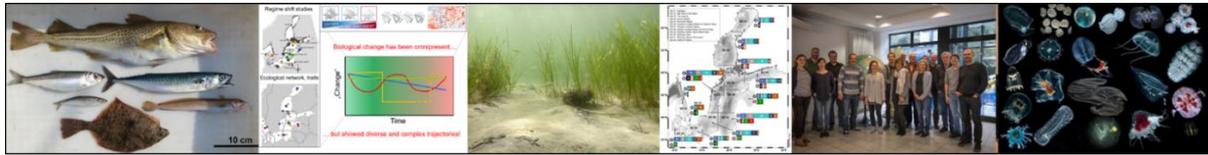




BONUS XWEBS policy brief no. 2¹



A perspective for Baltic Sea food web research - *How food web knowledge can be integrated in adaptive ecosystem-based management of marine resources*

Highlights

Baltic Sea food webs are likely to undergo alterations following projected major changes in future environmental conditions and anthropogenic pressures, with potentially severe impacts on ecosystem goods and services. Synthesis work in BONUS XWEBS now highlights what is needed to ensure that Baltic Sea food web research can provide the information that resource managers will need to address these challenges of the future. Although there is a substantial foundation of food web knowledge, information is often not easily accessible because it is dispersed, frequently hidden in grey literature and lacking synthesis and integration in openly accessible databases. Moreover, process information is lacking even for many key species, and new research on the dynamics of food web components and processes, as well as impacts of multiple drivers on food webs is needed. To improve this situation, important steps forward will be (1) the revision and continued or expanded financial support of existing monitoring programs, including improved integration of novel tools and focus on understudied system components and areas such as the coastal zone, (2) databases providing access to newly generated but also synthesized existing data and (3) research agendas that explicitly acknowledge not only the need for advanced modeling tools but also the necessary scientific underpinning including process information to parameterize these models. In combination, these steps would ensure that food web knowledge can truly become a cornerstone of the adaptive ecosystem-based management and governance of the Baltic Sea.

The problem

Food webs are central to the functioning of marine ecosystems, governing fluxes of energy and matter through communities, and by extension, providing ecosystem goods and services used by humans. Food webs mediate different pressures through top-down and bottom-up processes, and food web structure is further related to the stability of the community. Consequently, food webs are an integral part of assessments of ecosystem status (e.g. EU Marine Strategy Framework Directive) as well as

¹Our policy briefs are summaries of scientific knowledge produced in the BONUS XWEBS project, connected to current management and policy needs concerning the Baltic Sea.

ecosystem-based management of marine resources in the Baltic Sea. The question is where we stand with regard to the extent and depth of our knowledge regarding Baltic Sea food webs, and our ability to use this knowledge in leading policy initiatives. Future changes in the Baltic Sea environment and biota are likely to influence food web structure and functioning, including our ability to sustainably use marine resources while promoting ecosystem health. However, few recent research agendas and calls for action focus explicitly on food webs in the marine environment. Based on collective BONUS XWEBS efforts, we here highlight some outstanding challenges in Baltic Sea food web research, with emphasis on:

- (i) The fundamental knowledge of Baltic Sea food web dimensions, dynamics and drivers.
- (ii) Approaches and data in Baltic Sea food web research.
- (iii) The use of food web knowledge in conservation and management of marine resources.

Key results and conclusions

Knowledge gaps in Baltic Sea food web dimensions: Although species interactions form the core of ecological communities, and Baltic ecosystems are comparatively well-studied, gaps still remain in our understanding of what species actually do in the food web, and how species roles change over space and time. Knowledge

gaps exist for native organisms (e.g. microbes, invertebrates, non-commercial fishes), as well as non-indigenous species, for which impacts have not been sufficiently considered in food web studies. Diet information is generally better for species higher up in the food web, but knowledge gaps are found across trophic levels, and even exist for key Baltic species like cod (*Gadus morhua*), for which diet information for younger age classes and shallower regions is lacking.

“Synthesis work in BONUS XWEBS now highlights what is needed to ensure that Baltic Sea food web research can provide the information that resource managers will need to address these challenges of the future.”

