WORKSHOP FOR THE REVISION OF ECOSYSTEM OVERVIEWS OF THE BALTIC SEA ECOREGION (WKBALEO)

VOLUME 6 | ISSUE 91

ICES SCIENTIFIC REPORTS

RAPPORTS
SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
CIEM CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 6 | Issue 91

WORKSHOP FOR THE REVISION OF ECOSYSTEM OVERVIEWS OF THE BALTIC SEA ECOREGION (WKBALEO)

Recommended format for purpose of citation:

ICES. 2024. Workshop for the revision of Ecosystem Overviews of the Baltic Sea Ecoregion (WKBALEO). ICES Scientific Reports. 6:91. 71 pp. https://doi.org/10.17895/ices.pub.27203316

Editors

Carolyn Faithfull • Riikka Puntila-Dodd

Authors

Yosr Ammar • Andrea Belgrano • Lena Bergström • Joanna Całkiewicz • Aleksander Drgas
Carolyn Faithfull • Elena Gorokova • Janis Gruduls • Maysa Ito • Iveta Jurgensone • Katriina Juva
Astra Labuce • Piotr Margoński • Inigo Martinez • Rasa Mokune • Barbel Muller-Karulis
Marie Nordström • Monika Normant-Saremba • Mikko Olin • Okko Outinen • Heikki Peltonen
Guilherme Pinto • Riikka Puntila-Dodd • Ivars Putnis • Mariusz Sapota • Marco Scotti • Jesper Stage
Peter Thor • Maciej Tomczak • Raisa Turja • Christian von Dorrien • Staffan Waldo • Agata Weydmann

ICES
CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Contents

i Executive summary

Workshop for the revision of the Ecosystem Overview of the Baltic Sea Ecoregion (WKBALEO) worked to synthesize the knowledge that underpins the revision of the ICES Baltic Sea Ecosystem Overview. The Baltic Sea Ecosystem Overview aims to determine the main human activity sectors that cause pressures impacting the ecosystem components.

WKBALEO experts have evaluated the links between sectors, pressures and ecosystem components using a linkage framework and pressure assessment process that examines and scores all direct pressures and human activities for the Baltic Sea ecoregion following the ICES technical guidelines methodology and using the most up-to-date scientific knowledge.

The results indicate that most prevalent pressures in the Baltic Sea are related to nutrient discharge from multiple sources as well as impacts from species extraction, e.g. fishery including bycatch and substrate disturbance. Furthermore, contaminants and litter, mainly due to their persistence and widespread prevalence, were identified as significant pressures in the Baltic Sea.

This report also includes a description of the current ecosystem state in the Baltic Sea, where large areas of low oxygen concentration in the Central Baltic affecting benthic productivity, internal nutrient cycling, and fish recruitment, are especially concerning. Despite extensive literature on the Baltic Sea there are still knowledge gaps on the cumulative effects of pressures on ecosystem components, particularly for contaminants and their sources.

The workshop discussed emerging issues such as the increased requirement for offshore wind farms and mining, which can have impacts on the ecosystem as well as on management decisions in the future.

ii Expert group information

Expert group name	Workshop for the revision of the Ecosystem Overview of the Baltic Sea Ecoregion (WKBALEO)
Expert group cycle	Annual
Year cycle started	2023
Reporting year in cycle	1/1
Chairs	Carolyn Faithfull, Sweden
	Riikka Puntila-Dodd, Finland
Meeting venue and dates	6–8 November 2023, Gdynia, Poland (27 Participants)

1 Introduction

The Workshop for the production of the Ecosystem Overview of the Baltic Sea Ecoregion (WKBALEO) was held in Gdynia, Poland with participation of two ICES secretariat members and contributed to directly by 27 experts from the Baltic Sea area (see agenda below; Table 1.1). The report was finalized in a follow up meeting in Kiel, Germany in May 2024. The pressures on the Baltic Sea Ecosystem were assessed using the ICES Technical Guidelines for ICES Ecosystem Overviews. The guidelines list 18 activities which all were considered. All 16 pressures were considered. Finally, eight ecological characteristics are listed in the Technical Guidelines, but here we assessed the impacts for altogether 14 ecosystem components that were considered to be important for the Baltic Sea ecosystem. Following the workshop the assessment of these 14 ecosystem components were collapsed to fit the eight components for the Ecosystem Overview.

Table 1.1 Agenda for the WKBALEO.

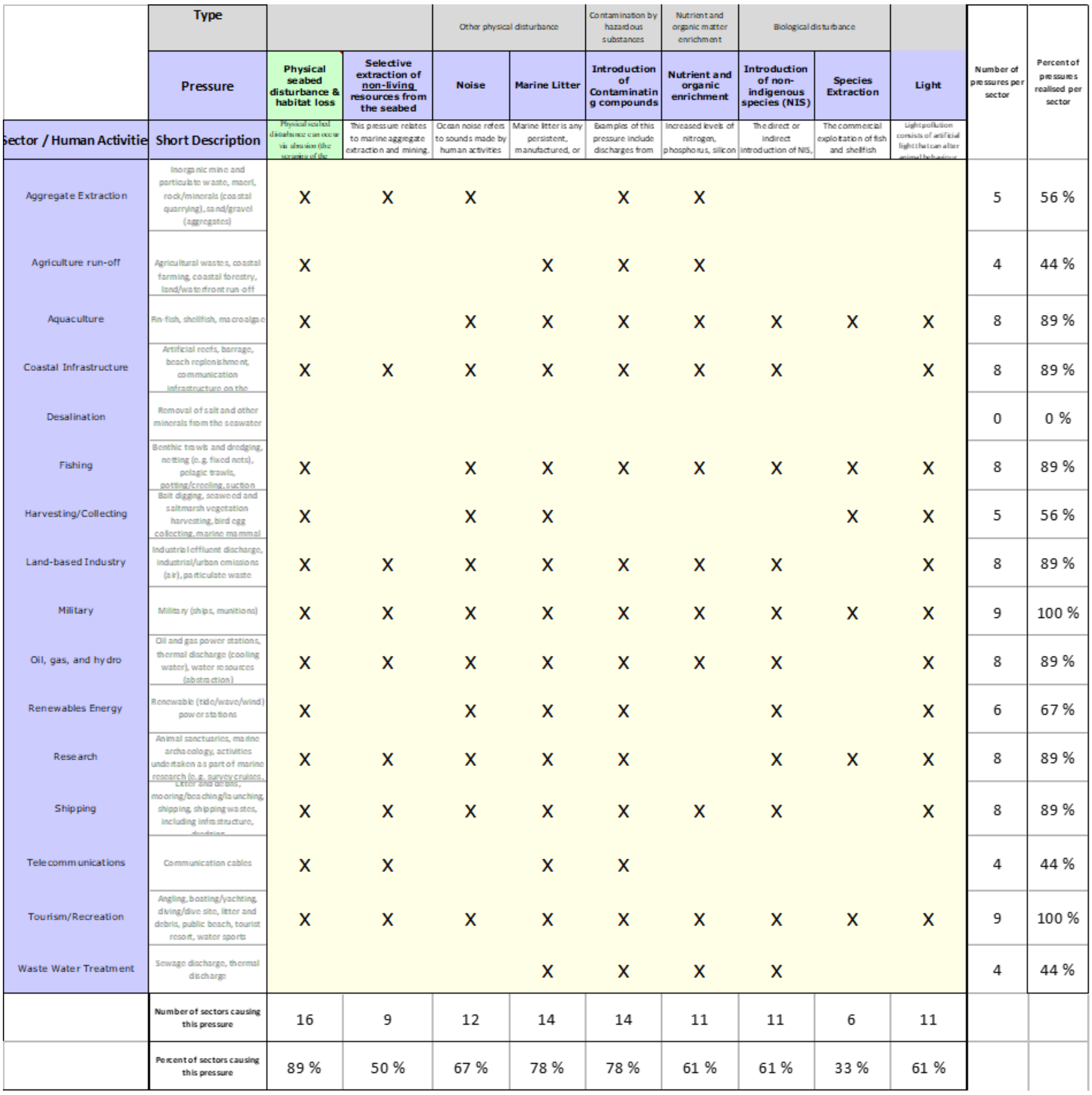
Monday 6 November 2023	
Time	**Topic**
9:00-12:00	Welcome words, round of introductions, practical things, walking through the procedures and timetables. Inigo introduced the ICES advisory process and the EOs Carolyn introduced the ODEMM approach and how EO compares to HOLAS 3. Any other pressing issues.
12:00-13:00	Lunch
13:00-17:00	Assessment of specific pressures that are widespread: Invasive species, litter, species extraction.
Tuesday 7 November 2023	
9:00-12:00	Eutrophication assessment, whole group.
12:00-13:00	Lunch
13:00-17:30	Contaminants and seabed disturbance
Wednesday 8 November 2023	
9:00-12:00	Contaminants, noise and finishing off NIS.
12:00-13:00	Lunch
13:00-17:00	Wrap-up and general discussion. Assigned writing tasks and timeline.

2 Results

2.1 Stage 1 – Linkage framework

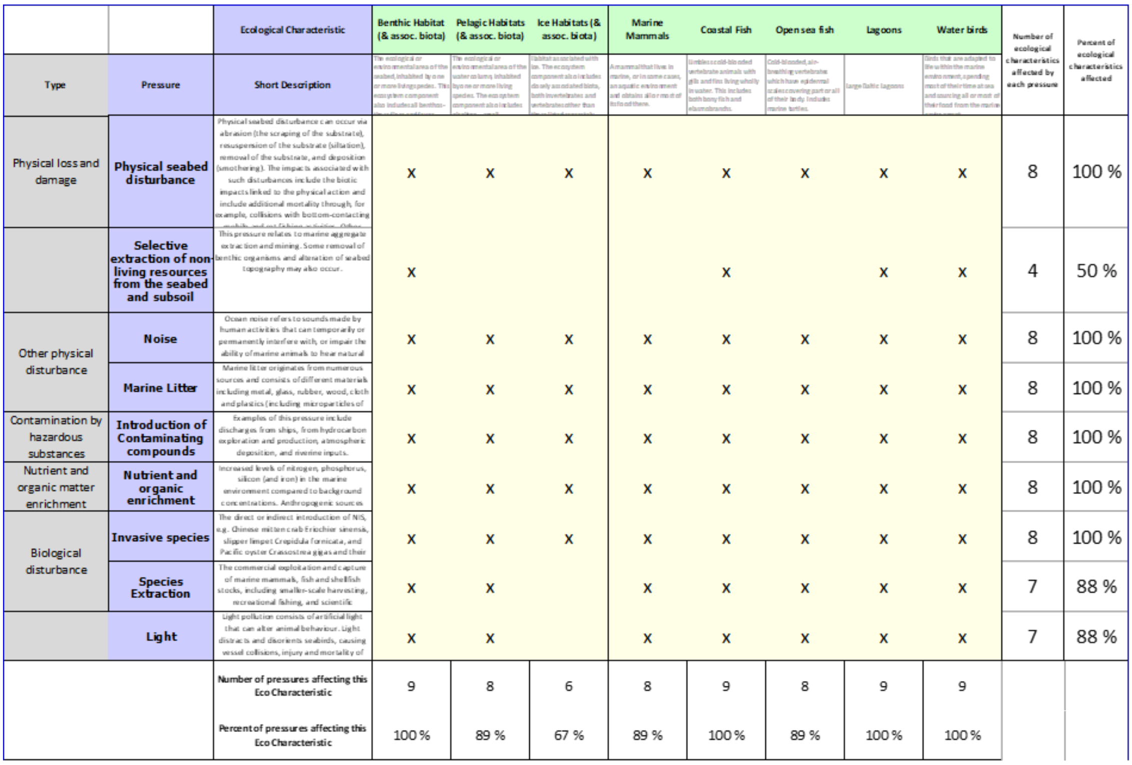
At the core of the Ecosystem Overviews are wire diagrams that illustrate the current main regional pressures alongside (a) the main human activities that cause these pressures and (b) the ecosystem components most impacted by these pressures. These wire diagrams are informed by a driver–pressure–state approach using a linkage framework and pressure assessment process that examines and scores all direct pressures and human activities in a given ecoregion. The assessment was semi-quantitative, informed by both quantitative information where available and qualitative expert judgement where little or no quantitative information is available. To create the linkage framework, we assessed which actions and pressures, and pressures and components are linked at a pre workshop meeting (see Table 2.1 and 2.2). This was done by first identifying all relevant pressures and human activities present in the Baltic Sea (see Annex 1 and 2 in ICES Technical Guidelines for ICES Ecosystem Overviews for definitions) and linking them in a matrix which was available from the Ecosystem Overviews SharePoint site (Table 2.1). Secondly, we assessed which pressures affect which ecosystem state components (see Annex 1–3 and 5 in ICES Technical Guidelines for ICES Ecosystem Overviews for definitions) and linked these in a matrix (Table 2.2). All members of Joint ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB) contributed to the discussion and provided examples/justification from data sources and their expert knowledge. At this point, no scoring of attributes took place, only establishment of links.

Table 2.1 Linkage framework between human activities and associated pressures.



	Type			Other physical disturbance		Contamination by hazardous substances	Nutrient and organic matter enrichment	Biological disturbance				
	Pressure	Physical seabed disturbance & habitat loss	Selective extraction of non-living resources from the seabed	Noise	Marine Litter	Introduction of Contaminating compounds	Nutrient and organic enrichment	Introduction of non-indigenous species (NIS)	Species Extraction	Light	Number of pressures per sector	Percent of pressures realised per sector
Sector / Human Activitie	Short Description	Physical seabed disturbance can occur via abrasion (the scraping of the	This pressure relates to marine aggregate extraction and mining.	Ocean noise refers to sounds made by human activities	Marine litter is any persistent, manufactured, or	Examples of this pressure include discharges from	Increased levels of nitrogen, phosphorus, silicon	The direct or indirect introduction of NIS,	The commercial exploitation of fish and shellfish	Light pollution consists of artificial light that can alter animal behaviour		
Aggregate Extraction	Inorganic mine and particulate waste, maerl, rock/minerals (coastal quarrying), sand/gravel (aggregates)	X	X	X		X	X				5	56 %
Agriculture run-off	Agricultural wastes, coastal farming, coastal forestry, land/waterfront run-off	X			X	X	X				4	44 %
Aquaculture	Fin-fish, shellfish, macroalgae	X		X	X	X	X	X	X	X	8	89 %
Coastal Infrastructure	Artificial reefs, barrage, beach replenishment, communication infrastructure on the	X	X	X	X	X	X	X		X	8	89 %
Desalination	Removal of salt and other minerals from the seawater										0	0 %
Fishing	Benthic trawls and dredging, netting (e.g. fixed nets), pelagic trawls, potting/creeling, suction	X		X	X	X	X	X	X	X	8	89 %
Harvesting/Collecting	Bait digging, seaweed and saltmarsh vegetation harvesting, bird egg collecting, marine mammal	X		X	X				X	X	5	56 %
Land-based Industry	Industrial effluent discharge, industrial/urban emissions (air), particulate waste	X	X	X	X	X	X	X		X	8	89 %
Military	Military (ships, munitions)	X	X	X	X	X	X	X	X	X	9	100 %
Oil, gas, and hydro	Oil and gas power stations, thermal discharge (cooling water), water resources (abstraction)	X	X	X	X	X	X	X		X	8	89 %
Renewables Energy	Renewable (tide/wave/wind) power stations	X		X	X	X		X		X	6	67 %
Research	Animal sanctuaries, marine archaeology, activities undertaken as part of marine research (e.g. survey cruises,	X	X	X	X	X		X	X	X	8	89 %
Shipping	Litter and debris, mooring/beaching/launching, shipping, shipping wastes, including infrastructure,	X	X	X	X	X	X	X		X	8	89 %
Telecommunications	Communication cables	X	X		X	X					4	44 %
Tourism/Recreation	Angling, boating/yachting, diving/dive site, litter and debris, public beach, tourist resort, water sports	X	X	X	X	X	X	X	X	X	9	100 %
Waste Water Treatment	Sewage discharge, thermal discharge				X	X	X	X			4	44 %
	Number of sectors causing this pressure	16	9	12	14	14	11	11	6	11		
	Percent of sectors causing this pressure	89 %	50 %	67 %	78 %	78 %	61 %	61 %	33 %	61 %		

Table 2.2 Linkage framework between pressures and ecological components.



		Ecological Characteristic	Benthic Habitat (& assoc. biota)	Pelagic Habitats (& assoc. biota)	Ice Habitats (& assoc. biota)	Marine Mammals	Coastal Fish	Open sea fish	Lagoons	Water birds	Number of ecological characteristics affected by each pressure	Percent of ecological characteristics affected
Type	Pressure	Short Description	The ecological or environmental area of the seabed, inhabited by one or more living species. This ecosystem component also includes all benthos-	The ecological or environmental area of the water column, inhabited by one or more living species. The ecosystem component also includes	Habitat associated with ice. The ecosystem component also includes closely associated biota, both invertebrates and vertebrates other than	A mammal that lives in marine, or in some cases, an aquatic environment and obtains all or most of its food there.	Limbless cold-blooded vertebrate animals with gills and fins living wholly in water. This includes both bony fish and elasmobranchs.	Cold-blooded, air-breathing vertebrates which have epidermal scales covering part or all of their body. Includes marine turtles.	Large Baltic lagoons	Birds that are adapted to life within the marine environment, spending most of their time at sea and sourcing all or most of their food from the marine		
Physical loss and damage	**Physical seabed disturbance**	Physical seabed disturbance can occur via abrasion (the scraping of the substrate), resuspension of the substrate (siltation), removal of the substrate, and deposition (smothering). The impacts associated with such disturbances include the biotic impacts linked to the physical action and include additional mortality through, for example, collisions with bottom-contacting	X	X	X	X	X	X	X	X	8	100 %
	Selective extraction of non-living resources from the seabed and subsoil	This pressure relates to marine aggregate extraction and mining. Some removal of benthic organisms and alteration of seabed topography may also occur.	X				X		X	X	4	50 %
Other physical disturbance	**Noise**	Ocean noise refers to sounds made by human activities that can temporarily or permanently interfere with, or impair the ability of marine animals to hear natural	X	X	X	X	X	X	X	X	8	100 %
	Marine Litter	Marine litter originates from numerous sources and consists of different materials including metal, glass, rubber, wood, cloth and plastics (including microparticles of	X	X	X	X	X	X	X	X	8	100 %
Contamination by hazardous substances	**Introduction of Contaminating compounds**	Examples of this pressure include discharges from ships, from hydrocarbon exploration and production, atmospheric deposition, and riverine inputs.	X	X	X	X	X	X	X	X	8	100 %
Nutrient and organic matter enrichment	**Nutrient and organic enrichment**	Increased levels of nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Anthropogenic sources	X	X	X	X	X	X	X	X	8	100 %
Biological disturbance	**Invasive species**	The direct or indirect introduction of NIS, e.g. Chinese mitten crab Eriochier sinensis, slipper limpet Crepidula fornicata, and Pacific oyster Crassostrea gigas and their	X	X	X	X	X	X	X	X	8	100 %
	Species Extraction	The commercial exploitation and capture of marine mammals, fish and shellfish stocks, including smaller-scale harvesting, recreational fishing, and scientific	X	X		X	X	X	X	X	7	88 %
	Light	Light pollution consists of artificial light that can alter animal behaviour. Light distracts and disorients seabirds, causing vessel collisions, injury and mortality of	X	X		X	X	X	X	X	7	88 %
		Number of pressures affecting this Eco Characteristic	9	8	6	8	9	8	9	9		
		Percent of pressures affecting this Eco Characteristic	100 %	89 %	67 %	89 %	100 %	89 %	100 %	100 %		

2.2 Stage 2 – Scoring

The Stage 2 scoring of the Ecosystem Overview was done in the Gdynia workshop, on 6–8 November 2023. Stage 2 scoring was revisited in Stage 3 when the resulting scores were quality assured, and some adjustments were made in order to maintain consistency. The final scores from Stage 2 can be seen in Figure 2.1–2.5.

