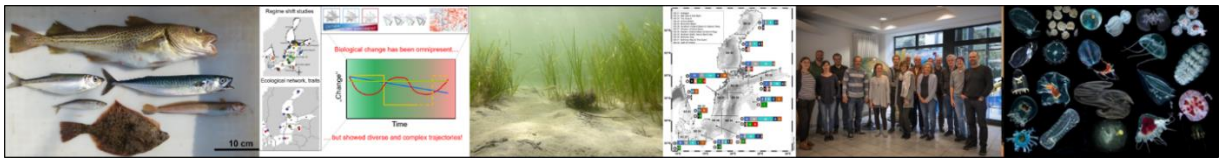
BONUS XWEBS policy brief no. 3[1]



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

Highlights

We propose to support assessments of Good Environmental Status of Baltic food webs by more formal use of the multitude of available trophic and ecosystem models for the region to complement and better operationalize the currently available suite of indicators. This way, the dynamic interactions between species that exploit the same resources can be simulated. Accounting for these interactions and interdependencies under dynamic forcing, including anthropogenic impacts and changing environmental conditions, is key to define envelopes for indicator values. This would represent a large conceptual leap forward, and would address the accumulating consensus that resource management in the temporally highly dynamic and rapidly changing Baltic Sea needs to be adaptive and account for moving targets.

The problem

A defining characteristic of marine resource management under EU directives and regulations is to aim for "good environmental status" (GES). More specifically, *'**Good environmental status**' means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive **within their intrinsic conditions**, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations […].'* (extract from Article 3(5) of the Marine Strategy Framework Directive (MSFD)).

Food web information plays an essential role in ecosystem assessments and in the move towards ecosystem-based fisheries management (Köster et al in review), which puts a prime on suitable indicators reflecting food web status. The descriptors defining food web indicators in the MSFD have recently changed (Box 1). They now exclusively aim to measure the diversity within groups of species exploiting the same resources, so called 'trophic guilds', as well as the balance between trophic guilds.

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

Box 1: Information on the EU MSFD criteria, and associated detailed information for the food web assessment.

COMMISSION DECISION (EU) 2017/848:

D4C1 — Primary: The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures.

D4C2 — Primary: The balance of total abundance between the trophic guilds is not adversely affected due to anthropogenic pressures.

D4C3 — Secondary: The size distribution of individuals across the trophic guild is not adversely affected due to anthropogenic pressures.

D4C4 — Secondary (to be used in support of criterion D4C2, where necessary): Productivity of the trophic guild is not adversely affected due to anthropogenic pressures.

Specifications and standardised methods for monitoring and assessment

1. Species composition shall be understood to refer to the lowest taxonomic level appropriate for the assessment.

2. The trophic guilds selected under criteria elements shall take into account the ICES list of trophic guilds and shall meet the following conditions:
(a) include at least three trophic guilds;
(b) two shall be non-fish trophic guilds;
(c) at least one shall be a primary producer trophic guild;
(d) preferably represent at least the top, middle and bottom of the food chain.

Units of measurement: — D4C2: total abundance (number of individuals or biomass in tonnes (t)) across all species within the trophic guild.

The 'intrinsic conditions' shaping guild balance and diversity are far from constant in the Baltic Sea, which has been identified as regional sea with outstandingly high vectors of change (Reusch et al 2018, BONUS XWEBS WP1 policy brief). Hence, species abundances and biomasses reflecting GES today might not do so in the future, e.g., due to climate change and eutrophication that change living conditions.

Furthermore, there is a decoupling between current regulations of fisheries activities and eutrophication and food web indicators, because the dynamic interactions between trophic guild diversity and balance, and the different forms of exploitation are largely unknown.

To evaluate progress and possibilities towards food web status assessments, XWEBS WP3 reviewed the suite of actual food web indicators in parallel to the portfolio of existing ecosystem models in the Baltic Sea. We then assessed the potential of models to derive or operationalize lacking indicators, and to integrate the dynamic aspects of Baltic systems into assessments.

Key results and conclusions

Available food web indicators cover primary and secondary producers, planktivores, sub-apex predators and sub-apex demersal predators. At the same time, indicators are lacking for filter feeders, deposit feeders and apex predators, planktivorous plankton organisms (e.g. jellyfish and mysids), and are insufficient for important trophic groups including macrozoobenthos, which is a driving force for

food web interactions in both the shallow coastal areas and open sea systems of the Baltic Sea, and for upper trophic levels. The available indicators are summarized in Tables 1 and 2.

Our analysis showed that the available suite of indicators did not meet the MSFD requirements for any of the primary descriptor criteria. Given these limitations and the potentially even more crucial problem that existing indicators fail to account for the dynamic nature of food webs, our approach was to assess the potential to use trophic models to both derive and operationalize food web indicators.

Table 1. Availability of indicators for MSFD D4C1 [*"The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures"*]. Green: at least one already existing or potential primary food-web indicator is available per guild. Red: no existing or potential primary food-web indicator is available. Indicator in grey: example/potential indicator, requires further developmental work.

