flow regime. The biomass of diatoms and all algal groups combined (cyanobacteria, green algae and diatoms) was on average higher in unshaded than in shaded treatments throughout the experiment, but this difference was not statistically significant.

Algae are key primary producers in streams and are therefore considered a food web foundation, and regulators of important ecosystem processes. However, their excess can be problematic; it can destabilise food webs and reduce dissolved oxygen. Additionally, cyanobacteria can produce toxins that may affect wildlife, water abstraction and amenity qualities. Our findings highlight that such impacts—typically associated with nutrient enrichment—can be magnified by non-nutrient stressors and regulated by stressor interactions. We will also be analysing responses in terms of invertebrate community and fundamental ecosystem processes, such as decomposition and respiration rates.

[1]Piggott JJ, Townsend CR and Matthaei CD 2015. Climate warming and agricultural stressors interact to determine stream macroinvertebrate community dynamics. *Global Change Biology* 21: 1887-1906 https://doi.org/10.1111/gcb.12861



INFORMING MANAGEMENT UNDER UNCERTAINTY: THE CASE OF KOSTERHAVET NATIONAL PARK, SWEDEN

Katharina Rettig, University of Duisburg-Essen, Germany

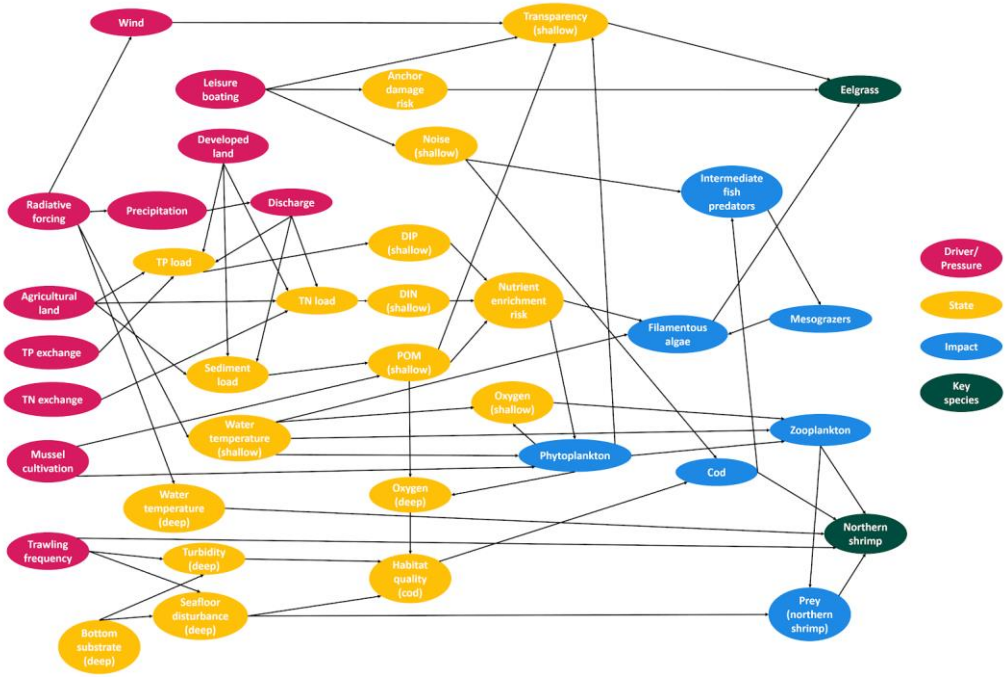
Human activities on land and at sea often cause deterioration at various levels in coastal ecosystems. In these complex systems, data and knowledge on cause-and-effect relationships are often limited. The resulting uncertainty may hamper decision making and appropriate management. Although the outcome of an event is uncertain, scenarios can help to predict the probability of several possible outcomes. To support informed decisions under uncertainty, Bayesian belief networks (BBNs) provide a suitable model framework. They graphically represent assumptions about cause-and-effect relationships and quantify them by conditional probabilities.