Categorical scores were assigned for the 1) spatial extent, 2) frequency of occurrence, and 3) degree of impact of each of the identified linkage chains (human activity–pressure–ecosystem state component). Data were used to inform scores and documented where available. The HELCOM state of the environment report (2023) and the HELCOM data and map service were used to inform assessment in addition to scientific papers and reports. Where published information was unavailable, expert judgement was used to score the linkages. The three types of information sources were given a confidence score, high (H) for scientific papers studying the Baltic Sea, medium (M) for grey literature or scientific studies outside the Baltic Sea, and low (L) for expert judgement.

Spatial extent refers to the spatial overlap between a pressure and its associated ecosystem state components. The spatial distribution of the pressure may be inferred from that of the human activity but, depending on the pressure, may differ due to e.g. dispersal. In the case of dispersal, the estimated spatial extent should be aligned to the estimated degree of impact. The overlap scores for the Baltic Sea area shown in Figure 2.1. The categorical scores of spatial extent were relatively broad and were defined as follows:

- Exogenous (an activity occurs outside of the area occupied by the ecosystem state component; the pressures would reach the ecosystem component through dispersal)
- Site (0–5% overlap)
- Local (5–50%)
- Widespread, patchy (> 50%)

- Widespread, even (> 50%)

Scores for the frequency of occurrence of a pressure from a specific human activity were based on the frequency of encounter between the pressure and ecosystem component (in an average year) in the area of overlap. This is pressure-specific and scores for the Baltic Sea are shown in Figure 2.2. Scores were assigned for frequency in the following categories:

- Rare (the pressure occurs up to one month per year)
- Occasional (the pressure occurs up to four months per year)
- Common (the pressure occurs up to eight months per year)
- Persistent (the pressure occurs in every month of the year)

Degree of impact is the severity (or likely degree of impact) of any pressure when it encounters an ecosystem component. The scores for the Baltic Sea are shown in Figure 2.3. The following scores were applied:

- Low pressures are not considered to (currently) cause (sub)population level/functional group effects.
- Chronic pressures may have a population-level/functional effect if they have a high enough spatial and/or temporal occurrence (i.e. chronic nature).
- Acute (immediate) impacts are expected/known to occur.

Each score was assigned independently of the other scores. For instance, the degree of impact of a specific pressure on an ecosystem state component was not expected to change depending on the human activity causing the pressure; e.g. ‘physical-seabed-disturbance’ affecting ‘habitats’ will have the same effect on the habitats whether it is caused by ‘fishing’ or by ‘navigational dredging’.

We initially scored the linkage framework for a greater number of fish and benthic habitats groups than required for the Ecosystem Overview (Table 2.3). For example, in the benthic habitats category we included aphotic soft and hard bottoms and photic soft and hard bottoms, littoral habitat and lagoons. Scores for these six ecosystem components were combined for the overall benthic habitats score. For fish we initially included four fish components, coastal fish, pelagic fish, demersal fish and migratory fish. Scores for these four fish groups were combined to form the fish ecosystem component. The basic rule for consolidating the multiple fish and benthic component scores into the single (fish or benthic habitats) components scores was that if two or more groups of fish or benthic habitats had the same degree of impact (DoI) and frequency scores these were taken as the effect for the whole benthic or fish group even if other groups were unaffected by the pressure. The distribution of the more detailed fish and benthic habitat types were considered when deciding if the consolidated effect should have a different spatial distribution, i.e. if lagoons and littoral areas were the only components affected by the pressure, the overlap score was set as site.

Table 2.3 ICES ecosystem components included in wire diagram and components scored in the workshop with examples.

Agreed ICES Ecosystem components	More detailed components for the Baltic Sea	Example species
Fish	Coastal fish	Pike, perch, carp, sander
	Open sea fish	Herring, sprat, sticklebacks
	Demersal fish	Cod, flounder
	Migratory fish	Eel, trout, salmon
Seabirds	Water birds	Seaducks, Red throated diver
Marine Mammals	Cetaceans	Harbour porpoise
	Seals	Grey, harbour and ringed seals
Pelagic habitats and assoc. Biota	Coastal pelagic waters	*Bosmina coregoni*
	Open pelagic waters	*Psuedocalanus* sp.
Ice habitats and Assoc. Biota	Ice habitats	Ringed seal, ice algae
Benthic Habitats and Assoc. Biota	Littoral zone 0-5 m depth	Cladophora, reeds
	Baltic sea lagoons	Macrophytes, Charophytes
	Shallow rock and biogenic reef 5-20 m depth	*Mytilus* sp., *Fucus* sp.
	Shallow sublittoral sediment 5-20 m depth	*Marenzellaria* spp., *Macoma balthica*
	Deep hard bottoms >20 m depth	*Saduria entomon*
	Deep soft bottoms >20 m depth	Mysids

The evidence/information used to underpin each decision/scoring was documented. A column was added to reflect confidence (1 = qualitative judgement, 2 = literature support, 3 = data support); and sources were provided where possible. The scores were also compared to recent scores for the Celtic Sea and North Sea in order to ensure our scoring was compatible, and to help identify any errors. After the scores were checked through and adjusted for errors, the table was sent out to experts again for confirmation that any changes made were reasonable and correct.

Impact risk scores were calculated as the product of the overlap, frequency and degree of impact scores (Figure 2.4).

Figure 2.1 Overview of Overlap scores. See ICES Technical Guidelines for ICES Ecosystem Overviews for definition of the scores. (E = Exogenous, S = Site, L = Local, WP = Widespread patchy, WE = Widespread even)

Figure 2.2 Overview of Frequency scores. See ICES Technical Guidelines for ICES Ecosystem Overviews for definition of the scores. (R = Rare, O = Occasional, C = Common, P = Persistent)

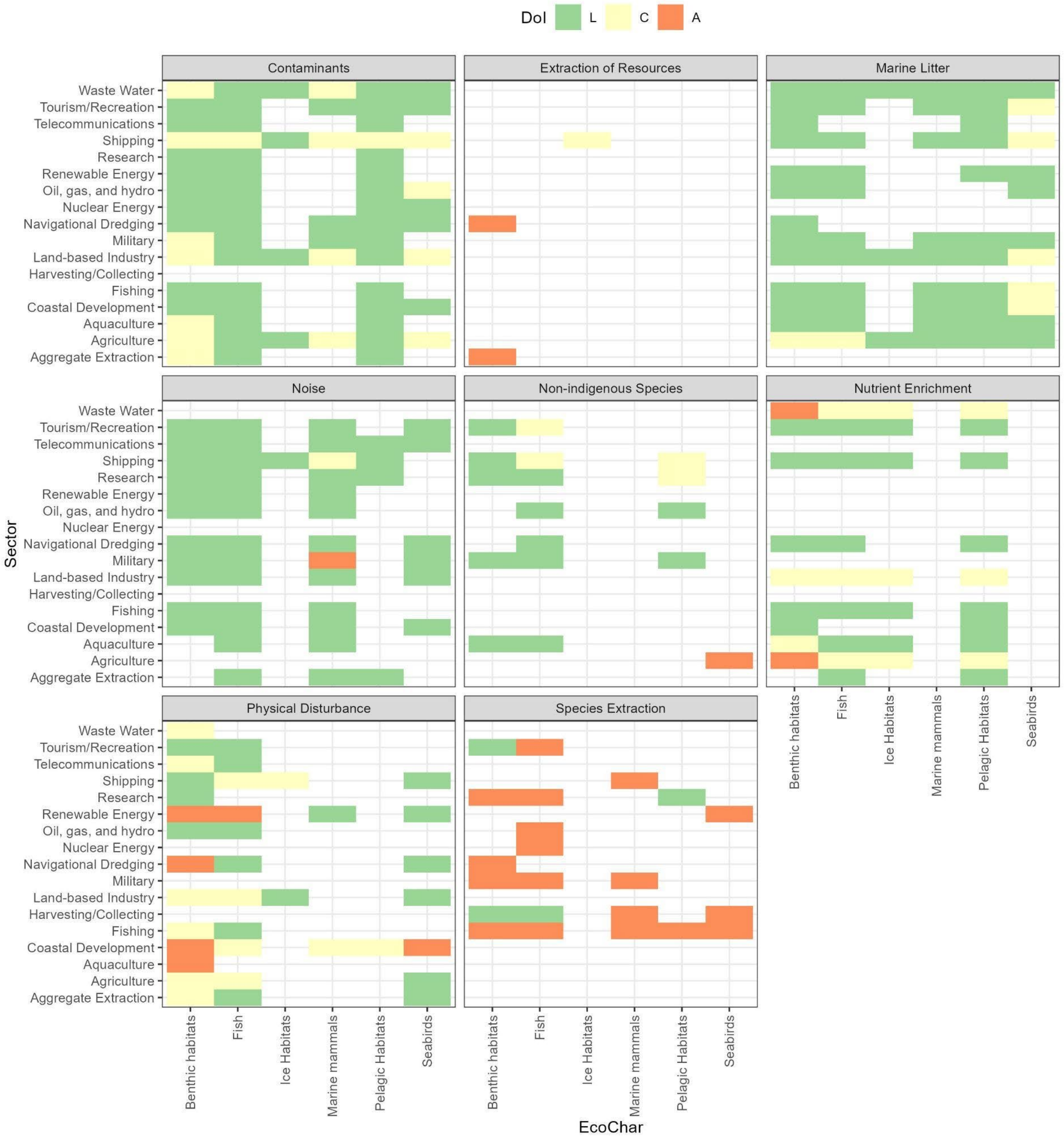


Figure 2.3 Overview of the Degree of Impact scores. See ICES Technical Guidelines for ICES Ecosystem Overviews for definition of the scores. (L = Low, C = Chronic, A = Acute)

Figure 2.4 Overview of impact risk scores. Due to the relatively high impact risk of fisheries, this shows up as the only high score and most other scores are in shades of blue, i.e. low.

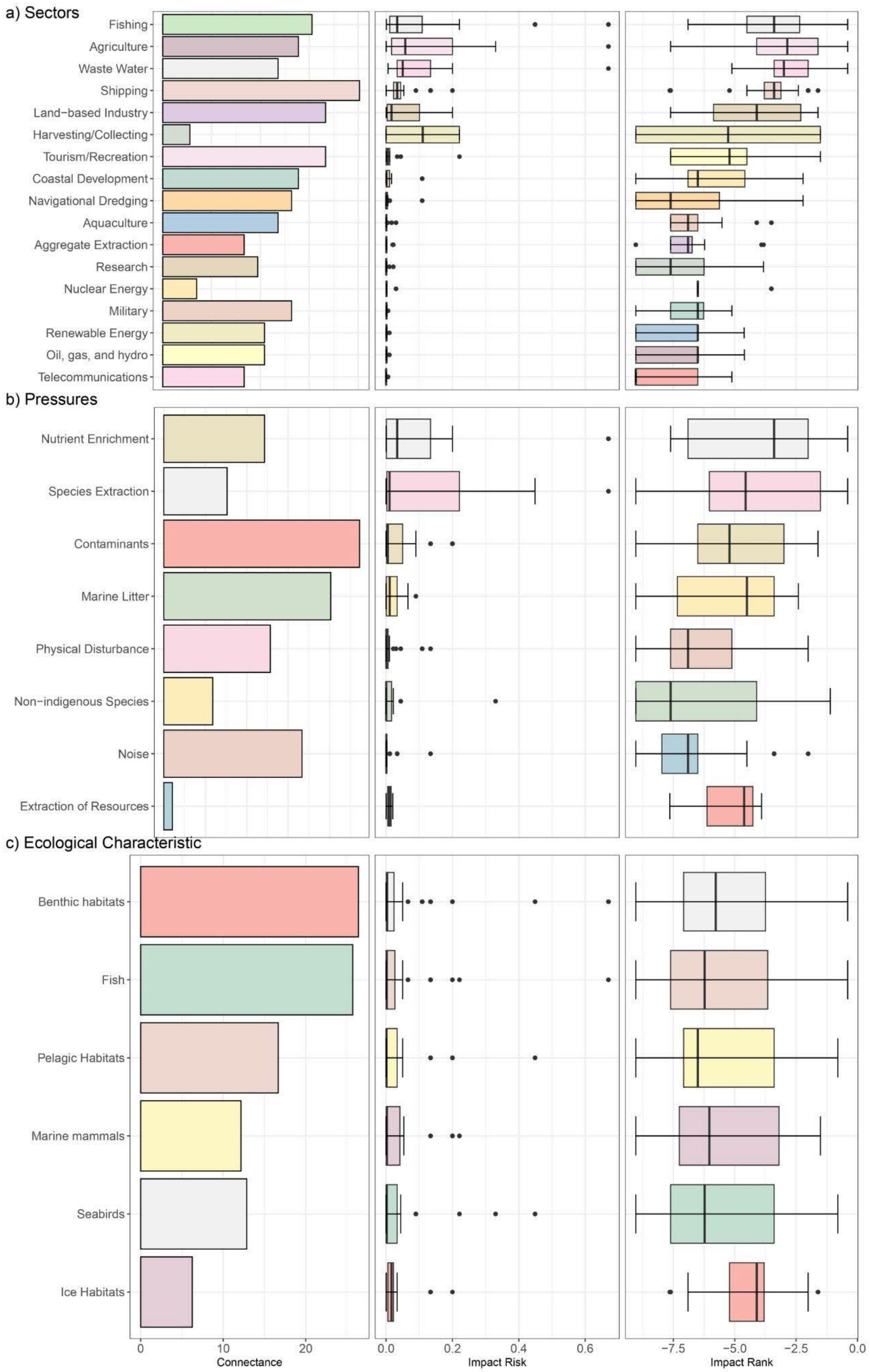


Figure 2.5 Connectance, impact risk scores, and impact risk scores on a log scale that allows lower impact risks to become visible.

2.3 Stage 3 – Analysis and quality assurance

All identified linkages are shown in the Sankey diagram (Figure 2.6), the sums are shown in Table 2.4, percent contribution to the risk scores in Table 2.5 and a draft plot of the ecosystem pressures in Figure 2.7. The total absolute sum of impact risk scores is 11.78, which can be compared to impact risk scores in other ecosystems.

Categorical scores are converted to numerical scores according to Table 1 in the ICES Technical Guidelines for ICES Ecosystem Overviews. Impact risk scores per linkage chain were calculated as the product of the three scores assigned in Stage 2 (i.e. spatial extent × frequency of occurrence × degree of impact). Each impact risk score is then calculated as a percentage of the total risk (= the sum of all chains) in the ecosystem, and those contributing more than 1% to the total risk score are identified as top risks relevant for management action. Further comprehensive analyses are available via R script, with outputs included in IEA group reports.

The wire diagram has been created by the ICES Secretariat in consultation with the WKBALEO expert group.

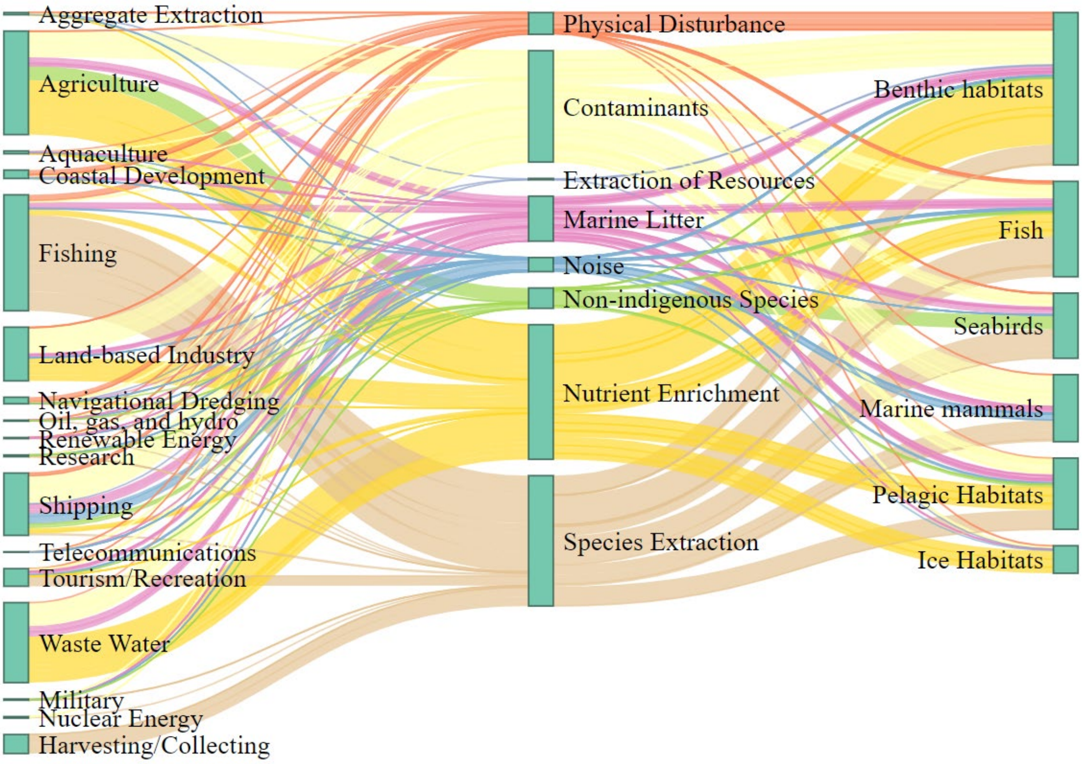
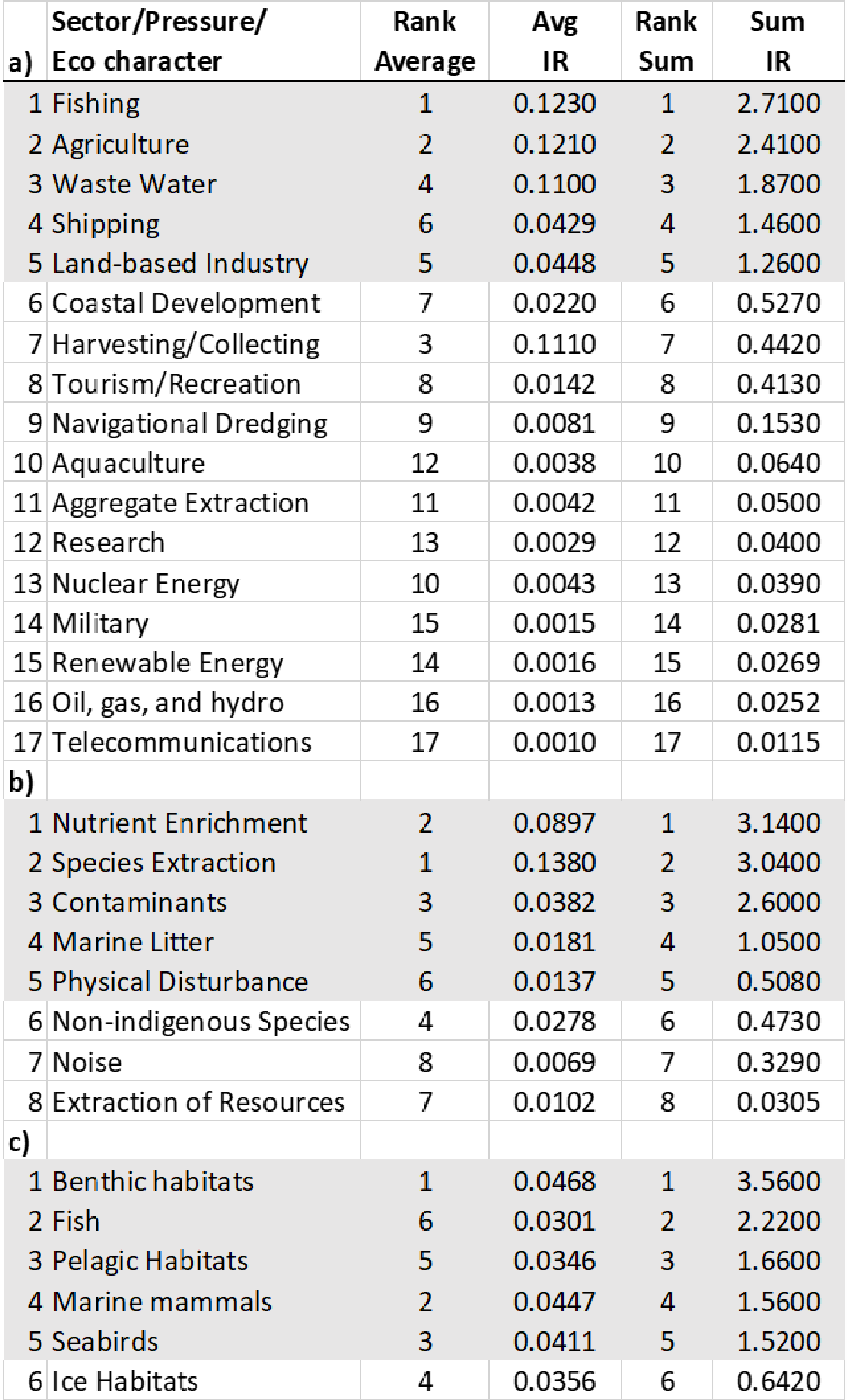