Guild\Taxonomic group	Phytoplankton	Zooplankton	Benthos	Nekton (excl. warm-blooded)	Seabirds	Marine mammals
Primary producers	1.Seasonal succession of dominating phytoplankton groups 2.Diatom to dinoflagellate ratio					
Secondary producers		4.Ratio of cladocerans to copepods 5. Microphagous mesozooplankton biomass				
Filter feeders						
Deposit feeders						
Planktivores				8.Abundance of key fish species	N/A	N/A
Sub-apex pelagic predators				9.Abundance of coastal fish key functional groups		N/A
Sub-apex demersal predators				8.Abundance of key fish species 9.Abundance of coastal fish key functional groups 13.Biomass of large predatory fish		N/A
Apex predators				N/A		

Table 2. Availability of indicators for MSFD D4C2 [*"The balance of total abundance between the trophic guilds is not adversely affected due to anthropogenic pressures"*]. For details and legend, see Table 1.

Guild\Taxonomic group	Phytoplankton	Zooplankton	Benthos	Nekton (excl. warm-blooded)	Seabirds	Marine mammals
Primary producers	3.Ratio of total zooplankton biomass to total phytoplankton biomass					
Secondary producers		3.Ratio of total zooplankton biomass to total phytoplankton biomass 6. Zooplantkon mean size and total stock				
Filter feeders						
Deposit feeders						
Planktivores				8.Abundance of key fish species 14. Biomass of small prey fish	N/A	N/A
Sub-apex pelagic predators				12.Proportion of predatory fish		N/A
Sub-apex demersal predators				12.Proportion of predatory fish		N/A
Apex predators				N/A		

As first step towards the investigation of ecosystem models as tool to operationalize food web indicators, a review effort in BONUS XWEBS identified 30 models published for the Baltic Sea. These included a range of mathematical models, including population dynamics, mass-balance, statistics, artificial intelligence, bio-geochemical, agent-based and theoretical approaches. Taken together, these models are suitable to simulate the dynamic interactions under different intrinsic conditions.

All identified models represented the dynamics of species guilds, rendering them in principle suitable for the task at hand. At the same time, some pressures such as impacts of hazardous substances and non-indigenous species were not well covered and need to be integrated in the future.

Overall, further in-depth assessment showed that food web and ecosystem models can indeed become an indispensable tool in advancing indicator-based assessments, with the potential to alleviate current limitations of monitoring activities (XWEBS WP2 policy brief) and address functional linkages between food web indicators. While some indicator-based food web assessments can be operational based on observational data only, we consider model applications inevitable to obtain estimates for unsampled indicator values, to define reference levels or to evaluate the structural uncertainty in estimates.

Based on the above considerations, we reach the following set of conclusions and derived recommendations:

Conclusions and Recommendations

- The current suite of available indicators for the Baltic Sea is insufficient to assess GES under the MSFD criteria, stressing the need for indicator development or model-based calculation and validation.
- A large suite of trophic models for the Baltic Sea has been published and is in principle available to operationalize indicators. At the same time, these models need to be carefully considered for their assumptions, representation of food web processes on adequate temporal and spatial scales, and interlinkages with other drivers and purposes.
- Moreover, data to parameterise indicators and models are sometimes lacking or insufficient, due to either lack of sampling or lack of accessibility for existing datasets.
- Diversity within and abundance/biomass balance between trophic guilds are not independent of each other.
- GES is a vector that actually includes many dependent indicators beyond the food web.
- This vector is not necessarily constant, but depends on the system state and its state-specific intrinsic processes.
- Until we know more (and this takes time!): we should use all we have at once (existing indicators, model ensemble approach, including narratives), and look for common signals in hind-, now- and forecasts of abundances, biomasses and vital rates.

This policy brief is based on synthesis work and thoughts developed in XWEBS WP3 "Integration and Transformation", and the corresponding WP3 manuscript:

Neuenfeldt S, Nordström MC, Dierking J, Uusitalo L, Tomczak MT, Haldin J, Opitz S, Bonsdorff E, Ojaveer H (in review) Food web indicators in the 21st century: bridging the gap between scientific advice and resource management needs. AMBIO

Please cite this policy brief as:

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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.

Nordström, M., Dierking, J. and EU BONUS XWEBS team (2021) BONUS XWEBS policy brief No. 2.: A perspective for Baltic Sea food web research – How food web knowledge can be integrated in adaptive ecosystem-based management of marine resources. EU BONUS project XWEBS, Kiel, Germany, 5 pp. DOI 10.3289/XWEBS_Policy_brief_2.

Eero M, Dierking J, Humborg C, Undeman E, MacKenzie B, Ojaveer H, Salo T, Köster F (in review) Use and usefulness of food web knowledge in resource management and marine environmental conservation. ICES Journal of Marine Science

Reusch TBH, Dierking J, Andersson HC, Bonsdorff E, Carstensen J, Casini M, Czajkowski M, Hasler B, Hinsby K, Hyytiäinen K, Johannesson K, Jomaa S, Jormalainen V, Kuosa H, Kurland S, Laikre L, MacKenzie BR, Margonski P, Melzner F, Oesterwind D, Ojaveer H, Refsgaard JC, Sandström A, Schwarz G, Tonderski K, Winder M, Zandersen M (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances 4

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