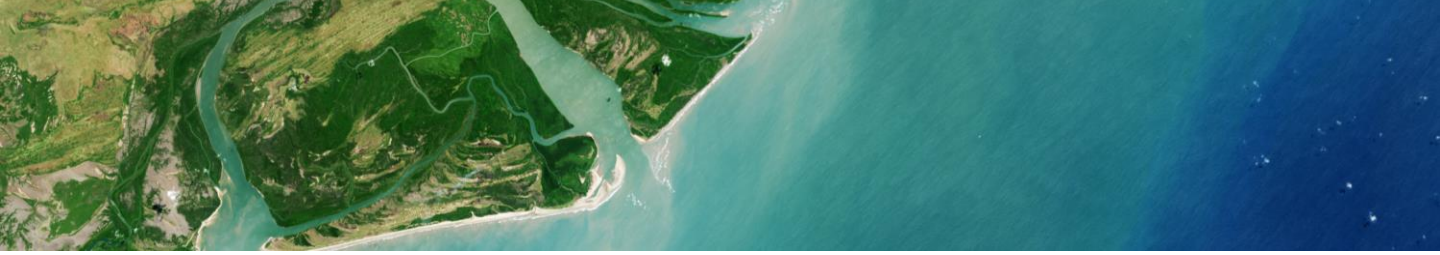
A BBN for Kosterhavet National Park, Sweden, was built within Land2Sea to identify the most influential causes of ecosystem change and thus investigate potential management options for northern shrimp (*Pandalus borealis*) and eelgrass (*Zostera marina*). Despite its protection status, Kosterhavet National Park is subject to various commercial and recreational uses. Hence, the BBN links human activities on land and at sea and climate change via abiotic and biotic cause-and-effect relationships to these two species.

Based on data and expert opinion, the developed BBN comprises the best available knowledge. Northern shrimp and eelgrass were most sensitive to human activities and related pressures within the national park, such as trawling frequency or anchor damage risk. Further, both species responded to system changes driven by pressures outside the national park, such as water temperature or nitrogen exchange with adjacent water bodies. On this basis, local measures together with joint mitigation and adaptation programs on different scales need to be implemented to sustainably manage Kosterhavet National Park. These findings may also be relevant for other intensively used coastal systems and their management.

Rettig K, Skriver Hansen A, Obst M, Hering D and Feld CK 2022. A Bayesian network to inform the management of key species in Kosterhavet National Park under contrasting storylines of environmental change. *Estuarine, Coastal and Shelf Science* 108158 https://doi.org/10.1016/j.ecss.2022.108158

(Below) BBN for Kosterhavet National Park, Sweden, showing the network of influences. Drivers and pressures are shown in pink, environmental states are shown in yellow, impacts on biodiversity are shown in blue and key species in green.





ECOLOGICAL-ECONOMIC MODELING OF WATER QUALITY-FISHERY LINKAGES IN THE ESTUARY AND GULF OF ST. LAWRENCE, CANADA

Edward B. Barbier and Michelan Wilson, Colorado State University, USA

Ecological-economic modeling can be employed to answer important policy questions about fisheries and the environment, such as determining the current and future impacts of pollution and changes to water quality on the markets for fish, the consumers and producers affected, and the gains and losses incurred by different stakeholders. The modeling can also be used to examine how these various effects may change when pollution is reduced or increased, for example through curbs on nitrogen and phosphorus loads in rivers[1] or decreases in hypoxia in marine environments[2].

In Lac St. Pierre of the St. Lawrence River, nitrogen (N) and phosphorous (P) concentrations impact Yellow Perch directly through altering fish growth and rate of survival and indirectly by influencing fish habitat through changes in sub-aquatic vegetation[1]. However, our results show that it is the N:P ratio that matters to these impacts more than the individual nutrient loads. Our simulations show that with a 5% lower N:P ratio the fishery would not have been closed in 2011, and profits in every year would have been higher. Reducing the N:P ratio by 10-20% would have resulted in even larger industry profits.