Figure 2.6 Sankey diagram showing all linkages between Activities, Pressures and Ecosystem Components.

Table 2.4 Overview over the sums of Impact Risks and Relative Impact Risks based the total scores. The tables a and b show the Sectors and Pressures that have a Relative Impact Risk >1, and, on the left, the corresponding Human Activities that cause these Pressures. The lower two tables show the sum of all Impact Risks caused by Pressures (right hand side) and Human Activities (left hand side). The top five Pressures and corresponding Human Activities are highlighted in grey.



a)	Sector/Pressure/ Eco character	Rank Average	Avg IR	Rank Sum	Sum IR
1	Fishing	1	0.1230	1	2.7100
2	Agriculture	2	0.1210	2	2.4100
3	Waste Water	4	0.1100	3	1.8700
4	Shipping	6	0.0429	4	1.4600
5	Land-based Industry	5	0.0448	5	1.2600
6	Coastal Development	7	0.0220	6	0.5270
7	Harvesting/Collecting	3	0.1110	7	0.4420
8	Tourism/Recreation	8	0.0142	8	0.4130
9	Navigational Dredging	9	0.0081	9	0.1530
10	Aquaculture	12	0.0038	10	0.0640
11	Aggregate Extraction	11	0.0042	11	0.0500
12	Research	13	0.0029	12	0.0400
13	Nuclear Energy	10	0.0043	13	0.0390
14	Military	15	0.0015	14	0.0281
15	Renewable Energy	14	0.0016	15	0.0269
16	Oil, gas, and hydro	16	0.0013	16	0.0252
17	Telecommunications	17	0.0010	17	0.0115
b)					
1	Nutrient Enrichment	2	0.0897	1	3.1400
2	Species Extraction	1	0.1380	2	3.0400
3	Contaminants	3	0.0382	3	2.6000
4	Marine Litter	5	0.0181	4	1.0500
5	Physical Disturbance	6	0.0137	5	0.5080
6	Non-indigenous Species	4	0.0278	6	0.4730
7	Noise	8	0.0069	7	0.3290
8	Extraction of Resources	7	0.0102	8	0.0305
c)					
1	Benthic habitats	1	0.0468	1	3.5600
2	Fish	6	0.0301	2	2.2200
3	Pelagic Habitats	5	0.0346	3	1.6600
4	Marine mammals	2	0.0447	4	1.5600
5	Seabirds	3	0.0411	5	1.5200
6	Ice Habitats	4	0.0356	6	0.6420

Table 2.5 Percent contribution of the top five sectors and pressures with the highest relative scores to the entire assessment.

Sectors	Percent relative contribution	Pressures	Percent relative contribution
Fishing	23	Nutrient enrichment	27
Agriculture	21	Species Extraction	26
Wastewater	16	Contaminating compounds	22
Shipping	13	Marine Litter	9
Land-based Industry	11	Physical Disturbance	4
Grand Total	**84**	**Grand Total**	**88**

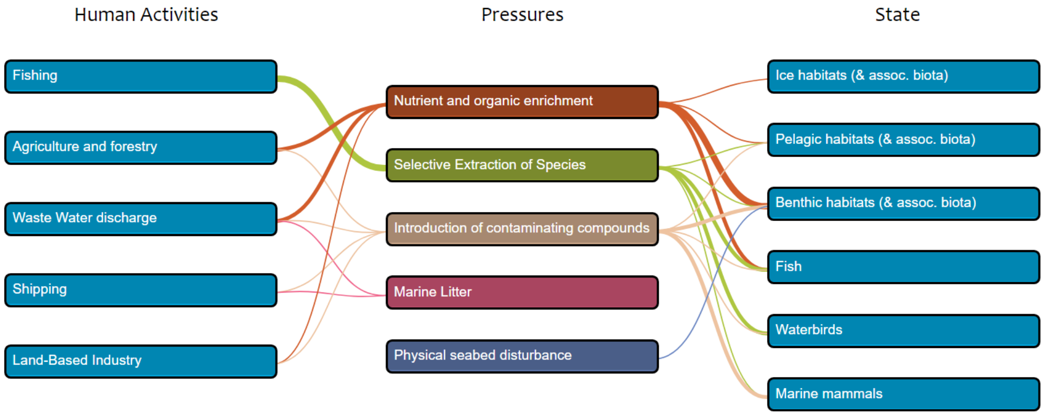


Figure 2.7 Draft wire diagram for the Baltic Sea Ecoregion.

The 'top' risks illustrated in the wire diagrams represent the linkage chains that contribute the most (≥ 1%) to the overall risk score, and the top five pressures in a given ecoregion are those with the highest summed impact risk scores per pressure (Table 2.5). The percentage of risk illustrated in the wire diagram caused by the top five pressures (Figure 2.7) is 85% of the total impact risk. Human activities and ecosystem state components are ordered in relation to their summed impact risk score (largest contributors on top, lower contributors on bottom). The absence of a line does not necessarily imply a total absence of any link as only the main links are shown. The thickness of the connecting lines in the wire diagram is determined based on the sum of the impact risk scores of the elements illustrated in the wire diagram divided into three size class bins (thus thickness reflects magnitude).

3 Highest Impact risk pressures

Based on the assessment, nutrient enrichment, Selective Extraction of Species, and Contaminating compounds are the highest pressures on the ecosystem and account for 75% of the total impact risk, with Nutrient Enrichment and Selective Extraction of Species accounting for 53%. Nutrient enrichment is mainly caused by agriculture, wastewater, and land-based industry, which accounts for 48% of the impact originating from human activities. Furthermore, species extraction is comprised almost exclusively from fishing, which accounts for 23% of the impact originating from human activities (see also Figure 2.4). Marine Litter and Physical disturbance are also included in the top five pressures; however, they account for approx. 13% of the impact and are therefore of less importance to the region in terms of management.

3.1 Nutrient and Organic enrichment

Nutrient enrichment contributed 27% to the overall Impact Risk score and has far-reaching consequences for the Baltic Sea ecosystem. The Total Absolute Impact for Nutrient enrichment is 3.14 (See ICES Technical Guidelines for ICES Ecosystem Overviews for more details). Nutrient enrichment is linked to multiple sectors and the main anthropogenic nutrient sources, agriculture and wastewater treatment, are widespread and emit continuously, contributing to the high impact risk scores. In the semi-enclosed, stratified Baltic Sea, increased primary production and organic matter sedimentation cause declining deep-water oxygen concentrations, leading to permanent hypoxia/anoxia below the halocline in various parts of the Central Baltic Sea and to seasonal hypoxia in shallow areas (Carstensen *et al.*, 2014; Carstensen and Conley, 2019). According to a recent assessment (HELCOM, 2023), only few, mainly coastal areas, are considered to have close to natural nutrient levels. Primary effects of nutrient enrichment, i.e. increased phytoplankton growth, impact all areas except the Kattegat and a few coastal regions. Only in these areas, as well as the Gulf of Bothnia, bottom oxygen conditions have not deteriorated to critical levels, and benthic communities are not significantly affected.

The combined effect of increased productivity and deteriorating oxygen conditions have far-reaching effects on Baltic Sea foodwebs. Hypoxia (Figure 3.1) affects benthic organisms and the recruitment of Eastern Baltic cod (*Gadus morhua*) (Köster *et al.*, 2017; Plikshs, 2015), a major predator in an unimpaired Central Baltic Sea, and habitat contraction limits its growth (Casini *et al.*, 2016; Eero *et al.*, 2011). In the Central Baltic Sea, foodweb dynamics have been altered by widespread hypoxia, with trophic transfers shifting towards pelagic dominance after 1990 and sprat being a central component of the community (Tomczak *et al.*, 2022).

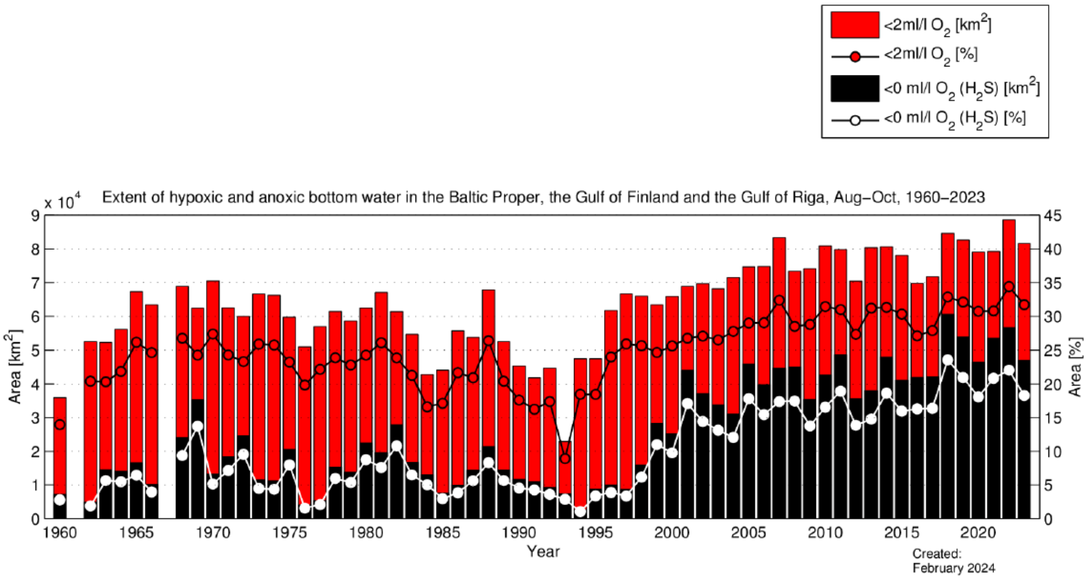


Figure 3.1 Extent of hypoxic and anoxic bottom water in the Baltic Proper, the Gulf of Finland and the Gulf of Riga. Results from 1961 and 1967 have been removed due to lack of data from the deep basins. Note that the hypoxic area is defined as all area with oxygen concentration below the limit for acute hypoxia, thus it includes both hypoxic and anoxic areas. (Source: Hansson and Viktorsson 2023, Swedish Meteorological and Hydrological Institute).

3.2 Species extraction (including bycatch)

Mainly fish is extracted from the Baltic Sea, although there are ten human activity sectors included in Species extraction-pressure, mainly considered to have acute impact on ecosystem compartments. This pressure accounts for 26% of the total Relative Impact Risk in the region. The Total Absolute Impact from Species extraction is 3.04 (See ICES Technical Guidelines for ICES Ecosystem Overviews for more details).

Fisheries are the main activity contributing to selective extraction of species in the Baltic Sea. The principal species targeted in the commercial fishery are herring *Clupea harengus*, sprat *Sprattus sprattus*, and cod, which together constitute about 95% of the total catch. Other species having local economic importance are salmon *Salmo salar*, plaice *Pleuronectes platessa*, dab *Limanda limanda*, brill *Scophthalmus rhombus*, turbot *Scophthalmus maximus*, European flounder *Platichthys flesus*, Baltic flounder *Platichthys solemdali*, pikeperch *Sander lucioperca*, pike *Esox lucius*, perch *Perca fluviatilis*, vendace *Coregonus albula*, whitefish *Coregonus sp*., eel *Anguilla anguilla*, and sea trout *Salmo trutta*. (ICES, 2022d)

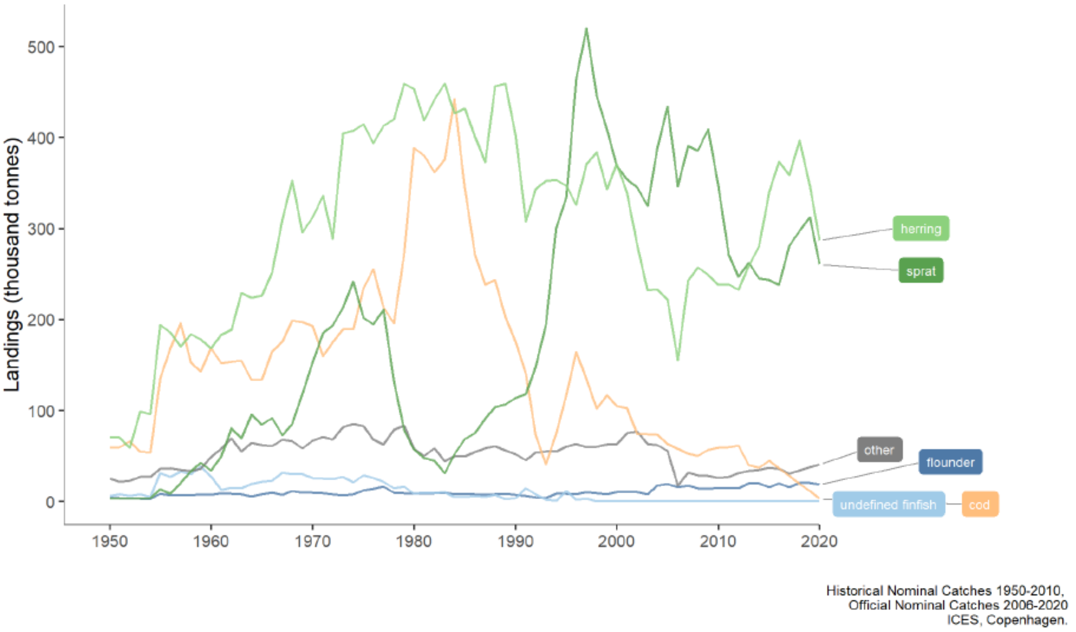
From 2020, the most important cod fishery in the Baltic Sea has been banned. There is no quota for commercial cod fishing, although there is total allowable catch (TAC) in place for unavoidable bycatch quota. Recreational fishing on cod in the Western Baltic is not permitted (Commission proposal fishing opportunities Baltic Sea 2024), however cod is recreationally caught in many other Baltic regions.

The total fish catch for the Baltic Sea has been in the range 700–800 thousand tonnes during the last two decades.

3.2.1 Landings

Since the early 1950s, landings of herring and sprat from the pelagic fisheries have dominated the total landings of fish from the Baltic Sea (Figure 3.2). A decrease in sprat landings in the late 1970s, followed by a decline in cod landings in the late 1980s, led to a marked decline in total landings (ICES, 2022d). Pelagic landings increased in the early and mid-1990s reflecting an increase in sprat abundance during this period. Since 2003, total Baltic Sea landings have remained fairly stable (Figure 3.2) despite declining fishing effort. However, crucial commercial stocks of ecological relevance, such as western Baltic spring-spawning herring, western Baltic cod, and eastern Baltic cod have recently reached their lowest levels ever. In many areas, recreational catches of coastal species outnumber the commercial catches (ICES, 2022d).

The pelagic fisheries, which account for the largest catches (by weight) in the region are the mid-water trawl fisheries for sprat and herring. The most important demersal fisheries are the bottom-trawl fisheries for cod and flatfish. Recreational fisheries in the Baltic catch a diversity of species, with cod and salmonids accounting for the largest landings and are therefore included in the assessments (ICES, 2022d).



Historical Nominal Catches 1950-2010,
Official Nominal Catches 2006-2020
ICES, Copenhagen.