Knowledge gaps in Baltic Sea food web dynamics: Food webs can change, e.g. through shifting species composition due to range expansions, through local extinctions of native species or the establishment of non-indigenous species, as well as changes in species interactions due to altered behavioral responses of consumers. Central here is the level of our knowledge concerning the feeding links among species. Where information about links is available, it is often static with limited temporal and spatial resolution. As an example, we oftentimes still use information on feeding links generated decades ago, although food webs and species communities have undergone major changes since then. There is also a major gap in the data available on prey preferences, functional or weighted interactions in the food webs, which are available only for some time periods and sub-regions. Individual case studies for sub-areas of the Baltic show how important this information is for our understanding of the dynamics of energy fluxes in the sea (Fig. 1), and highlight the need for more systematic, spatio-temporally resolved quantitative information on dynamics of food web components and processes.

Knowledge gaps in Baltic Sea food web drivers: With a changing environment, we can expect local populations to respond to shifting conditions. However, there are gaps in our knowledge of species tolerance levels (including adaptation potential), which hampers our ability to anticipate which species or traits are likely to be impacted. For example, what are the knock-on effects on the food web if the distribution of Baltic Sea foundation species like *Fucus vesiculosus* and *Zostera marina* shift due to a changing environment? The associated impact on food web structure, function, redundancy

and resilience remains unclear. In addition, the overall food web consequences of top-down vs. bottom-up effects (e.g. fisheries vs. eutrophication and climate change) are still not well understood, and difficult to quantify or predict. In summary, we need to account for multiple drivers as well as novelty in the system, which can manifest in the abiotic environment, as well as in the food web itself. In turn, this will also strengthen our understanding of the potential for both buffering and amplification of initial pressures mediated via eco-evolutionary dynamics and food web processes, a key research need highlighted in BONUS XWEBS policy brief No 1.

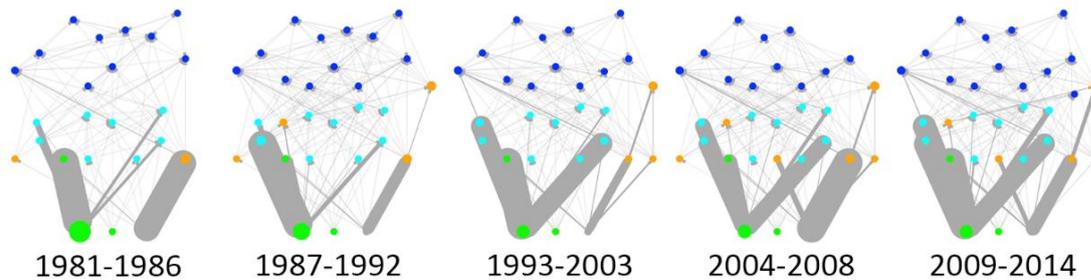


Figure 1. Temporal dynamics in the energy fluxes in the Gulf of Riga food web. Different time periods between 1981 and 2014 are highlighted. The width of the interactions corresponds to the magnitude of the energy flux, providing an estimate of ecosystem functioning in complex, multitrophic systems (Kortsch et al. *in review*).

Approaches and data in Baltic Sea food web research: Research into complex food webs requires multiple, complementary approaches, from methods establishing and quantifying specific feeding interactions to methods and models that aim to characterize entire food webs and model their structure, function, and stability, and changes therein. XWEBS synthesis work shows that Baltic Sea food web research rests on a strong methodological foundation, mirroring the ‘high science density’ in the region. This is illustrated e.g., by the large spatial coverage and range of scientific topics addressed by peer-reviewed stable isotope studies with an ecological focus in the Baltic Sea (Fig. 2). At the same time, food web data in the Baltic Sea are characterized by significant heterogeneity in spatial-temporal and taxonomic coverage. Moreover, existing data are often dispersed, unpublished, and primary data underlying publications are often not available publicly. Thus, of primary importance for the future advancement of the field is enhanced data availability, accessibility and integration in order to ensure flow of relevant information on primary feeding relationships into overarching food web characterizations and models.