Although policies implemented in Quebec have reduced nutrient pollution caused by agriculture, they have largely caused a shift from using fertilizers with high phosphorus content to fertilizers with high nitrogen content. Nutrient reduction policies should target maintaining a nutrient balance rather than absolute nutrient loads. The implementation of agricultural policies to reduce the influx of nitrogen into the fluvial lakes of the St. Lawrence River, similar to those implemented for phosphorus, may achieve this goal.

In the case of the shrimp fishery in the Estuary and Gulf of St Lawrence, we found that the effectiveness of policies that reduce hypoxia, thus increasing oxygen saturation in shrimp habitats, depends on whether the fishery is also efficiently managed[2]. If fishing effort is successfully restricted, a 5-percentage point increase in oxygen saturation will cause industry profits to fall but consumer benefits to increase. Thus, the average annual gain in welfare is C$4.4 million (1990 prices) from 1991 to 2018. These results suggest that additional policies are needed for reducing hypoxia through controlling the agricultural and urban sources of nutrient pollution in the EGSL. However, higher price floors would shield the fishing industry from any excessive reductions in profits. Alternatively, an adjustment of the quota rule that puts stricter rules on how harvest changes with increasing fish stock may prevent prices from falling too quickly or too low.

[1]Wilson M, Barbier EB, Mingelbier M 2022. Bioeconomic impact of nutrient pollution in freshwater fisheries: the case of yellow perch in the St. Lawrence river, Quebec, Canada, mimeo. Department of Economics, Colorado State University.

[2]Wilson M, Barbier EB, Archambault P, Carrier-Belleau C 2022. Estimating water quality impacts in marine fisheries: The case of the northern shrimp in the estuary and gulf of St. Lawrence, mimeo. Department of Economics, Colorado State University.

BIODIVERSITY CONCERNS IN SECOND PLACE? THE CASE OF THE TIDAL ELBE, GERMANY

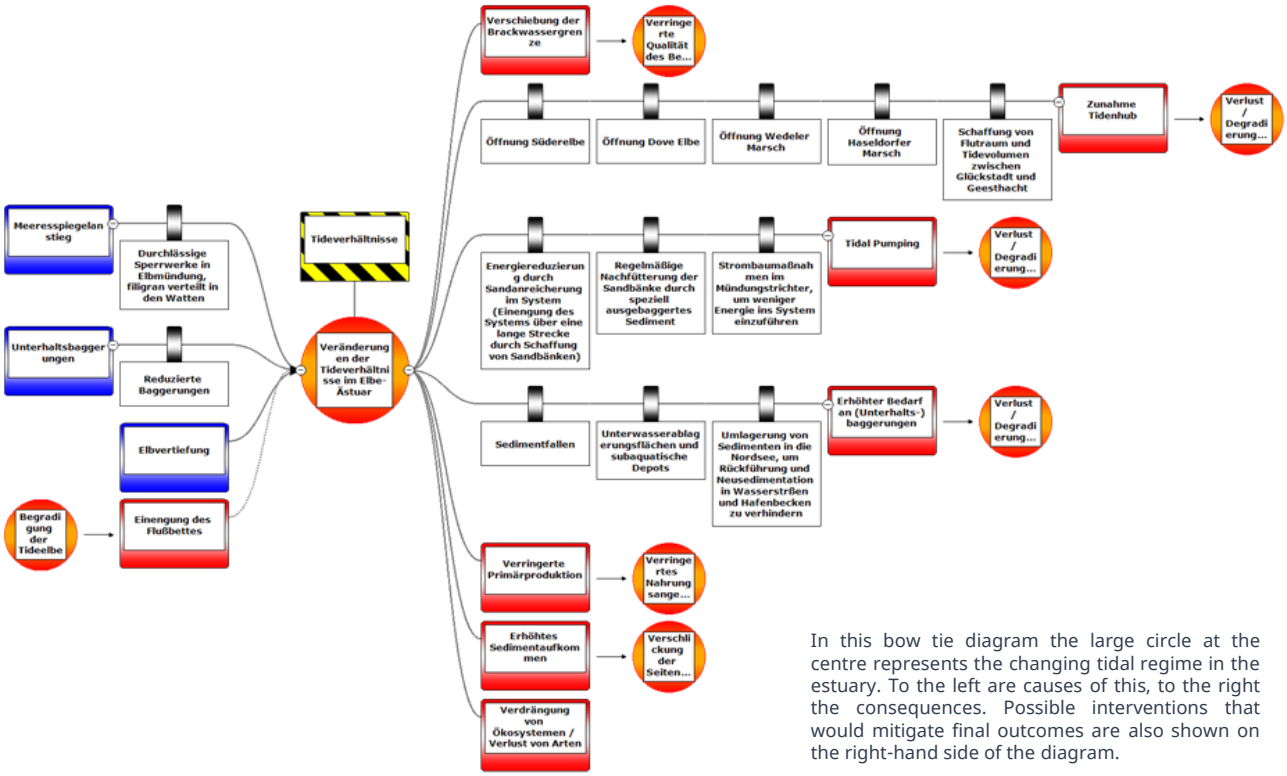
Kira Gee, Andreas Kannen, Jürgen Schaper and Valentin Volland, Helmholtz Zentrum Hereon, Germany