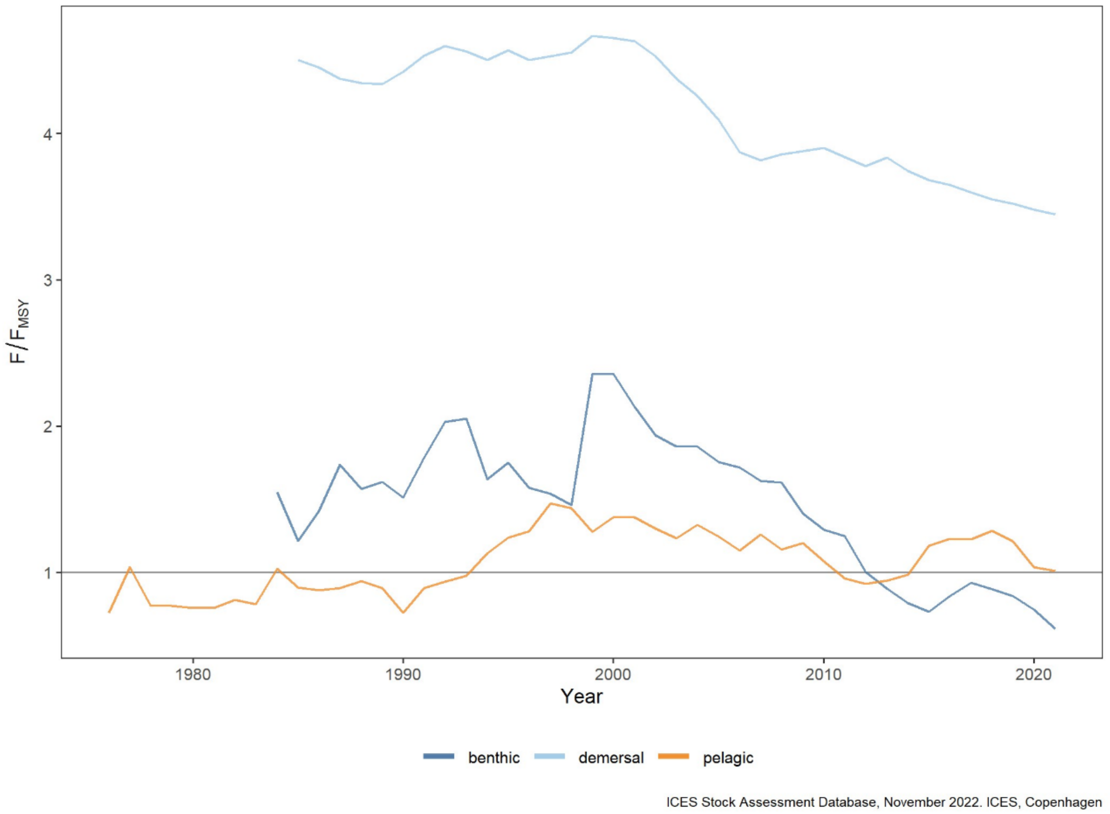
Figure 3.2 Landings (thousand tonnes) from the Baltic Sea in 1950–2020, by species. The five species with the highest landings are displayed separately; the remaining species are aggregated and labelled as "other". The "undefined finfish" category is due to inadequate reporting in early years. (Source: ICES 2022d).

3.2.2 Impacts on commercial stocks

The two major pelagic fish stocks (central Baltic herring and Baltic sprat) are fished above F_{MSY}. The other assessed herring stocks are also fished above F_{MSY} and all stocks are experiencing overfishing, except for Gulf of Riga herring. The mean F for the pelagic fish stocks has decreased in the late 2000s but has increased in the last few years (Figure 3.3).

There are two main commercially exploited demersal fish stocks in the Baltic Sea, namely the western Baltic cod and the eastern Baltic cod. The fishing mortality (F) of both cod stocks is above F_{MSY}. It is hypothesized that the reduced mean size and growth of the eastern Baltic cod stock since the 1990s is due to size-selective fishing, reduced size at maturation, poor condition, hypoxia (causing a reduction in food resources), and parasite infestation (Bryn *et al*. 2022).

In general, benthic fish stocks (flatfish species that live on the seabed, such as flounder) show a reduction of overall F since 2010, but an increase in the last few years.



ICES Stock Assessment Database, November 2022. ICES, Copenhagen

Figure 3.3 Time-series of annual relative fishing mortality (F to F_{MSY} ratio) for benthic, demersal, and pelagic stocks.

3.2.3 Discards

Discards for pelagic species in the Baltic Sea are very low, as both sprat and herring are target species, and bycatch (e.g. stickleback) is also landed. The highest discard rate is for the benthic species; however, it has been decreasing since 2016. An overall decreasing trend is also seen for demersal discard rates. Release rates for species targeted by recreational fisheries are available for most target species and are high but vary between years and countries. Post-release mortality estimates are missing for the majority of species; further studies are needed (ICES 2022d).

3.2.4 Impacts on foodwebs and regime shift

Fishing has changed both foodwebs and the community structure in the Baltic Sea. Sudden changes occurred in the foodweb of the central Baltic ecosystem in the late 1980s and early 1990s (Tomczak *et al*. 2022) which, in addition to climate forcing, can be partly explained by unsustainable fishing pressure. Patterns of seabed habitat disturbance largely reflect the distribution of bottom-trawl fishing effort.

3.2.5 Impacts on seabirds and marine mammals

Although the commercial fishery aims only for fish, diving seabirds and mammals have been impacted by fishing activities. Using only partial data, drowning in fishing gear is considered to be a significant source of anthropogenic mortality for sea ducks (i.e. common eider, long-tailed duck, common scoter and velvet scoter), and constituted most of the incidental captures of birds observed in Baltic commercial gillnets. Estimates in the early 2000s indicate that between 100 000 and 200 000 waterbirds were being caught as bycatch annually in nets in the Baltic and North seas, mostly in the Baltic (Žydelis *et al*. 2009); later estimates remain at the same level. Drowning in fishing gear is considered to be the main cause of anthropogenic mortality for harbour porpoise populations in the Baltic Sea and is also a concern for grey seals (Glemarec *et al*. 2021).

Although countries are required by European law to report official bycatch data, collection protocols for the latter are either absent or not implemented over time to allow for systematic quantification of seabird and mammal bycatch in the Baltic Sea (Morkūnas *et al*. 2022).

3.2.6 Hunting

Hunting was the main reason for a drastic decline in grey seal and ringed seal populations in the first half of the 1900s, with environmental pollution contributing to further declines until the 1970s. In the 1970s and 1980s, seals were protected by all countries in the Baltic Sea region. After recovery of the populations, controlled hunting is allowed. The highest permissible annual quota is currently around 2 000 grey seals, 230 ringed seals, and 235 harbour seals. White-tailed sea eagle *Haliaeetus albicilla* and cormorant *Phalacrocorax carbo* almost disappeared from the Baltic Sea in the early 1900s due to hunting and intentional mortality, while the populations have recovered in recent times (Bregnballe *et al*. 2022; Herrmann *et al*. 2014).

Sea ducks have traditionally been hunted, with the most common target species in the Baltic Sea being common eider *Somateria mollissima,* long-tailed duck *Clangula hyemalis* and velvet scoter *Melanitta fusca*. Shotgun practices may put extra pressure on populations not only by direct hunting mortality but also crippling and lead poisoning from ingestion of pellets (Liljebäck *et al*. 2023).

3.3 Contaminants

Contaminants have been ranked the third most important pressure in the Baltic Sea. They contribute to 22.1% of the relative pressures. Their sources span various sectors, with notable contributions from Wastewater Treatment (26%), Oil gas and hydro (19.5%), Shipping (52%) and Agriculture (2.5%). The Total Absolute Impact from Contaminants is 2.6. The overlap of contaminants with different sectors is mainly widespread patchy; although contaminants are ubiquitous in the Baltic region, their concentration varies across basins. They are identified in sediment, water, and biota and bioaccumulate across all trophic levels.

Contaminants belong to diverse substance groups (persistent organic contaminants, metals, pharmaceuticals among others). They are persistent, often enduring for decades (10 to 100 years) even after the cessation of input. Therefore, the persistence in most ecosystem components was rated high. Their introduction from multiple sources and their persistence makes their impact chronic with notable differences between substance groups. Additionally, given their persistent nature and chronic impact, the resilience of ecosystem components is rated low, necessitating prolonged recovery times.

3.4 Marine litter

Marine litter in the Baltic Sea poses a significant environmental challenge, impacting both offshore and coastal areas. The ecoregion has many types of human activities located in the sea and in surrounding nine countries. Almost all indicated human-induced pressures impact the ecological characteristics of the Baltic Sea through marine litter, with the exception of the ice environment, which experiences lower impacts from marine litter compared to other ecological characteristics. While the severity of the pressure is generally low, there are several chronic impacts.

Marine litter accounts for 9% of the total Relative Impact Risk in the region. The Total Absolute Impact from Marine litter is 1.05 (See ICES Technical Guidelines for ICES Ecosystem Overviews for more details).

3.4.1 Effects on the ecosystem

The accumulation of seabed litter, discarded fishing gear, and microplastics poses significant threats to marine life, leading to habitat destruction, organism entanglement, ingestion of litter items, and chemical effects. However, the impacts of marine litter, particularly micro- and nanoplastics, on marine organisms are still not fully understood (ICES, 2021b). Studies have revealed concerning findings that plastic litter has been discovered in the digestive tracts of fishes (cod, 15% and herring, 13%) and diving seabirds (Białowąs *et al.* 2022), e.g. long-tailed duck (5%), common murre (4.5%) and red-throated diver (3%) (Morkūnas *et al.* 2021). Furthermore, gills serve as an important pathway for plastic transfer to cod, with 9.9% of cod individuals affected in the Baltic Sea (Białowąs *et al.* 2022).

3.5 Physical seabed disturbance

Physical seabed disturbance has been ranked as the fifth most important pressure in the Baltic Sea with a total contribution of 4% to the pressure impact. Seabed physical disturbance is caused by the scraping of the substrate (abrasion), the resuspension of the substrate (siltation), the removal of the substrate, and deposition (smothering). The physical seabed disturbance impacts biotic components through physical action, including mortality caused by collisions and unintended species removal. The activities that mostly contribute to physical seabed disturbance are fishing (benthic trawls and dredging), coastal development, navigational dredging, shipping (anchoring) and aquaculture. Beside benthic habitats and associated biota, fish, ice habitats and seabirds are the ecosystem components mostly affected by the disturbance. The distribution of physical seabed disturbance caused by sectors are mainly local, except for fishing which is widespread patchy. The persistence ranges between 0 and 10 years depending on the sector. Nevertheless, the pressure on benthic habitats and some species can persist for longer periods of time, mainly in relation to infrastructure development (e.g. coastal development, land-based industry, and renewable energy). In general, despite presenting a degree of impact ranging between chronic and acute, the resilience of the ecosystem to this pressure is moderate, and the recovery time ranges between 2 and 10 years.

4 Comments on the scoring in Stage 1 and 2

As the scoring was carried out, notes were taken about the data used in the scoring, and potential data sources that can be used in the next Ecosystem Overview analysis. Knowledge gaps were also discussed (Table 4.1).

For some activities and pressures, the description for assessment were either not comprehensive or not applicable for the Baltic Sea ecosystem. For these cases, the experts have clarified how and what has been assessed. This is listed below:

4.1 Human activities

4.1.1 Aggregate Extraction

In the Western Baltic Sea sand, gravel and stone has been extracted for over a century. Current sites and estimates for extraction activities may be available on a country-by-country basis, but obtaining an overview of all current aggregate extraction sites and the frequency of extraction in the Baltic is difficult. There is an increasing demand for sand extraction for beach nourishment in the southern parts of the Baltic Sea due to sea level rise. Therefore, it would be informative if the HELCOM map service could include aggregate extraction sites with estimates for annual extraction.

4.1.2 Military

The extent of military activities in the Baltic is shrouded in secrecy making it hard to assess the frequency and spatial extent of activities. Historical munitions dumps, sunken military ships and ordinance are known problems (Beldowski *et al.* 2016; Siebert *et al.* 2022). Military forces were contacted for assessment, but we did not receive any information on the extent or impact of the actions.

4.1.3 Navigational dredging

We attempted to include the known effects of small-scale dredging in the Gulf of Bothnia here, however, the extent of small-scale dredging is difficult to assess as it is widespread and often unreported, as in most cases it does not require a permit.

4.1.4 Oil, gas and hydro

There are few oil and gas platforms in the Baltic Sea, and these are located primarily in Poland and Russia. However hydropower is widespread on the major rivers flowing into the Baltic Sea, and these power plants often lack effective measures to aid fish migration, thus acting as barriers preventing the spawning of many migratory fish (Soininen *et al.* 2019). The effects of hydropower on migratory fish are acute if migration is prevented, and effects have been considered within the oil, gas and hydro pressure section. Unfortunately, there are a significant number of sites missing on the location and extent of hydropower stations in the Baltic from the HELCOM map service (Figure 4.1). However, as these hydropower stations are located outside the Baltic Sea area the overlap was scored as exogenous, which significantly lowers the impact risk score. Thus, we propose that in the analysis these scores do not reflect the true impact and are scored too low, as the effect of hydropower stations is acute on local migratory fish populations when spawning is prevented.

Figure 4.1 Hydropower stations reported by Member Countries for the HELCOM total assessment of the environment (HELCOM Map Service). This map is incomplete and lacks some Swedish stations, Polish stations, Russian, German and Lithuanian hydropower, and therefore cannot be considered to be representative of the extent of hydropower surrounding the Baltic Sea.

4.1.5 Research

The negative effects of research are not well documented in the literature, probably because the effects are low. However, most experts involved in the scoring are also involved directly in research activities, therefore, there is a tendency to score research highly as a pressure. In our analysis we were aware of this bias and attempted to compare the relative effects of research to other activities (i.e. fishing and shipping) to give perspective to the potential effects of research activities.

4.1.6 Shipping

The effects of cruise ships are included under shipping, not under tourism/recreation.

4.1.7 Telecommunications

There are many cables crossing the Baltic Sea, although maps of cable distributions have been recently removed from the public domain, making it more difficult to assess their extent of overlap with ecological components. The effects of cable noise, heat and electromagnetic fields on species is still relatively poorly studied (Otremba *et al.* 2019), therefore we have given these effects low confidence.

4.2 Pressures

4.2.1 Contaminants

The effects of contaminants on ecological components are widespread in the Baltic Sea, have long-term consequences and are often cumulative, which makes it difficult to tease apart the effects of contaminants from different types of pressures. Here we have taken a conservative approach to effects of contaminants and given many scores a low degree of impact. With future research and better knowledge of individual and population level effects, the degree of impact may be scored higher in the future.

4.2.2 Non-indigenous species

Non-indigenous species are common in the Baltic Sea. The impact scores of the non-indigenous are here considered as the impacts of the species that have been introduced through the particular activity. Both positive and negative impacts were discussed during the scoring. Reported impacts of non-indigenous species are in many cases local and as the assessment is regional, impact scores remained low.

4.2.3 Marine litter

The effects of marine litter consider the effects of all sizes of litter including microplastics. The effects of marine litter can be coupled to certain activities, but for others are difficult to tease apart, i.e. marine litter originating from fisheries vs. from aquaculture.

4.2.4 pH changes

pH is changing in the Baltic Sea due to land-use changes, climate change, wastewater, and freshwater inflows (Gustafsson and Gustafsson 2020). Currently, there is not a great deal of research on the effects of pH change from some sources (i.e. wastewater) in the Baltic Sea.

4.2.5 Salinity

Salinity is variable across a North to South and East to West gradient in the Baltic Sea and will likely be influenced by climate change (Lehmann *et al*. 2020). The local effects of salinity change due to particular activities are not well studied.

Table 4.1 Overview over confidence and potential sources to be used in a future ecosystem assessment.

Activity	Pressure	Ecological characteristic	Confidence	Comment	Potential references	Knowledge gap
Aggregate extraction	Contaminants	All	Low	Need data on frequency and magnitude of dredging. Unsure how much contaminants that are released from dredging.	HELCOM? Maps available for dredged areas (large-scale dredging)	Yes

	Noise	All	Low	Need data on frequency and magnitude of extraction.		Yes
	Nutrients	All	Low	Uncertain how much nutrients are released from the sediment due to extraction activities.		Yes
Agriculture	Marine litter	All	Low	Agriculture can be a major source of microplastics, however how much they contribute to the Baltic Sea is unknown.	Urban-Malinga *et al*. 2018	Yes
	Physical disturbance/abrasion/siltation etc.	All	Moderate	Agriculture is a source of siltation. New satellite methods show extent. The effect can be acute (total loss of communities outside of California), but not well documented for the Baltic Sea.	Kratzer *et al*., 2020	Yes
Aquaculture	Marine litter	All	Low	No direct estimates of the amount of litter originating from only aquaculture as these estimates are combined with fishing (often same types of litter). Activities are limited in the Baltic currently. In general there are low amounts of litter in the Baltic Sea compared to the North Sea	Kamman *et al*. 2018	ICES aquaculture group and marine litter group, HELCOM marine litter?
	Nutrients	Ice habitats	Low	Difficult to know the exact contribution of nutrients from this source to ice, this is similar for all sectors.		Yes

Coastal development	Physical disturbance/abrasion/siltation etc.	Pelagic habitats	Low	Coastal development is a source of siltation. New satellite methods show extent. The effect can be acute (total loss of communities outside of California), but not well documented for the Baltic Sea.	Newell *et al.* 1998; Törnqvist *et al.* 2021	Yes
	Light	Seabirds	Moderate	Birds can be attracted to light, disruptions in migratory patterns. No evidence from Baltic.	Gjerdrum, *et al.*, 2021.	Not studied in the Baltic that we know of.
	Noise	Benthic habitats	Moderate	Low-frequency noise (LFN) affects burial behaviour of marine amphipods and burrowing behaviour of bivalves. Laboratory + review. Not much known from insitu Baltic	Wang *et al.* 2022; Roberts and Elliott 2017	Not studied insitu in the Baltic that we know of
	Noise	Fish	Moderate	Not studied insitu in the Baltic that we know of	Dylewska *et al.*, 2023; Nichols *et al.* 2015; Bagočius, 2015	
	Marine litter	All	Low	Effects on biota unclear this is the same for all sources of marine litter. As there is not so much marine litter in the Baltic the DoI is low for all.	ICES marine litter group	Yes
	Salinity regime	All	Low	Channelling of water flows, and high run-off during extreme events. Distribution of species changes. Similar to barriers, not specific for coastal development, but quite a number of studies exist. Klapedia lagoon is an example	Dailidienė and Davulienė 2008	The effects of coastal development on salinity.

				where salinity changes have been linked to exploitation.		
Fishing	Noise	All	Moderate	Fish, benthos and harbour porpoise are all disturbed by noise. The amount of this disturbance that comes specifically from fishing is unclear. Most studies based on shipping.	Mustonen, *et al*. 2019.	
	Nutrient and organic enrichment	All	low	The direct contribution of fishing to nutrient release of sediments in the Baltic Sea is still unclear. Circumstantial evidence suggests it could be large.	Sciberras *et al*. 2016	
Harvesting	Species extraction	All	low	Unclear how much harvesting of different species occurs in the Baltic Sea.	ICES groups/HELCOM?	Yes
Land-based Industry	Abrasion, siltation/smothering and Substrate Loss	Seabirds	Low	Specific examples are lacking - depends on the type of industry. Difficult to give a score that applies to all industries. Historically higher.	HELCOM or ICES seabirds groups	Yes
	Barriers	Fish	Low	Specific examples are lacking - depends on the type of industry. Difficult to give a score that applies to all industries.		
	Marine Litter	Ice Habitats (and assoc. biota)	Low	Effects on biota unclear this is the same for all sources of marine litter. As there is not so much marine litter it the Baltic	ICES marine litter group	

				the DoI is low for all.		
	Noise	Benthic habitats and biota	Low	Do not know how much effect of noise industry specifically has on benthic habitats.		
	Noise	Seabirds	Low	Can be disturbing to nesting birds, no references that are Baltic specific	Buxton, *et al.* 2017	
Military	Contaminants	All	Moderate	The extent of military activities in the Baltic is shrouded in secrecy making it hard to assess the frequence and spatial extent of activities. Historical munitions dumps, sunken ships and ordinance are a known problem.	Rekker *et al.* 2007; Jakacki *et al.* 2020	Yes
	Marine Litter	All	Low			
	Non-indigenous Species	All	Low			
	pH changes	All	Low			
	Noise	Marine mammals	Moderate	Detonation of ordinance killed and injured harbour porpoise	Siebert *et al.* 2022	
Navigational Dredging	Contaminants	All	Low	Data uncertainties on the extent and frequency of navigational dredging. Many small-scale projects are not reported.	HELCOM reports large-scale projects, small-scale projects are lacking.	
	Marine Litter	All	Low			
	Noise	All	Low			
	Non-indigenous Species	Fish	Low			
	Nutrient and organic enrichment	All	Low			
Oil, gas, and hydro	Marine Litter	All	Low	Don't know how much marine litter originates from these sources.		Yes
	Non-indigenous Species	Fish	Low	Don't know how much NIS originates from these sources.		

	pH changes	All	Low	Oil, gas and hydro do affect pH, but difficult to know the extent of the effect on the Ecological components.		
	Salinity regime	All	Low	Difficult to calculate the proportion of effects due to oil, gas and hydro		
Renewable Energy	Contaminants	Benthic habitats and biota	Low	Difficult to calculate the proportion due to renewable energy		
	Marine Litter	All	Low			
Research	Contaminants	Benthic habitats and biota	Low	There is not so much specifically documented on the effects of research, probably because the effects are low. However, the expert opinions are probably quite accurate.		Yes
	Contaminants	Fish	Low			
	Contaminants	Pelagic Habitats (and assoc. biota)	Low			
	Noise	All	Low			
	Non-indigenous Species	Fish	Low			
Shipping	Extraction of Non-living Resources	Ice Habitats (and assoc. biota)	Low	Grey literature. A lot on disturbance of ringed seals by shipping noise etc, but not specifically on loss of habitat.	Antti Halkka and Petteri Tolvanen (eds.) 2017	Yes
	Marine litter	All	Moderate	Exact amount originating from shipping difficult to quantify, contributes significantly, but less than tourism.	Schernewski *et al.* 2018	
	pH changes	All	Moderate	Sulphur and nitrogen oxides have been quantified.	Jägerbrand, *et al.* 2019.	
	Species Extraction	Marine mammals	Low	Many cases of collisions are probably not reported.	Schoeman, *et al.* 2020, WG MAMA and HELCOM mammals groups.	Data on collisions is scarce.