Food web knowledge in Baltic Sea resource management and conservation: Food web knowledge enters Baltic Sea environmental resource management and conservation through direct, indirect as well as informal ways, depending on management context and purpose. The benefits of food web knowledge use in management were underscored by an XWEBS analysis of the environmental concerns contaminants, eutrophication, non-indigenous species and fishing (Köster et al *in review*). However, our analysis also showed that existing management frameworks are often not suitable for the systematic incorporation of food web knowledge. Additionally, our current understanding of complex food web processes may not be sufficient to meet the needs of management. Importantly, current monitoring programs do not provide long-term, integrated information across trophic levels, nor on food web processes or simultaneously occurring stressors, which complicates and limits the use of food web knowledge in Baltic Sea management. Further complications arise from the suite of available food web indicators to assess Good Environmental Status (GES), which do not cover all trophic guilds and frequently fail to account for the environmental dynamics of the Baltic Sea - a situation that may be alleviated by the use of trophic models in the future (XWEB policy brief No. 3).

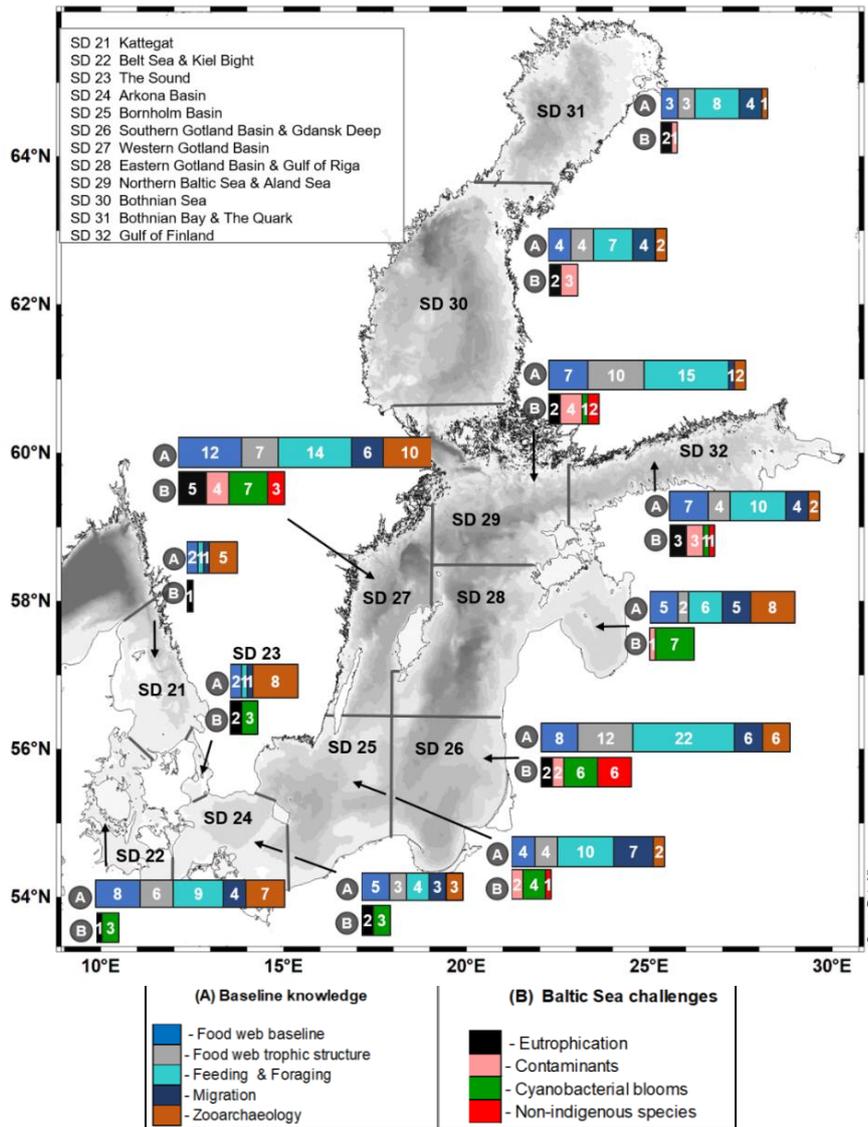


Figure 2. Spatial coverage and scientific topics of peer-reviewed stable isotope studies with an ecological focus in the Baltic Sea ($n = 116$), synthesized in a systematic review effort within BONUS XWEBS. The grouping by primary focus on "Baseline knowledge" (Panel A) and "Baltic Sea challenges" (Panel B) and by International Council for the Exploration of the Sea (ICES) sub-divisions (SDs) shows the broad spatial coverage and range of scientific and resource management related questions addressed. At the same time, individual studies often had a spatio-temporally limited coverage and rarely integrated across more than two trophic levels, which limited conclusions on the scales that are relevant for resource management of the Baltic Sea. From Eglite et al. (*in prep.*).