The Tidal Elbe is the largest estuary in Germany, linking the North Sea with the Port of Hamburg. Access to the port has always been important, as has flood protection in the surrounding region, which is why the Tidal Elbe has been heavily altered over the last decades.

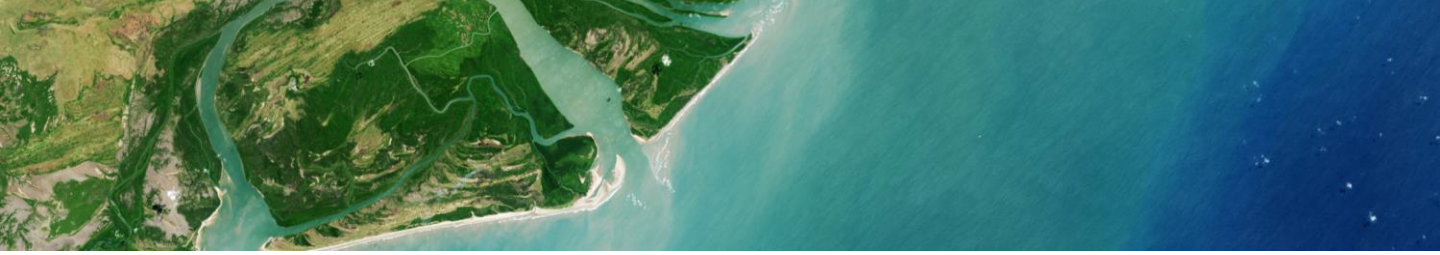
In Land2Sea, we traced the impacts of a hydrologically altered river and climate change on biodiversity. We first developed a simplified system diagram with cause-and-effect chains for the Tidal Elbe, structured around smelt, a species of fish with cultural and economic significance. We then verified our system understanding in stakeholder workshops and additional interviews before applying the bowtie method to identify where in the system intervention could make sense to avoid or reduce impact. As it also uses cause-and-effect chains, it complements the system diagram, although the logic it employs is more stringent.

We found that only a few interventions in the system could potentially make a difference to ensure the continued presence of smelt, especially when also considering climate change. These interventions all relate to the hydro-morphological characteristics of the river, affecting the presence of oxygen in the water and the availability of shallow water habitats that are used for spawning and as nursery areas. Opening up side arms of the Elbe would be one such intervention as it could mitigate the effects of tidal pumping and support biodiversity more generally.

While people do appreciate biodiversity and losing smelt would make a difference to nature's contribution to people, the Port of Hamburg remains the most important driver in the region. Climate change is likely to exacerbate ecological challenges that are being observed in the Tidal Elbe. At least in the short term, securing access to the Port is being given greater priority than biodiversity in this case.



In this bow tie diagram the large circle at the centre represents the changing tidal regime in the estuary. To the left are causes of this, to the right the consequences. Possible interventions that would mitigate final outcomes are also shown on the right-hand side of the diagram.