Telecommunications	Marine Litter	Pelagic Habitats (and assoc. biota)	Low	Unknown what amount originates from telecommunications		
	Barriers		Low	Effects of electromagnetic fields are not well studied.	Taormina, *et al*. 2018.	
	Noise	Fish	Low	Cable installation is a spatially localized temporary event, so the impact of noise on marine communities is expected to be minor and brief. HVAC cable vibration, although significantly lower than potential SPL during the installation phase, requires special attention though because its long-term impacts remain unknown.	Taormina, *et al*. 2018.	Yes
Tourism/Recreation	Contaminants	Seabirds	Low	Unclear the amount of tourism based pollution that contributes to seabirds.		Yes
	Nutrient and organic enrichment	Ice Habitats (and assoc. biota)	Low	Unclear how tourism contributes to nutrient and organic enrichment of ice habitats.		Yes
Wastewater	Abrasion and Substrate Loss	Benthic habitats and biota	Moderate	PFAS linked to wastewater outflows and presence in benthos, fish and marine mammals.	Bossi, *et al*. 2008	
	Marine Litter	Ice Habitats (and assoc. biota)	Low	Microplastics. Few studies which look at effects on the ice habitat.	Magnusson, K., 2016. (Sweden)	Yes
	pH changes	All	Low	Not sure, but wastewater pH can differ from the surrounding water. Lack of studies		

	Salinity regime	All	Low	Channelling of water flows, and high run-off during extreme events. Distribution of species changes. Uncertain how much wastewater outflows influence salinity

4.3 Ecosystem components

As the Baltic Sea is less species rich than many sea areas, we have defined the specific ecosystem components used in the assessment in Table 4.2. When scoring the impact on the ecosystem components we originally made the scoring on more detailed ecological components than required for the Ecosystem Overview, these components are listed in the "Baltic further details" column of Table 4.2. Methods for consolidating the pressure scores for these groups can be found in section 2.2 of this report. Generally, scoring considers the most sensitive or affected groups, for example fishing and species extraction have "acute" effects on fish although not all species of fish are extracted from the ecosystem. Considerations for each ecosystem component were made as follows:

4.3.1 Benthic habitats and associated biota

Pressure scores were originally made for six types of benthic habitats that were subsequently combined to the single ecosystem component "Benthic habitats and associated biota". To combine scores effectively we considered the spatial distribution of the benthic habitats, i.e. if lagoons and littoral areas were the only components affected the overlap score was set as site. Benthic habitats and biota considered all biota found in or on both hard and soft substrate, see Table 4.2 for examples.

4.3.2 Marine mammals

The Baltic Sea contains a small number of mammal species, including three seal species (*Phoca vitulina*, *Halichoerus grypus* and *Pusa hispida*) and harbour porpoise (*Phocoena phocoena*). Furthermore, Eurasian otters (*Lutra lutra*) inhabit some of the coastal regions. Seal populations are generally increasing, and mortality caused by harvesting and bycatch does not currently have population level effects. The ringed seal depends on ice for breeding and warming winters in the future will pose a risk for their populations (Räsänen 2020). Harbour porpoises are rare and any additional mortality exceeding natural mortality levels (i.e. bycatch) can have significant negative effects on the population level (Cervin *et al*. 2020). The assessment was directed to marine mammals as a whole group, which poses a challenge when the effects of a pressure within the group vary widely.

Table 4.2 Ecosystem components with Baltic Sea specific examples that were included in the pressure assessment.

Agreed ICES Ecosystem components	More detailed components for the Baltic Sea	Example species
Fish	Coastal fish	Pike, perch, carp
	Open sea fish	Herring, sprat, sticklebacks
	Demersal fish	Cod, flounder
	Migratory fish	Eel, trout, salmon
Seabirds	Water birds	Seaducks, Red throated diver
Marine Mammals	Cetaceans	Harbour porpoise
	Seals	Grey and ringed seals
Pelagic habitats and assoc. Biota	Coastal pelagic waters	*Bosmina coregoni*
	Open pelagic waters	*Psuedocalanus* sp.
Ice habitats and Assoc. Biota	Ice habitats	Ringed seal, ice algae
Benthic Habitats and Assoc. Biota	Littoral zone 0-5 m depth	Cladophora, reeds
	Baltic sea lagoons	Macrophytes, Charophytes
	Shallow rock and biogenic reef 5-20 m depth	*Mytilus* sp., *Fucus* sp.
	Shallow sublittoral sediment 5-20 m depth	*Marenzellaria* spp., *Macoma balthica*
	Deep hard bottoms >20 m depth	*Saduria entomon*
	Deep soft bottoms >20 m depth	Mysids

5 Threatened and declining species

5.1 Mammals

Although seal populations are generally increasing and mortality caused by harvesting and bycatch does not currently have population level effects, overall marine mammals are not in good status in the Baltic Sea (HELCOM 2023e). Seal populations are lower and distributed less widely compared to the beginning of the 20th century (Harding *et al*. 2007). The ringed seal depends on ice for breeding and warming winters in the future will pose a risk for their populations. Grey seals and some harbour seal populations show increasing population sizes, but population growth rates are slowing. According to HELCOM, both reproductive and nutritional status of seals are below the threshold values for good status. The status of both populations of the harbour porpoise is not good in terms of abundance and distribution. Furthermore, data on harbour porpoise abundance is mostly qualitative. Harbour porpoises are rare in most of the Baltic Sea and any additional mortality exceeding natural mortality levels (i.e. bycatch) can have significant negative effects on their populations (Räsänen 2020).

5.2 Birds

According to the HELCOM Red List, of the 58 breeding species or subspecies of birds analysed, 23 were red-listed. The gull-billed tern (*Gelochelidon nilotica*) was formally a regular breeding bird in the Baltic region, but is considered Regionally Extinct (RE) today. One species occupies the category Critically Endangered (CR), the Kentish plover (*Charadrius alexandrinus*), which has formerly been a regular breeder in Denmark, Sweden and Germany, but after 2000 has only bred with single pairs in Sweden and Germany (Mecklenburg-Western Pomerania). Four species are Endangered (EN) (Southern dunlin *Calidris alpina schinzii*, Terek sandpiper *Xenus cinereus*, Mediterranean gull *Larus melanocephalus* and Black-legged kittiwake *Rissa tridactyla*). Eight species or subspecies were classified as Vulnerable (VU) and nine as Near Threatened (NT).

For wintering populations of the Baltic Seabirds, a total of 47 species, subspecies, or populations were included in the assessment; out of those, 16 were red-listed. Two piscivorous diver species, the Red-throated diver (*Gavia stellata*) and the Black-throated diver (*Gavia arctica*), have dramatically decreased as wintering birds in the Baltic Sea and are classified as Critically Endangered (CR). The category Endangered (EN) comprises seven species, including five sea duck species. Three taxa classify for the category Vulnerable (VU) and four for the category Near Threatened (NT).

5.3 Fish

Fourteen species of fish and lampreys have been evaluated as threatened according to the HELCOM Red List (HELCOM 2013). The American Atlantic sturgeon (*Acipenser oxyrinchus*), which used to be common in the Kattegat and more rarely occurring in the Sound, is considered regionally extinct. The list of critically endangered species includes the European eel (*Anguilla anguilla*), which is also considered a commercial species, and grayling (*Thymallus thymallus*), which mainly occurs in coastal areas of the Gulf of Bothnia, and the sharks porbeagle (*Lamna nasus*) and spurdog (*Squalus acanthias*) in the Kattegat. The sharks have a wide distribution range and the populations occurring in the Kattegat are mainly influenced by pressures outside of the Baltic Sea region. Three fish species are listed as endangered on the HELCOM red list, and seven are listed as vulnerable, including sea lamprey (*Petromyzon marinus*). At the level of commercially relevant species, western and eastern Baltic cod stocks have collapsed due to fishing extraction, the detrimental effects of which have been further accentuated by eutrophication and ocean warming (Möllmann *et al*. 2009, 2021). Likewise, the western Baltic spring-spawning herring has attained its lower stock size during the last years (HELCOM 2023e).

5.4 Habitats

Most of the threatened habitats highlighted in the HELCOM report (HELCOM 2023e) were associated with benthic ecosystems, while few pelagic habitats were listed. The soft-bottom macrofauna were evaluated as having good status in most areas of the Baltic Sea except for the Gulf of Finland, the Gulf of Riga and the Bay of Mecklenburg in the western Baltic Sea. These findings display some overlap with the level of the shallow-water near-bottom oxygen, which did not reach good status in the Eastern Gulf of Finland and the western Baltic Sea (i.e. the Kattegat, Great Belt, the Sound, Kiel Bay, Bay of Mecklenburg and Arkona Basin). Benthic habitats in the Baltic Sea are threatened by alien species, climate change, construction, contaminant pollution, ditching, epidemics, fishing, litter, oil spills, mining and quarrying, tourism, and ship traffic (HELCOM 2013).

One of the disturbances of highest concern for Baltic Sea benthic habitats is eutrophication, as it indirectly causes oxygen depletion. This indirect effect is due to nutrient enrichment, which increases phytoplankton primary productivity and its biomass. Consequently, water turbidity augments this effect, reducing the depth at which macroalgae and seagrasses can be found. Additionally, the degradation of the organic matter contributes to the expansion of oxygen minimum zones. These low-oxygen areas negatively impact the survival of benthic invertebrates and hinder fish recruitment by increasing the mortality of eggs and larvae.

Deep habitats occurring on soft sediments have declined due to destructive fishing methods such as bottom trawling. Furthermore, many threatened habitats occur in the shallow areas of the southwestern Baltic Sea, which is particularly exposed to ocean warming.

Seagrass meadows in the Baltic Sea declined 67% from 1869 to 2016 (de los Santos *et al*. 2019). The decline was attributed mostly to water quality, wasting diseases (caused by *Labyrinthula* sp.), coastal development and seabed disturbances. Nevertheless, in the 2000s, the meadows composed by *Zostera marina* experienced a gain of 2.1% decade^{-1} (de los Santos *et al*. 2019). Recently, there have been efforts for seagrass restoration around the Baltic Sea, for example in the coast of Germany (https://www.geomar.de/en/discover/seagrass-meadows).

6 Operational products to potentially improve the scientific basis of the advice for future iterations of the Baltic Sea EO

The use of foodweb and ecosystem models can clarify the cause–effect relationships linking multiple pressures (e.g. fisheries, climate change and eutrophication) to the response of species and trophic groups by tracking the spread of indirect effects through the anatomy of trophic interactions (Scotti. *et al*. 2022; Ito *et al*. 2023). Bayesian Network models may be used to extend the classical ecological representation with the inclusion of the socio-economic context thus easing the consideration of emerging pressures like those related to the expansion of offshore wind farms (Niquil *et al*. 2021; Thermes *et al*. 2024).

Ecosystem indicators can aid in stock assessments in short term to provide insights into ecological interactions that may impact the stock. Therefore, identifying the relevant indicators and including them into Ecosystem Overviews should be considered.

Furthermore, short (or long) term risk metrics for each of the ecosystem components and socio-economic activities should be included. The metrics could include the use of ecosystem and socio-economic indicators revealing the state of the system. The socio-economic indicators could then be used to support stock assessment and bring advice closer to ecosystem-based fisheries management (EBFM).

7 Contribution from WKBALEO to the Ecosystem Overview in the Baltic Sea ecoregion

This section contains the contributions of WKBALEO to the science underpinning the advice in the Baltic Sea ecoregion Ecosystem Overview (ICES, 2024). This section was reviewed by three independent external reviewers before being drafted into the advice by the Advice Drafting Group (2024 ADGEO). The external reviewers' merged consensus report and ADGEO 2024 output can be found in Supplementary Documents 1 and 2, respectively. This section is structured with the same subsections as the Ecosystem Overview. Sections, figures, and tables marked with n/a are ones to which the group did not contribute.

Key signals

n/a

Ecoregion description

The Baltic Sea is one of the largest brackish water bodies in the world, covering 420 000 km^2. It is a semi-enclosed shallow sea with an average depth of 60 m, where one third of the area is less than 30 m deep (Figure 7.1). This ecoregion has many islands and a long and diverse coastline. It is characterized by strong temperature and salinity gradients, from relatively warmer and saline waters in the southwestern part to cold and almost freshwater in the northernmost parts. In addition, there is strong permanent vertical stratification in much of the Baltic Sea. The northernmost parts are covered by ice in winter. Based on its bathymetry and hydrology, the Baltic Sea can be subdivided into three main areas:

- The transition area, consisting of the Belt Sea and the Arkona Basin, with salinities of 8-20 PSU and an average depth of 18 m.
- The central Baltic Sea, consisting of the deep areas (>150 m) of the Bornholm Basin, Gdańsk Deep, Gotland Basin and the Gulf of Riga.
- The northern Baltic Sea, including the Gulf of Bothnia, the Gulf of Finland and the Archipelago Sea, which are strongly influenced by large river inputs, with salinities ranging from 0-7 PSU.

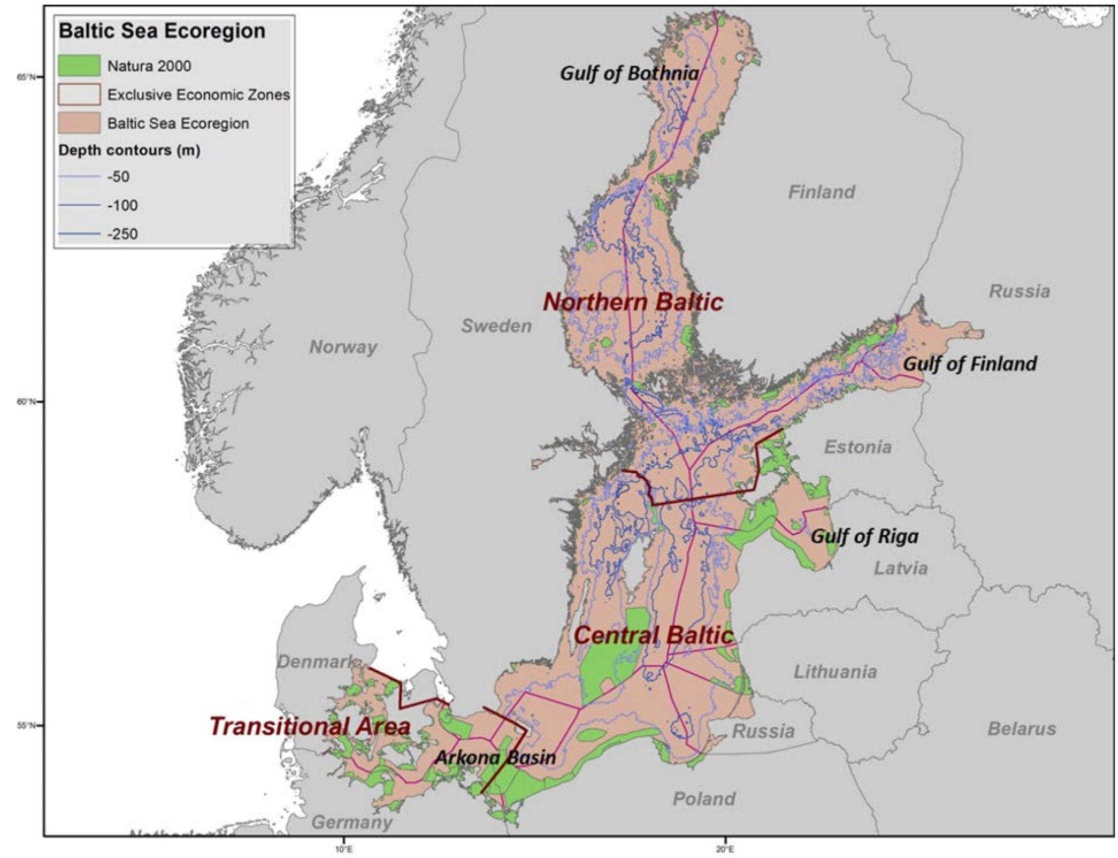


Figure 7.1 The Baltic Sea ecoregion, showing EEZs and larger Natura 2000 sites.