Recommendations

Baltic Sea food webs are complex, but the knowledge base for the region has grown significantly over the past decades. There is a strong foundation for advancing food web research through the existing high-quality research, monitoring and regulation frameworks for the Baltic. At the same time, substantial knowledge gaps, e.g., for non-commercial fishes, invertebrates, impacts of non-indigenous species, and differential data availability for different regions and zones (e.g., coastal vs. offshore) of the Baltic, complicate the assembly of Baltic-wide datasets. Another problem concerns the accessibility of biological data: excavating and synthesizing existing data consumes substantial amounts of time, because databases and access in open repositories for primary data are often lacking.

Aims for the future therefore include:

- Strengthening foundational data. Coherent information is needed on feeding relationships and -preferences on relevant temporal and spatial scales (native species as well as introduced non-indigenous taxa, across trophic levels).

- Moving towards coherent biological datasets in the Baltic Sea; i.e., compile and maintain easily accessible and comprehensive Baltic-wide databases of key food web parameters.
- Acquiring quantitative information to assess dynamics of food web components and processes, including aspects of coupling and decoupling.
- Improving our understanding of food web consequences of multiple drivers (top-down & bottom-up, non-indigenous species), including novelty.
- Incorporating the needs of management of the marine resources when defining aims and approaches for monitoring of the Baltic Sea food webs.

This policy brief is based on synthesis work and thoughts developed in XWEBS WP2 “Gap analysis and vision for food web research”, and the corresponding WP2 manuscript:

Nordström MC, Salo T, Eero M, Neuenfeldt S, Blenckner T, Bonsdorff E, Eglite E, Häubner N, Jacob U, Jonsson P, Köster F, Kotta J, Lindegren M, MacKenzie B, Margonski P, Möllmann C, Oesterwind D, Ojaveer H, Otto SA, Reusch T, Sommer U, Temming A, Tomczak M, Tomkiewicz J, Uusitalo L, Winder M, Dierking J (to be submitted to AMBIO in January 2021) Gap analysis and a future perspective for Baltic Sea food web research.

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Contact details - For more information about the research underlying this policy brief, please contact Dr. Marie Nordström, marie.nordstrom@abo.fi or Dr. Jan Dierking, jdierking@geomar.de.

BONUS XWEBS - For more overarching information on Baltic food webs and other project output and policy briefs, visit our XWEBS [website](#)

Further literature cited:

Dierking, J. and EU BONUS XWEBS team (2021) BONUS XWEBS policy brief no. 1: Managing marine resources in a sea of change – Lessons from past trajectories of biological change in the Baltic time machine. EU BONUS project XWEBS, Kiel, Germany, 4 pp. DOI [10.3289/XWEBS_Policy_brief_1](https://doi.org/10.3289/XWEBS_Policy_brief_1).

Neuenfeldt, S., Ojaveer, H., Dierking, J. and EU BONUS XWEBS team (2021) BONUS XWEBS policy brief No. 3.: Using trophic models to solve the food web indicator dilemma – How to match the legislative needs of food web assessments with the structure of food web constituents and associated key ecological processes. EU BONUS project XWEBS, Kiel, Germany, 5 pp. DOI [10.3289/XWEBS_Policy_brief_3](https://doi.org/10.3289/XWEBS_Policy_brief_3).

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Kortsch S, Frelat R, Pecuchet L, Olivier P, Putnis I, Bonsdorff E, Ojaveer H, Jurgensone I, Strāķe S, Rubene G, Krūze Ē, Nordström MC (in review) Disentangling temporal food web dynamics facilitates understanding of ecosystem functioning. Journal of Animal Ecology.

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