THE LAND2SEA DECISION SUPPORT TOOL

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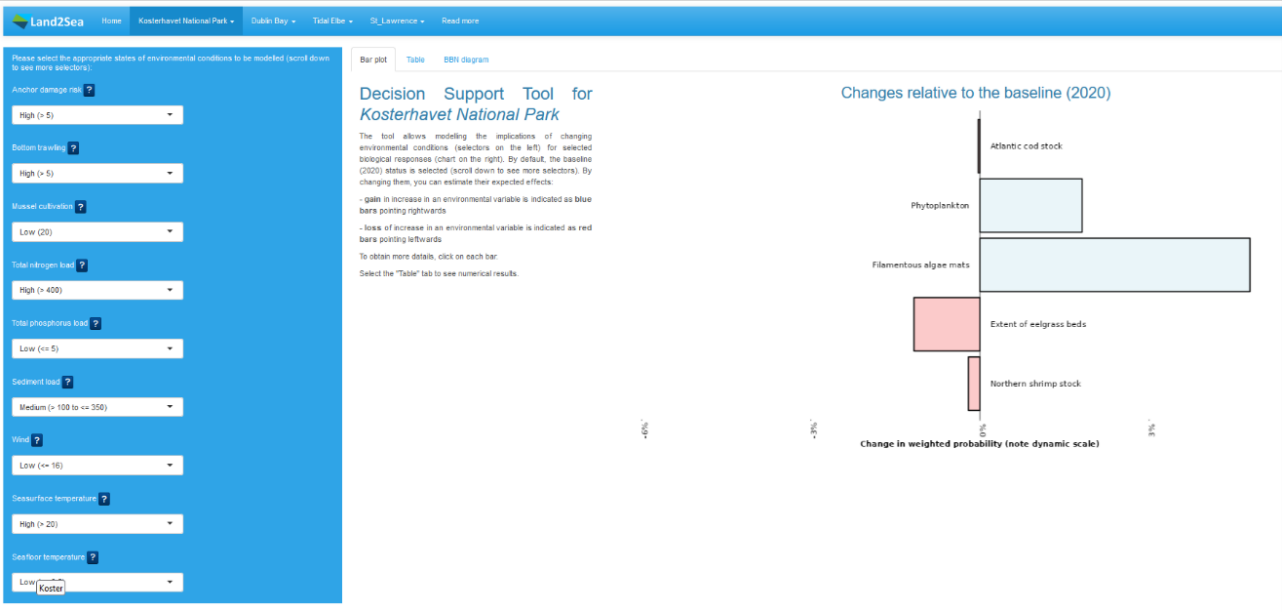
[1]University College Dublin, Ireland [2]University of Duisburg-Essen, Germany

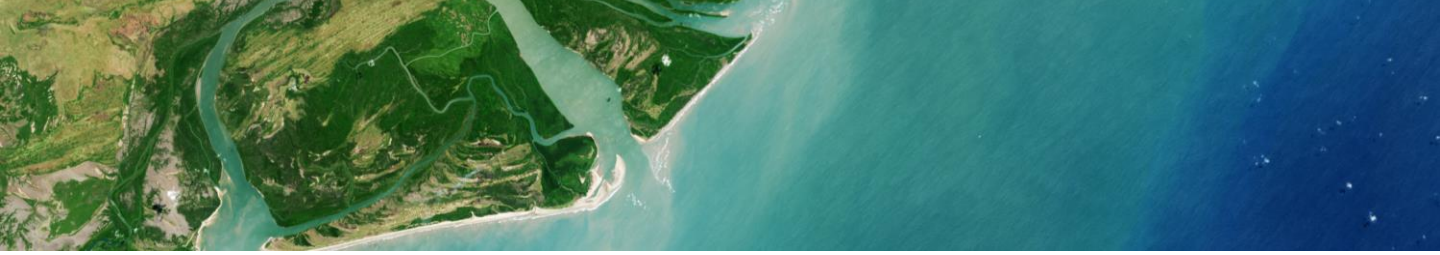
In Newsletter #1 Christian Feld and Katherina Rettig described the "River Doctor", a suite of tools developed at the University of Duisburg-Essen to diagnose the possible causes of river ecosystem changes. Building on their methods, the Land2Sea decision support tools (Land2Sea_DSTs) aim at informing decisions about the management of coastal and marine environments. The DSTs incorporate both numerical and conceptual approaches to investigate changes in environmental aspects of coastal systems. The tools link to four case study regions in Sweden, Canada, Ireland and Germany https://esdecide.shinyapps.io/Land2sea_DST/.