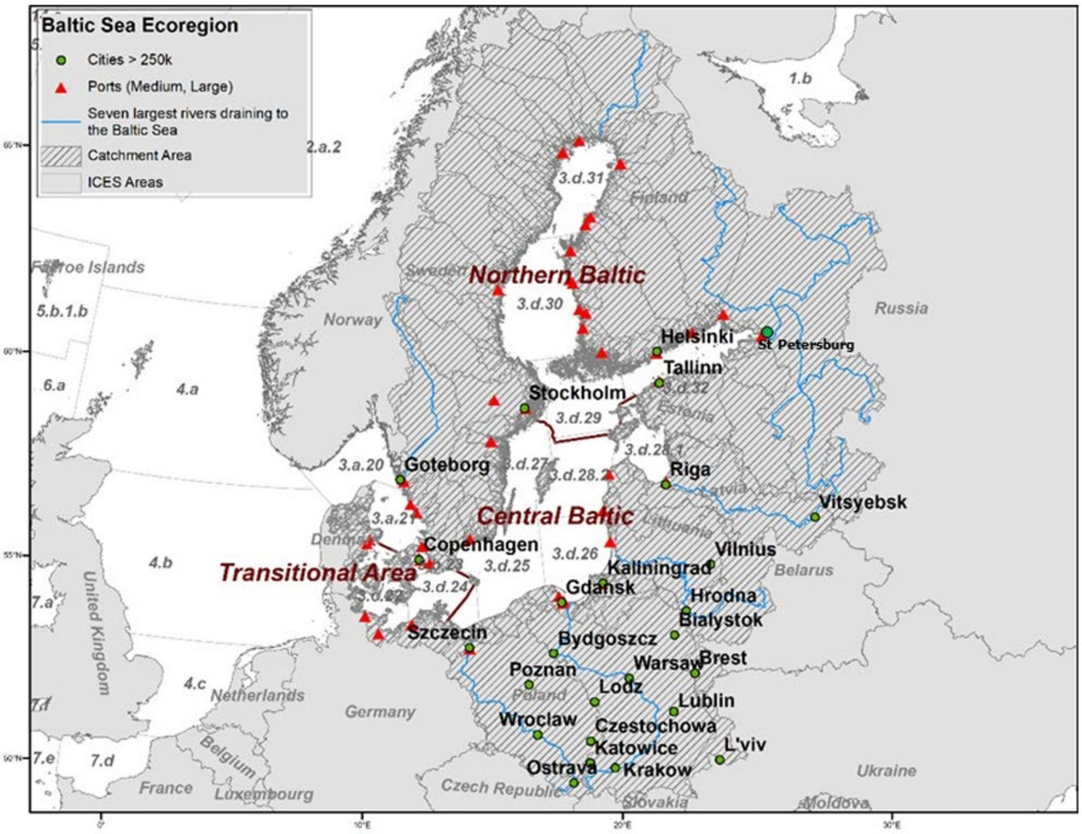


Figure 7.2 Catchment area for the Baltic Sea ecoregion, showing major cities, ports, and ICES areas.

Management

Nine countries border the Baltic Sea, and a further five countries are partly within the catchment area (Figure 7.2). The catchment area has a total population of around 85 million. All countries bordering the Baltic Sea, except Russia, are EU Member States, and all countries and the EU are contracting parties of the Convention on the Protection of the Marine Environment in the Baltic Sea (the Helsinki Convention). The convention establishes the Baltic Marine Environmental protection Commission, commonly referred to as the Helsinki Commission or HELCOM. HELCOM has updated the Baltic Sea Action Plan (BSAP) with the vision of “a healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in a good ecological status and supporting a wide range of sustainable economic and social activities” (HELCOM 2021). The focal issues of the BSAP are biodiversity conservation, eutrophication, hazardous substances, and maritime activities. The goals of the BSAP to a large degree overlap with those of the EU’s Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD). This overlap has resulted in strong coordination in the implementation of measures.

Policies regarding commercial fisheries in the Baltic Sea are regulated under the EU’s Common Fisheries Policy (CFP) and bilaterally with Russia. Recreational fisheries are mostly managed at the national level. Fisheries advice is provided by ICES, the European Commission’s Scientific, Technical and Economic Committee for Fisheries (STECF), the Baltic Sea Advisory Council (BSAC), and BALTFISH (Rodriguez-Perez *et al*. 2023). BALTFISH is a regional body involving the eight EU Member States bordering the Baltic Sea, which submits joint recommendations to the European Commission. BSAC is an advisory body composed of representatives from the commercial fisheries and other interest groups, mainly environmental non-governmental organizations.

In the Baltic Sea, the protected areas network is a combination of HELCOM marine protected areas (MPAs) that were established to protect valuable marine and coastal habitats and the Natura 2000 network of the EU Birds Directive and EU Habitats Directive (Figure 7.1), which protect certain natural habitats and species. Many of the MPAs and Natura 2000 sites overlap. The network of MPAs in the Baltic Sea is gradually expanding and is now at about 16.5% of the total sea area (HELCOM 2023a).

Pressures

ICES has evaluated 17 human activities and 8 pressures relevant to the Baltic Sea ecoregion. The 5 most important pressures are nutrient enrichment, species extraction, contaminating substances, marine litter and physical seabed disturbance. These pressures are linked mainly to the following human activities: agriculture, wastewater, land-based industry, fishing, and shipping. The main pressures identified below are described in the ICES Ecosystem Overviews Technical Guidelines (ICES 2023a).

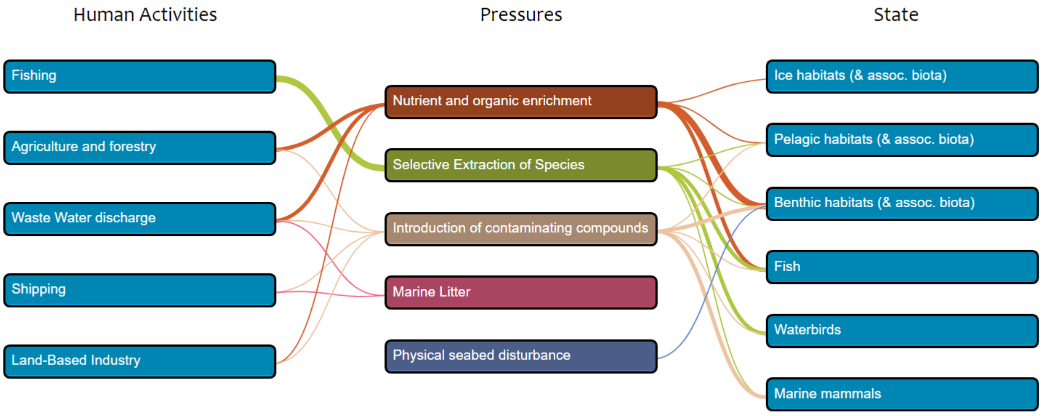


Figure 7.3 Wire diagram for the Baltic Sea Ecoregion.

Nutrient enrichment

Nutrient enrichment, species extraction and contaminants are the strongest pressures on the ecosystem and account for 75% of the impact, with nutrient enrichment accounting for 27% of the total impact risk (Figure 7.3). Nutrient enrichment is mainly caused by agriculture, wastewater, and land-based industry which together account for 48% of the impact originating from human activities. Furthermore, species extraction accounts for 23% of the impact originating from human activities, which is almost exclusively from fishery extraction. For more information on fisheries, please see the ICES Fisheries Overview for the Baltic Sea Ecoregion (ICES, 2024). The effects of nutrient enrichment and fisheries are widespread in the Baltic Sea. In addition, other highly scoring human activities in the assessment were shipping, coastal development and tourism/recreational activities.

Eutrophication

Eutrophication is caused by excessive nutrient inputs. In the Baltic Sea, primary production can be limited by both nitrogen and phosphorus (Granéli *et al*., 1990; Rolff and Elfwing, 2015; Vahtera *et al*., 2007), which implies that inputs of both nutrients have to be controlled to manage eutrophication. Nutrient inputs to the Baltic Sea peaked around 1980, with waterborne inputs of nitrogen reaching about three times and phosphorus inputs five times the preindustrial loads (Figure 7.4). Since then waterborne nitrogen loads have approximately halved and phosphorus loads have dropped to approximately one third of peak inputs (Kuliński *et al*., 2022), mostly due to improved sewage treatment (HELCOM, 2022), but also because of reduced fertilizer application in agriculture (McCrackin *et al*., 2018). However, nutrient inputs still exceed the targets set in the HELCOM Baltic Sea Action Plan for the Baltic Proper, the Gulf of Finland, and potentially the Gulf of Riga (HELCOM, 2023b) and eutrophication remains one of the major pressures on the Baltic ecosystem, having both direct and indirect impacts.

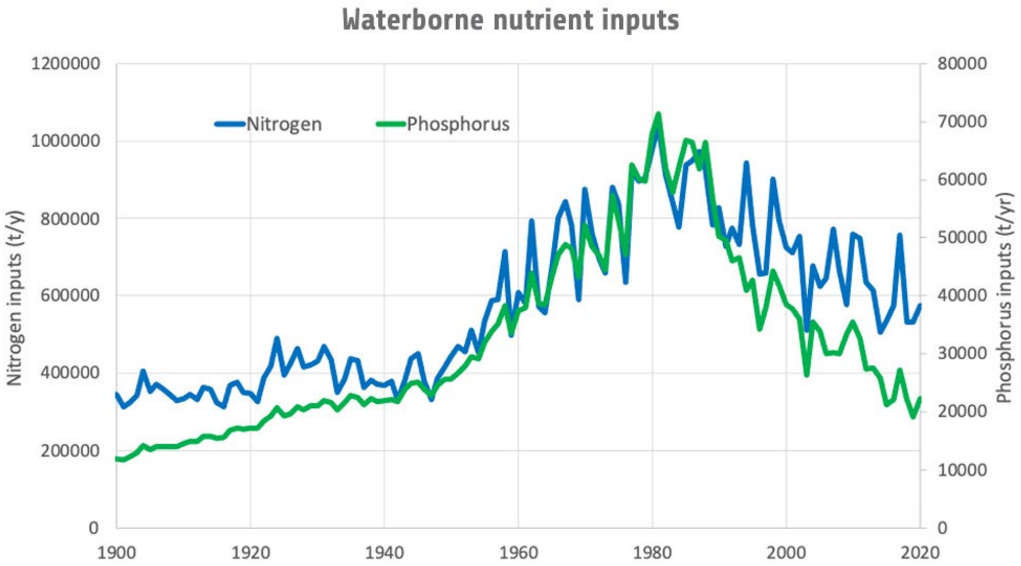


Figure 7.4 The waterborne nutrient inputs in the Baltic Sea (HELCOM HOLAS 3 thematic assessment of eutrophication; data source (Kuliński *et al*., 2022.).

Of the total nitrogen input to the Baltic Sea, 49% stem from diffuse agricultural sources, 9% from wastewater treatment, and 24% from atmospheric deposition to the sea surface itself. Thus, anthropogenic sources dominate and only 18% of nitrogen inputs are attributed to natural background loads. For phosphorus, diffuse agricultural sources make up 56% of the inputs, wastewater 17%, atmospheric deposition 7% and natural background loads 20% of the total inputs (HELCOM, 2022). Therefore, in our scoring, we attributed most of the eutrophication effects to the agricultural sector, followed by wastewater treatment and a small fraction of nitrogen deposition to shipping (Figure 7.5).

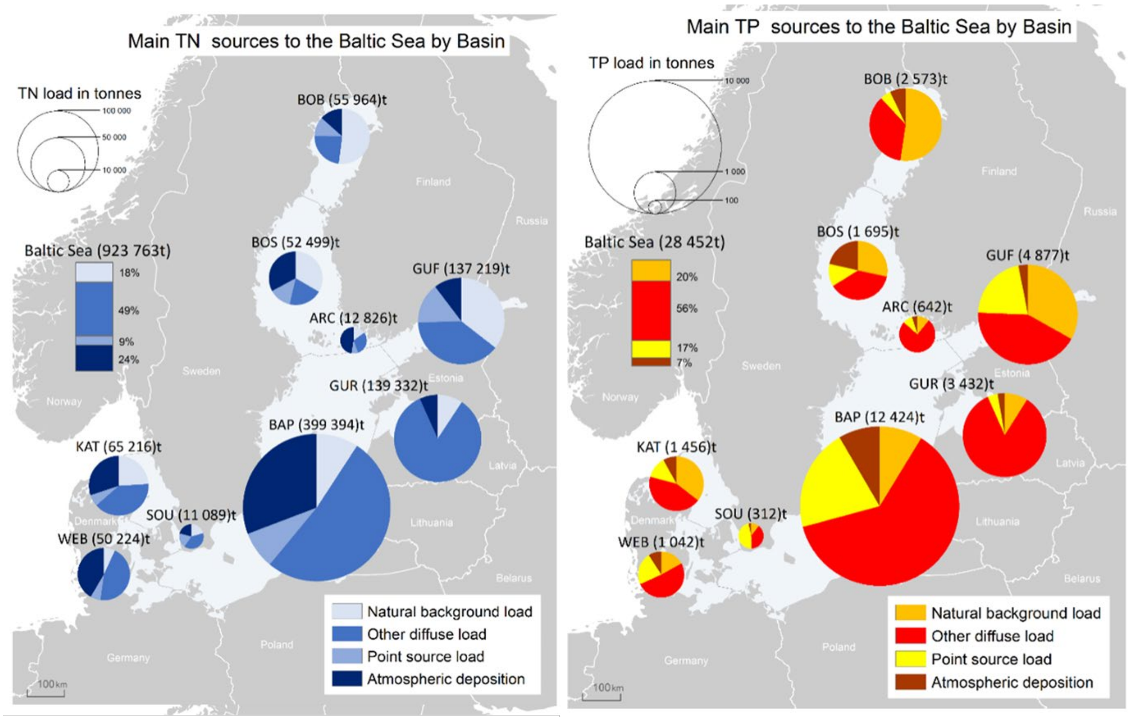


Figure 7.5 Major sources of A) total nitrogen (left) and B) total phosphorus (right) loads to the Baltic Sea sub-basins in 2017 (HELCOM HOLAS 3 thematic assessment of eutrophication; data source PLC7).

Despite declining nutrient loads, HELCOM (2023b) classified the eutrophication status of the Baltic Sea as mainly poor to moderate for 2016–2021, with only a few coastal areas and parts of the Kattegat reaching good status. Compared to the previous assessment for 2011–2016, phosphorus concentrations have declined in many open sea areas, whereas nitrogen concentrations mainly remained unchanged, apart from decreases in parts of the Baltic Proper, and increases in the Western Baltic. Still, only one of the assessed open sea areas, the Great Belt, reached good nutrient status below the thresholds for the HELCOM Baltic Sea Action Plan.

As a consequence of high nutrient levels and productivity, bottom water oxygen concentrations have further deteriorated in the Baltic Proper, the Bornholm Basin, the Eastern Gulf of Finland, and to some extent in the Bothnian Sea, Bothnian Bay and the Gulf of Riga (HELCOM, 2023b). Nutrient residence times have been estimated to be as long as 9 years for nitrogen and almost 50 years for phosphorus (Gustafsson *et al*., 2017), which explains the slow response of nutrient pools in the water column and sediments of the Baltic Sea to load reductions.

Selective extraction of species

There are ten human activity sectors inducing species extraction in the Baltic Sea, however, commercial fish extraction has the largest and most widespread effect on ecosystem components. This pressure accounts for 26% of the total Relative Impact Risk in the region. The Total Absolute Impact from Species extraction is 3.04 (See ICES Technical Guidelines for ICES Ecosystem Overviews for more details).

Fisheries are the main activity contributing to selective extraction of species in the Baltic Sea. The principal species targeted in the commercial fishery are herring *Clupea harengus*, sprat *Sprattus sprattus*, and cod, which together constitute about 95% of the total catch. Other species having local economic importance are salmon *Salmo salar*, plaice *Pleuronectes platessa*, dab *Limanda limanda*, brill *Scophthalmus rhombus*, turbot *Scophthalmus maximus*, European flounder *Platichthys flesus*, Baltic flounder *Platichthys solemdali*, pikeperch *Sander lucioperca*, pike *Esox lucius*, perch

Perca fluviatilis, vendace *Coregonus albula*, whitefish *Coregonus sp.*, eel *Anguilla anguilla*, and sea trout *Salmo trutta*.

From 2020, the most important cod fishery in the Baltic Sea has been banned. Cod fishing will not be available for commercial or recreational purposes (Commission proposal fishing opportunities Baltic Sea 2024).

Contaminants

Organic contaminants and metals introduced historically persist for an extended time in the environment. The levels of certain previously concerning contaminants have improved today, such as hexachlorocyclohexane (HCH, lindane) and dichlorodiphenyltrichloroethane (DDT), dioxins and furans, polychlorinated biphenyls (PCBs), hexabromocyclododecane (HBCDD), polyaromatic hydrocarbons (PAH) and a few metals (HELCOM 2023c). However, there are still significant concerns about the concentrations of Polybrominated diphenyl ethers (PBDEs) in biota, Tributyltin (TBT) in sediment, mercury in biota, and copper in sediment across all sub-basins (HELCOM 20223c). Certain contaminants like PAHs in sediment and biota, perfluorooctane sulfonate (PFOS) in water, Cadmium in sediment and biota, and TBT in biota and water remain elevated in some sub-basins (HELCOM 2023c).

Oil spills have decreased significantly in the past decade in all sub-basins. The levels of Caesium-137 (Cs-137), deposited after the Chernobyl nuclear power plant accident in 1986, have now dropped below pre-Chernobyl levels (HELCOM 2023c. However, chemical warfare agents are still released in water from dumping sites, and sediment in these areas might have chronic effects on neighbouring living species (e.g. secondary explosive 2,4,6-trinitrotoluene (TNT), sulphur mustard) (Maser *et al*. 2023; Strehse *et al*. 2023).

Several emerging persistent organic contaminants are now of high concern in the Baltic Sea, such as polyfluoroalkyl substances (PFAS), organophosphate esters (OPEs), short-chain, medium-chain and long-chain chlorinated paraffins (SCCPs, MCCPs, LCCPs), halogenated flame retardants (HFRs), microplastic and pharmaceuticals (Dereszewska *et al*. 2023; Białowąs *et al*. 2022; de Wit *et al*. 2020). Ongoing target and non-target screening programs aim to explore the prevalence of emerging contaminants, guide future mitigation strategies and fill knowledge gaps (HELCOM 2023c).

Physical seabed disturbance

Disturbance of seabed habitats due to physical abrasion from mobile bottom-contacting fishing gears occurs mostly in the southern parts of the Baltic Sea (Figure 7.6). This is mainly abrasion from otter trawls targeting demersal and benthic fish. Abrasion may affect the surface (top 2 cm of sediments) or the subsurface (> 2 cm). Few studies examine the impact of fishing-related abrasion on benthic communities in this part of the Baltic Sea, but from neighbouring regions, such as the North Sea and Kattegat, it is known that frequent disturbance by bottom trawls reduces benthic diversity and biomass and changes the composition of benthic species. Some of the trawled parts of the Baltic Sea are also affected by low oxygen concentrations at the seabed (Figure 7.6). Oxygen depletion can induce burrowing organisms to migrate to the sediment surface, making them potentially more vulnerable to trawling disturbance. For areas with even lower concentrations of oxygen, bottom trawling is unlikely to have any marked effects on habitats as the benthic biomass has already been reduced by hypoxia.

Physical disturbance of benthic habitats by mobile bottom-trawl fishing gear (mostly in the > 12 m vessel category) is evaluated using a vessel monitoring system (VMS) and logbook data and provides information on the extent of the pressure, its magnitude, and potential impact on the seabed habitats and associated benthic communities. A proportion of vessels < 12 m overall length, fish with MBCG are not represented in this advice because they are not monitored systematically with VMS. This may represent approximately 15% of the effort at the scale of the ecoregion, but higher effort in areas of the northern and eastern Baltic. Consequently, MBCG pressure and impacts will be underestimated (ICES, 2023b, 2024 trade-offs advice).

Results show that this pressure varies geographically across the ecoregion. ICES estimates that commercial fisheries have been deployed over approximately 29 000 km^2 of the ecoregion in 2022, corresponding to 8% of the ecoregion's spatial extent waters shallower than 200 m (Figure 7.6).

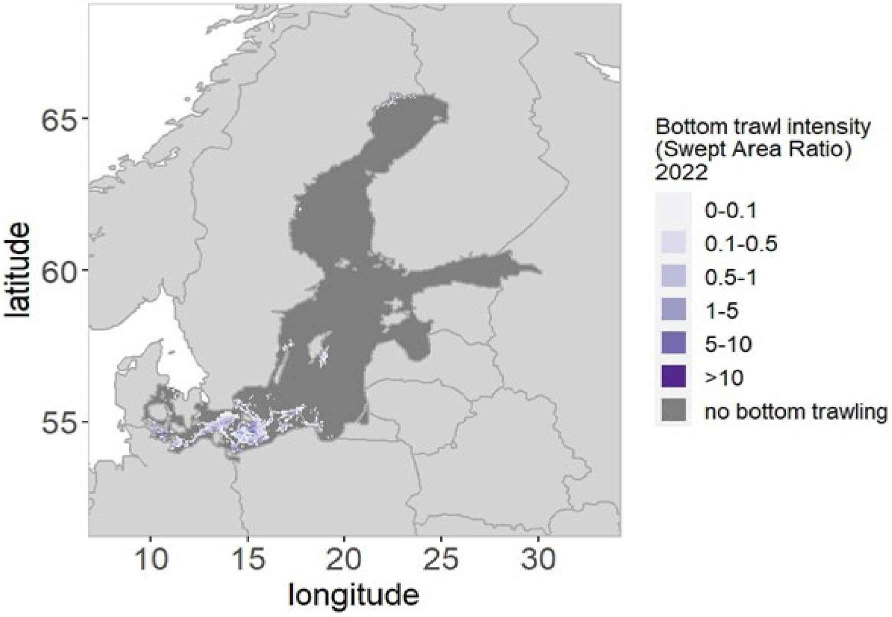


Figure 7.6 Average annual surface disturbance by mobile bottom-contacting fishing gear (bottom otter trawls, bottom seines, beam trawls) in the Baltic Sea during 2018–2021 (with available data), expressed as average swept-area ratios (SAR).

Habitat loss through physical disturbance in the Baltic Sea is connected to human activities such as sand extraction, dredging and deposit of dredged material, harbours and marinas, and to a lesser extent offshore installations and mariculture. Less than 1% of the Baltic Sea seabed is assessed as potentially lost due to human activities (ICES, 2023b).

Marine Litter

Marine litter in the Baltic Sea poses a significant environmental challenge, impacting both offshore and coastal areas. Almost all indicated human-induced pressures impact the ecological components of the Baltic Sea through marine litter, with the exception of the ice environment, which experiences lower impacts. While the severity of marine litter is generally low in the Baltic Sea the persistent nature of the majority of litter contributes to chronic impacts across affected ecosystem components.

Climate change effects

Climate change influences numerous elements of the Baltic Sea ecosystem. It affects particular ecosystem components differently but its overall impact is overarching. Due to climatic forcing, environmental conditions in the Baltic Sea have already changed considerably, as it has warmed faster than any other coastal sea since 1980 (Meier *et al*. 2023; Figure 7.7).

Based on recent projections from regionally downscaled climate models, further changes of various abiotic conditions are expected: (i) strong warming, particularly in the northern parts in winter, almost twice as the global average (Meier *et al*. 2023), (ii) precipitation is projected to increase throughout the Baltic Sea region, except for the southern part in summer (Gröger *et al*. 2019, Meier *et al*. 2023), (iii) due to high uncertainty, it is still unclear if the Baltic Sea will become less or more saline (Lehmann *et al*. 2022, Meier *et al*. 2022), (iv) sea level is expected to rise further, however, probably at a slower rate than the global average (since 1886, the mean absolute sea level in the Baltic Sea increased by about 25 cm i.e. ~2 mm yr^{-1} on average) (Meier *et al*. 2022, 2023), (v) the frequency of extreme events such as, marine heat waves, extremely mild sea ice winters, heavy precipitation and high-flow events are expected to increase (Meier *et al*. 2023).

Climate change will have multiple impacts on species, communities and ecosystem functioning including effects on species interactions, trophic dynamics and ecosystem function (Ito *et al*., *in press*). Climate change has already led to shifts in the seasonality of primary production, for example, a prolonged phytoplankton growing season, an earlier onset of the spring bloom and a delayed autumn bloom (Viitasalo and Bonsdorff, 2022). Some species benefit from the temperature rise. If projected nutrient reduction continues, the improvement in oxygen conditions may initially increase zoobenthos biomass, but the decrease in organic matter sedimentation would eventually lead to reduced biomass (Viitasalo and Bonsdorff, 2022).

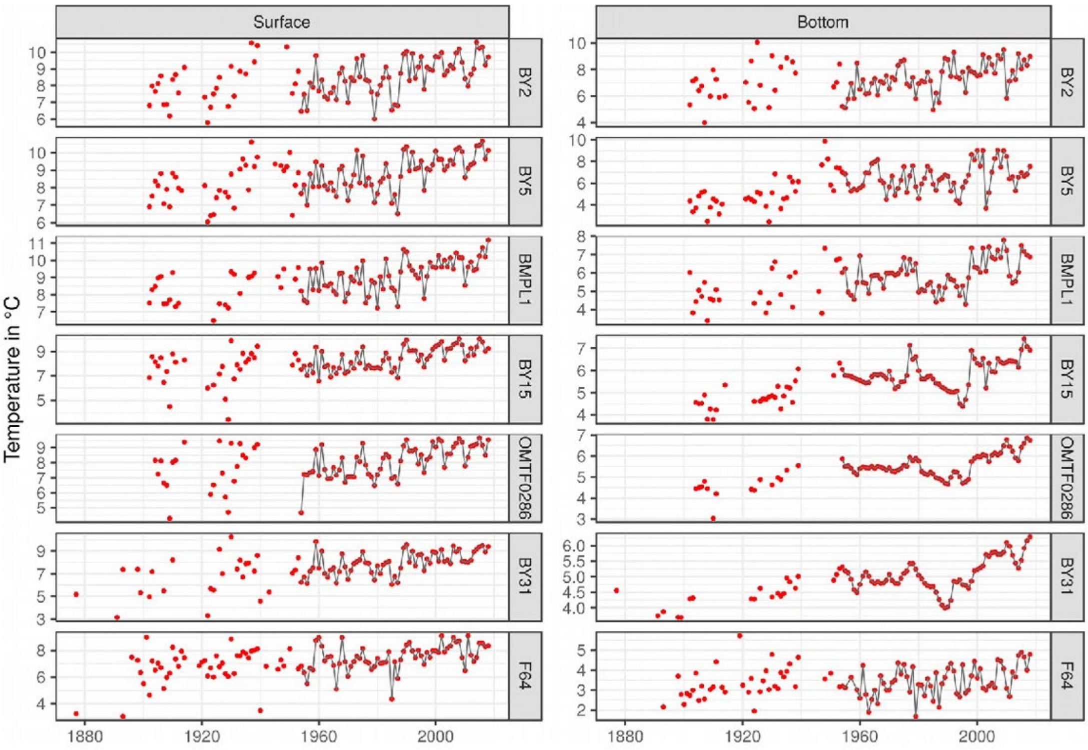


Figure 7.7 Annual mean values of daily sea surface temperature (left column) and bottom temperature (right column) at seven monitoring stations in the Baltic Sea during 1877–2018 (red dots). The grey lines indicate the period when every station has data for every year (1954–2018). The data shown have been post-processed to overcome possible seasonal biases due to missing values in the observations. For data sources and more details, see Meier *et al*. (2022). Data source: HELCOM HOLAS 3 report).

Impact on Fish (in foodwebs)

Climate change significantly impacts Baltic Sea fish communities, and the future climate is projected to undergo further changes, leading to unprecedented combinations of environmental conditions. The temporal and seasonal variations in environmental factors such as temperature, salinity and oxygen regimes profoundly affect fish and other organisms in the Baltic Sea (Viitasalo and Bonsdorff, 2022). The extent of these effects is linked to the biology and ecology of each species and can also fluctuate over time, depending on the state of the ecosystem. Climate change can impact various aspects of fish life, including recruitment, growth, distribution, reproduction, prey availability, and mortality across different life stages.

For example, changes in the temperature regime may affect fish reproduction, food availability and mortality in early life stages (MacKenzie and Köster, 2004; Voss *et al.*, 2011). Similarly, when combined with hypoxic conditions, these changes can impact feeding and distribution areas in adult stages, thereby affecting the growth and productivity of several species, e.g. cod, herring and flatfish (Neuenfeldt, 2002; Rau *et al.*, 2019). Salinity fluctuations could also strongly affect marine and freshwater fish communities in the Baltic Sea by changing suitable habitat availability (Olsson *et al.*, 2012, Koehler *et al.*, 2022).

Fish communities in the Baltic Sea are changing, and significant reorganization was observed after the regime shift in the Central Baltic Sea in the late 1980s (Möllmann *et al.*, 2009) when the fish community went from cod to clupeid dominance. Recently, planktivorous species have been dominating the fish community in the open-sea ecosystem, with certain freshwater and invasive species increasing in coastal waters. In combination with other environmental changes, especially eutrophication, fluctuations in fish communities may lead to changes in foodweb dynamics and functioning (Eero *et al.*, 2021; Viitasalo and Bonsdorff, 2022).

Knowledge gaps

Although the knowledge of the Baltic Sea ecosystem state and functioning is advanced when compared to other sea regions, it is apparent that substantial knowledge gaps exist. For example, there are gaps in some aspects of basic mechanistic understanding of ecosystem functioning, such as changing diet composition of key species resulting in change of trophic position in the foodweb while impacted by anthropogenic and/or climatic forcing. This kind of information is currently fragmented but crucial to fully understand the consequences of climate change and anthropogenic pressures.

There are also gaps when tracing the origin of pressures on the ecosystem components, for example, the main sectors contributing to various contaminants in the Baltic Sea. In many cases, there is a common agreement about the existence of the linkages but the significance is unknown and associated confidence is low (some examples are provided in Table 4.1). In general, although well-established knowledge exists on the impact of single pressures on individual ecological components, one of the most important challenges is the assessment of cumulative effects of multiple stressors. Additionally, there is a lack of understanding of how stressors affect the delivery of ecosystem services.

When assessing the state of the environment in the Baltic Sea there is a lack of indicators for foodweb status and threshold values have not yet been defined. This is also the case for many other MSFD descriptors, i.e. non-indigenous species, contaminants and benthic habitats. There exists a need for international collaboration across EU member states to standardize MSFD reporting.

Social and economic context

Fisheries

Countries around the Baltic Sea account for all the fishing in the area. Of the Baltic countries' fishing fleets, the Finnish fleet mainly fishes in the Baltic while the other countries' fleets also fish in the North Sea and other fishing regions. In 2020, the highest fishing effort was undertaken by fisheries in Finland (25.3% of days-at-sea in the Baltic Sea), followed by Estonia (20.9%), Germany (19.1%) and Sweden (13.9%). However, Sweden had the highest share of total landing value (22.6%). Total landing value in the ecoregion was EUR 156 million gained from catches of about 495 000 tonnes. Sprat and herring dominate the fishery in terms of weight and, after the decline of the cod fishery, value of landings. Effort, landings, and landing value is presented in Figure 7.8 below.

Figure 7.8 n/a

In 2021 approximately 4 600 active vessels were used in the Baltic Sea by EU Member States, a decrease by about 26% compared to 2013. Also, total fishing effort has decreased since 2013, from above 450 000 days at sea to about 292 000 in 2021. Total employment in the region was about 3 300 FTE in 2021 where the small-scale fleet contributed with 62%. The net profit for the total fleet was EUR 6.3 million in 2021 (a decrease by 42% compared to the year before), but the small-scale fleet had negative profitability (EUR -9.9 million). The Baltic Sea countries' economic dependence on fishing is generally low, with fishing accounting for less than 0.25% of GDP and employment in all, and less than 0.1% in most of the countries.

Specific socio-economic drivers

Offshore Renewable Energy

All Baltic Sea coastal states except Russia are members of the European Union and thus part of the Offshore Renewable Energy Strategy that sets ambitious targets for offshore energy production. The development of large offshore energy production in the ecoregion is likely to affect fisheries because mobile gears are often excluded from such areas, although static gears may be compatible (Figure 7.9).

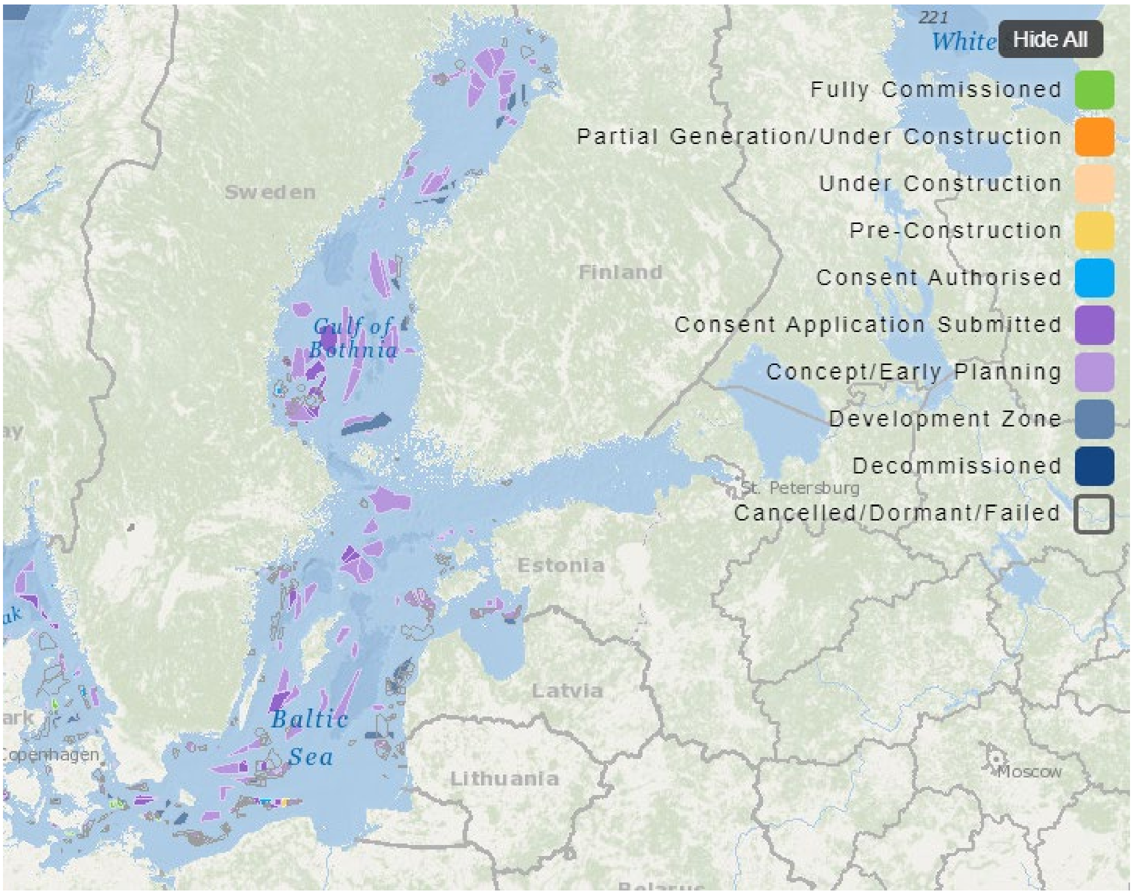


Figure 7.9 Offshore wind farms in the Baltic Sea under different stages of development as of 29 May 2024, courtesy of 4COffshore.com. (https://map.4coffshore.com/offshorewind/)

State of the ecosystem

Pelagic habitat and associated biota

Benthic habitat and associated biota

Cephalopods

Fish

Seabirds

Marine mammals

Foodwebs

Oceanographic conditions and circulation

The Baltic Sea is a young ecosystem formed after the latest glaciation, continuously undergoing postglacial successional changes and diversification. It is a semi-enclosed, non-tidal ecosystem and has distinct latitudinal and vertical salinity gradients (Figure 7.10). There is strong permanent vertical stratification for much of the Baltic Sea. Benthic substrate distribution (Figure 7.12) is affected by water movement. Muddy sediments and occasionally sand are most common in the deeper parts, whereas rocky and mixed sediments can occur in nearshore and wave-exposed areas. The southern parts, including the Belt Sea, are connected to the Kattegat and show salinity levels around 25–30. Surface salinity levels in the central Baltic Sea are around 7–8, dropping to around 5 at the entrances to the northern Gulfs. In the most northern and eastern parts of the Baltic Sea, conditions are close to those of freshwater.

Due to the limited water exchange with the global ocean, which leads to the long residence time (approx. 30 years), and permanent halocline, the Baltic Sea is naturally prone to hypoxic conditions, especially in the deep basins. In shallow coastal parts of the Baltic Sea, hypoxia may occur during summer in connection with high water temperatures. Nutrient input to the Baltic is the major cause of both anoxia and hypoxia. The extent of the affected areas (Figure 7.14) varies in relation to the intensity and frequency of the major inflows of water from the North Sea. Starting from the beginning of the 1990s, the frequency of the major inflows from the North Sea dropped from one event every second or third year to one event per decade, the last being in December 2023.