The Kosterhavet case study in Sweden links environmental drivers with biological and ecosystem services responses[1], which then translate to social-economic consequences in the case study area and beyond. The St Lawrence case study in Canada links water characteristics and pollution with the effects on the St. Lawrence fisheries. The Dublin Bay case study in Ireland examines the effects of water pollution on the ecology of Dublin Bay and includes environmental changes in wildlife values and ecosystem services of an inflowing river. The Tidal Elbe case study in Germany links changes in numbers of terns and smelt with socio-economic effects in the area. All DSTs integrate environmental causes of change, their biological/ecological effects and potential social-economic consequences for the society. Several of the case studies were integrated into probabilistic models (Bayesian Belief Networks) that combine numerous cause-and-effect relationships (see article by Katharina Rettig above) and allow for a quantification of the probabilities of biological and ecological responses in the case study areas. Others present interactive consequence maps developed from local socio-economic knowledge. Simple graphical user interfaces then allow end users to quickly access and apply each of the Land2Sea_DSTs.

The DST has been designed for general users and does not require any programming knowledge or detailed computer skills.

[1] Rettig K, Skriver Hansen A, Obst M, Hering D and Feld CK 2022. A Bayesian network to inform the management of key species in Kosterhavet National Park under contrasting storylines of environmental change. *Estuarine, Coastal and Shelf Science* 108158. https://doi.org/10.1016/j.ecss.2022.108158





PRACTICAL APPROACHES TO INTERDISCIPLINARY COLLABORATION FOR SUSTAINABILITY

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[1]University of Gothenburg, Sweden [2]University College Dublin, Ireland

Clearly, many challenges in sustainability require collaboration among scientists, engineers, social scientists and humanities researchers and effective stakeholder engagement to find workable solutions, encompassing social, environmental and economic dimensions. Calls for such interdisciplinary collaborations have been made for a number of years, but progress has not been impressive. Why is this? In addition to some significant systemic and institutional barriers, part of the answer might be the fact that little has been written about what interdisciplinarity means in practice, in 'everyday research work', for the scholars engaged, organizational attributes, concrete modes of working together etc.

As Land2Sea set out with high ambitions for interdisciplinary work, the project has presented an opportunity to contribute insights for developing and practicing interdisciplinary approaches and methodologies. Therefore we have, as part of the project, conducted a literature overview and also an empirical study, investigating the ideas, the perceptions and the experiences of the researchers participating in Land2Sea. The preliminary results point at three interlinked ingredients that need to be considered: *People – the composition of the group and the characteristics of the individuals in the group; Process – how the work is organized and structured;* and *Perspectives – differences in framings and concepts and terminology have proven to be the most challenging aspect of interdisciplinary work in practice*. Good communication, open-mindedness and leadership and allowing enough time for understanding each others' perspectives and finding possible solutions together have emerged as keys for successful interdisciplinary work.

Land2Sea is a collaboration between natural scientists, social scientists, economists and humanities researchers from University College Dublin (Ireland), Trinity College Dublin (Ireland), University of Gothenburg (Sweden), University of Duisburg-Essen (Germany), Helmholz-Zentrum Hereon (Germany), University of Colorado (USA) and Laval University (Canada).

The project is part of the BiodivScen programme, jointly supported and managed by Belmont Forum, Biodiversa and the European Commission, with national funding for partners provided by the Environmental Protection Agency (Ireland), the Marine Institute (Ireland), Deutsche Forschungsgemeinschaft (Germany), DLR Projektträger (Germany), Formas (Sweden), National Science Foundation (USA), NSERC (Canada), Fonds de recherche, Nature et technologies Québec (Canada).

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