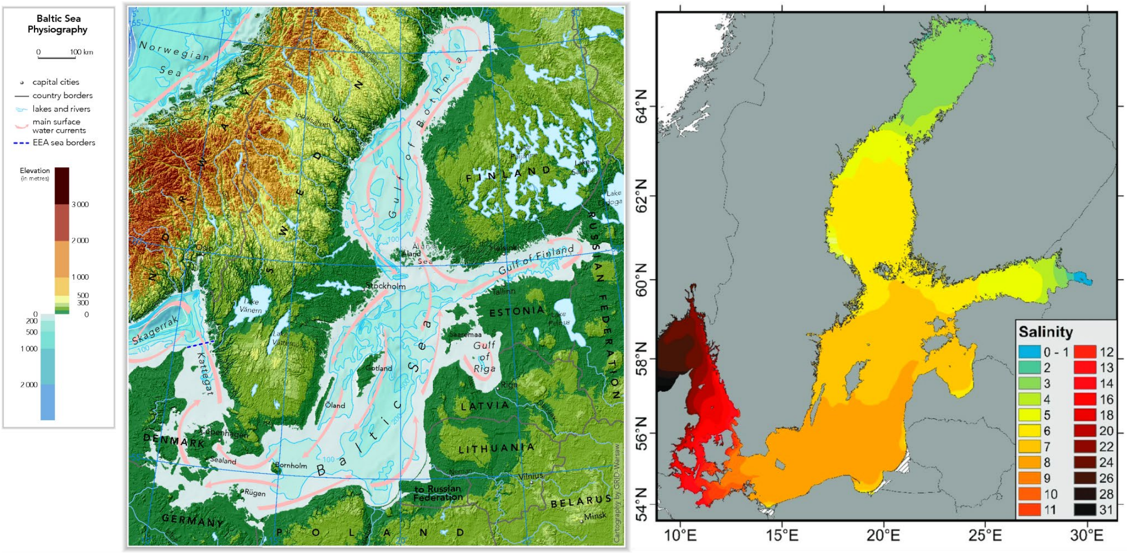


Figure 7.10 Circulation pattern of the Baltic Sea (left panel) (https://www.eea.europa.eu/legal/copyright). Copyright holder: European Environment Agency (EEA). On the right panel, salinity gradient of the Baltic Sea from Jaspers *et al.* 2021.

Pelagic habitat and associated biota

Primary Production

The pelagic primary production in the Baltic Sea ranges from 100 to 175 mg C m^{-2} y^{-1}, depending on the sub-basin. Phytoplankton productivity, total biomass, and species composition show strong seasonality. Around half of the annual carbon fixation takes place during spring. The proportion of diatoms to dinoflagellates in the phytoplankton has distinct seasonal and spatial patterns as well as decadal-scale trends and has been ascribed to climate-related factors, particularly the harshness of winter and nutrient load. The diatom/dinoflagellate ratio reflects the change in the dominant energy transfer pathway into the pelagic or benthic food webs as sedimentation of diatoms is much faster than that of dinoflagellates (HELCOM 2023e). The spring bloom is terminated by nitrogen limitation in most of the Baltic Sea; consequently, the pelagic community switches to a functionally more diverse community around May–June. A shift towards earlier, more prolonged spring blooms (but with lower average biomass) has taken place in the central Baltic Sea over the past 20 years. Chlorophyll concentrations have remained essentially unchanged during the past few decades (1990–2021), with the exception of the westernmost parts of the Baltic Sea, where it shows decreasing trends (HELCOM 2023f). On a decadal scale, the Baltic Sea summer phytoplankton community composition has gone through a gradual shift, most notably an increase in species richness, with subsequent effects on ecosystem functions.

Some of this increase in species richness may be due to anthropogenic vectors. Phytoplankton blooms are a natural phenomenon in the Baltic Sea ecosystem, with blooms in late summer dominated by nitrogen-fixing cyanobacteria. However, due to eutrophication the phytoplankton blooms become more frequent and extensive, and cyanobacterial blooms have increased in the Baltic since the late 1970s (HELCOM 2023d). In the coastal areas of the northern Baltic Sea, the symptoms of eutrophication are seen as e.g. decreased water clarity and an increased number of filamentous algae.

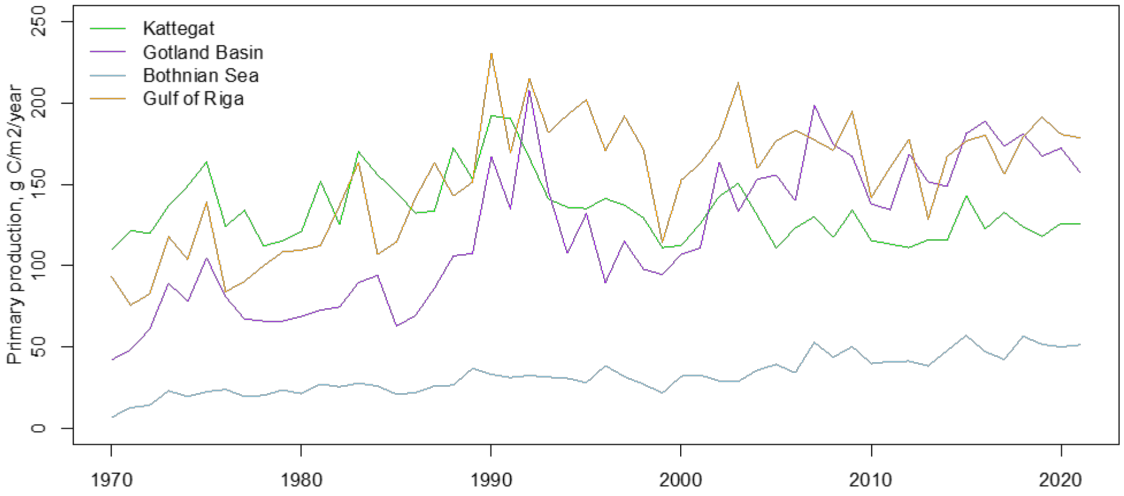


Figure 7.11 Primary production for selected Baltic Sea basins simulated with the BALTSEM model (Gustafsson *et al.*, 2012).

Zooplankton

The dominant zooplankton groups in the Baltic Sea include copepods, cladocerans, and rotifers, each thriving within their preferred salinity ranges and seasons. Over the past three decades the abundance and biomass of zooplankton have remained stable in certain regions (e.g. in the Gulf of Finland and the Eastern Gotland Basin) or have increased (e.g. in the Bothnian Sea and the Gulf of Riga). Yet, a decrease in zooplankton biomass and abundance has been observed specifically in the Bothnian Bay. In six out of ten assessed Baltic Sea sub-basins, there has been a decline in the mean size of zooplankton. However, when analysing the data over the last 12 years, these trends are less prominent, partly due to the lower statistical power of shorter datasets, and also in some cases (e.g. Western Gotland Basin) where the trend became positive. The decrease of mean size is attributed to both an increased contribution of rotifers and cladocerans, likely resulting from eutrophication, and a reduced presence of large-sized copepods, possibly due to size-selective predation by zooplanktivorous fish (HELCOM 2023g). The impact of eutrophication on zooplankton biomass and mean size is corroborated by the negative correlation between mean size of zooplankton and cyanobacteria biomass, as well as between total zooplankton biomass and the values of an eutrophication indicator, i.e. the Cyanobacterial Bloom Index. However, the significance of these correlations varies, showing substantial differences among sub-basins (HELCOM BLUES, 2023). Altered environmental conditions, e.g. decreased salinity, increased temperature and hypoxic areas, may also have an impact on zooplankton communities, although this has yet to be verified. Further population studies focusing on the demography of the key taxa, especially copepods, are necessary to clarify the reasons behind the observed changes (HELCOM 2023g).

Benthic habitats and associated biota

There is strong permanent vertical stratification for much of the Baltic Sea. Substrate distribution (Figure 7.12) is affected by water movement. Muddy sediments and occasionally sand are most common in the deeper parts, whereas rocky and mixed sediments can occur in nearshore and wave-exposed areas.

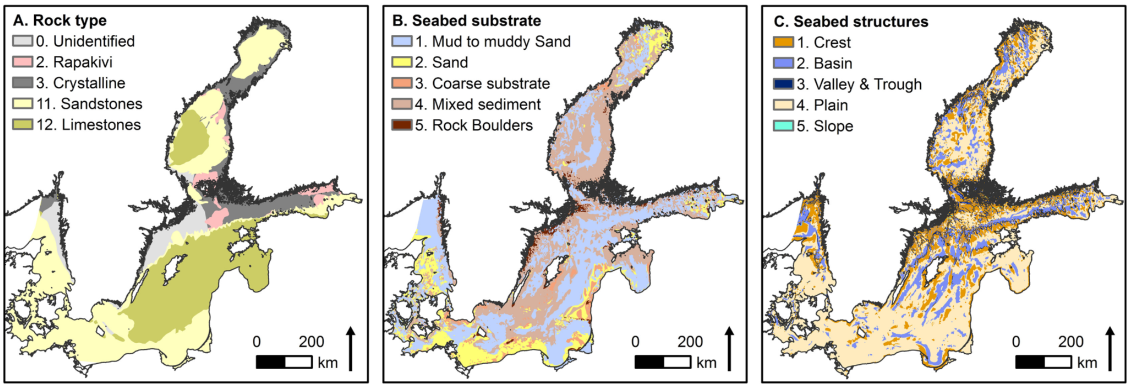


Figure 7.12 Substrate types in the Baltic Sea. Geological data layers used to assess the geodiversity of the Baltic Sea. A: Rock type (mod. from Koistinen *et al.*, 2001), B: Seabed substrate (EMODnet Geology, 2016b), C: Seabed structures. (Coastline: European Environment Agency, 2013).

Impact of bottom fishing on the seabed in the Baltic Sea is low. The actual impact of bottom trawls depends on the type of fishing, its intensity, and the seabed sensitivity (Figure 7.12). The impacts on seabed habitats and associated biota by these gears in the ecoregion have been assessed by combining data on benthic species-specific longevity, depth, habitat characteristics, gear specific characteristics and fishing intensity to generate a map of potential benthic impacts (Figure 7.13). In the ecoregion, the Southwestern areas have the most activity and impact.

In the absence of an agreed impact threshold, to categorize areas of low impact, a 0.2 impact level was arbitrarily chosen for illustration purposes. Nearly all Baltic seabed have an impact less than 0.2.

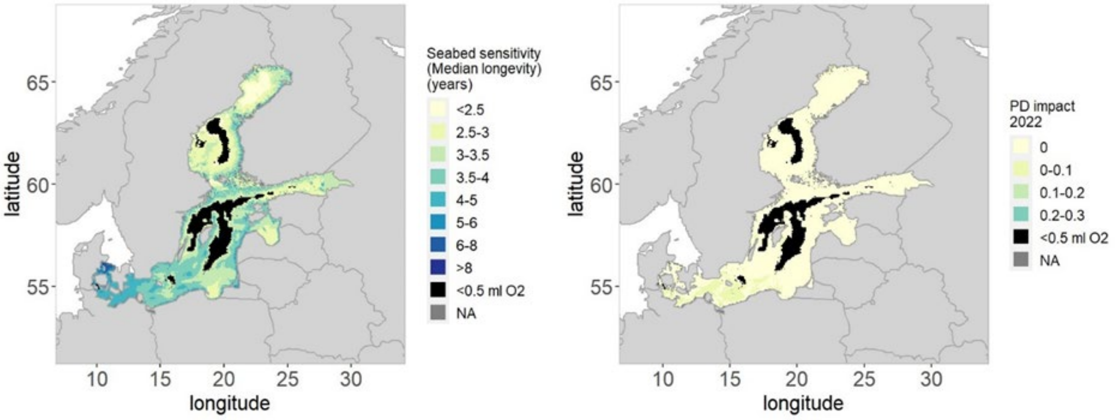


Figure 7.13 Assessment results for the Baltic Sea Ecoregion. Seabed Sensitivity (left) and impact (right). The indicators are explained in the technical guidelines for Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT) seafloor assessment (ICES 2021a); n/a = not analysed. Black cells have seasonal oxygen concentrations <0.5 ml O2 per l-1, a concentration below which oxygen deprivation generates mass mortality in benthos.

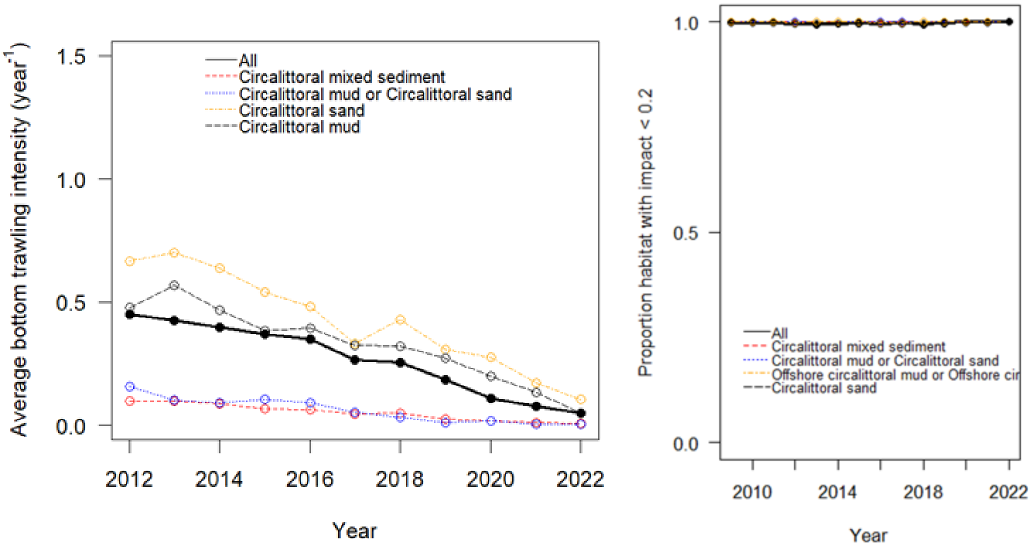


Figure 7.14 Temporal trends of bottom trawl intensity for the Baltic Sea Ecoregion. Pressure presented as abrasion for the four most common habitat types during the period 2012-2022. References to habitat types follow the EUNIS classification, comprising a zone and substrate type (EUSeaMap, 2023). Spatial distributions of substrate types in the Baltic Sea Ecoregion are shown in Figure 7.12. Note that "Circalittoral mud or Circalittoral sand" represent uncertainty in the habitat mapping information.

The sensitivity of a habitat is determined by the lifespan of the benthic communities in undisturbed conditions. A habitat with a higher fraction of longer living species would be considered sensitive compared to one with a higher fraction of short living species. The sensitivity of the Baltic Sea to bottom fishing disturbance is the highest in the southwestern waters where species longevity is high (Figure 7.13). Sensitivity is lower in the deeper and northern parts of the Baltic Sea.

Bottom trawling occurs almost entirely in the southern and southwestern part of the ecoregion (Figure 7.13). Average fishing intensity has decreased significantly since 2013 due to the poor status of the Baltic cod stocks, and at present only a limited trawl fishery targeting mostly flatfish is allowed. Average impact has been low since 2012 (Figure 7.14).

Anoxia

Oxygen concentrations are low in many areas, notably in deeper basins. In shallow coastal parts of the Baltic Sea, hypoxia may occur during summer in connection with high water temperatures (Conley *et al*. 2011). Nutrient input to the Baltic is the major cause of both anoxia and hypoxia. The extent of the affected areas (Figure 7.15) varies in relation to the intensity and frequency of the major inflows of water from the North Sea. Starting from the beginning of the 1990s, the frequency of the major inflows from the North Sea dropped from one event every second or third year to one event per decade, the last being in December 2023. Areal extent of oxygen depletion in the Baltic Sea (Figure 7.15) has been steadily increasing over time. In 2022, the extent of oxygen depletion was the largest ever measured with hypoxic waters (< 2 ml l^{-1} O_2) representing about 34% of the area and 21% of the volume of the central Baltic, the Gulf of Finland and the Gulf of Riga (Hansson and Viktorsson, 2024).

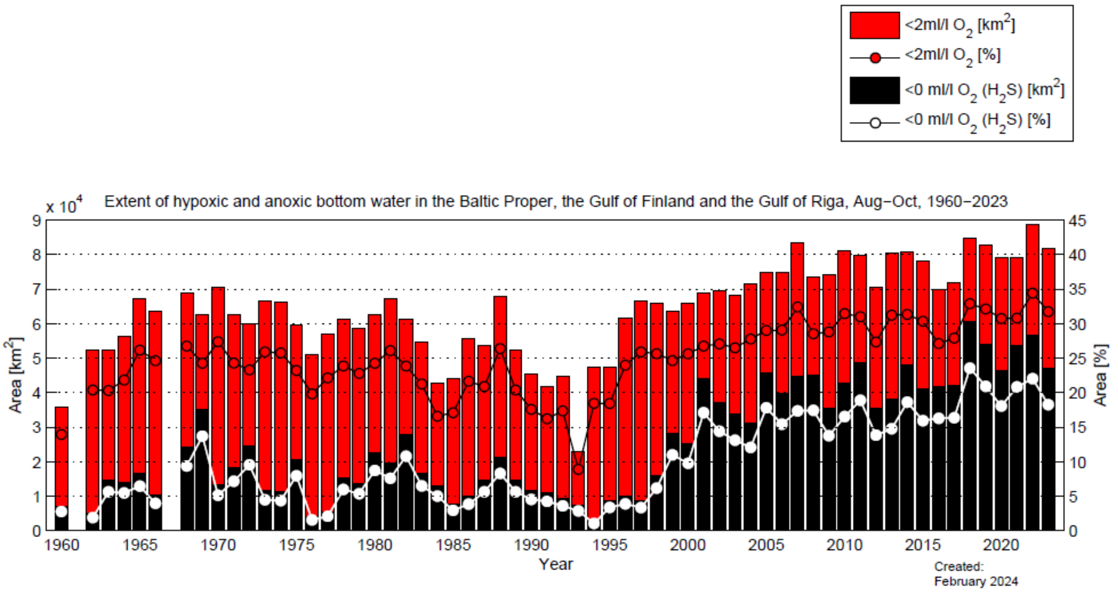


Figure 7.15 Extent of hypoxic and anoxic bottom water in the Baltic Proper, the Gulf of Finland and the Gulf of Riga, Swedish Meteorological and Hydrological Institute.

Ice Habitats

The sea ice has a direct impact on physical dynamics of water masses (e.g. windstress at the sea surface) and air-sea exchange processes (e.g. vertical heat fluxes) (Thomas *et al.* 2021). Furthermore, the process of ice formation, consolidation and melting influences the ecology of both the benthic and pelagic components of the Baltic Sea ecosystem (e.g. spring bloom timing and amplitude; Pärn *et al.* 2021).

The biota in the ice consists mainly of prokaryotic and eukaryotic microbes (bacteria, diatoms, dinoflagellates, flagellates), ciliates and rotifers. They form foodwebs inside the ice, which are truncated compared to the open-water food planktonic foodwebs since organisms larger than the brine channels are lacking in the species assemblages (Thomas *et al.* 2021).

There is considerable interannual variation in the extent of sea ice in the Baltic Sea, with a downward trend since the 1980s (Figure 7.16). This impacts the habitat size for all organisms that rely on the habitat (ranging from micro-organisms to the ringed seal, *Pusa hispida*). The Baltic Sea Ice habitat is listed as vulnerable in the HELCOM Red List of Habitats and Biotopes (HELCOM 2013) mostly due to predicted decline of the habitat due to climate change (ice extent, quality and the length of the ice season). Ice habitat is particularly important for the ringed seal (*Pusa hispida*) as they rely on ice for reproduction.

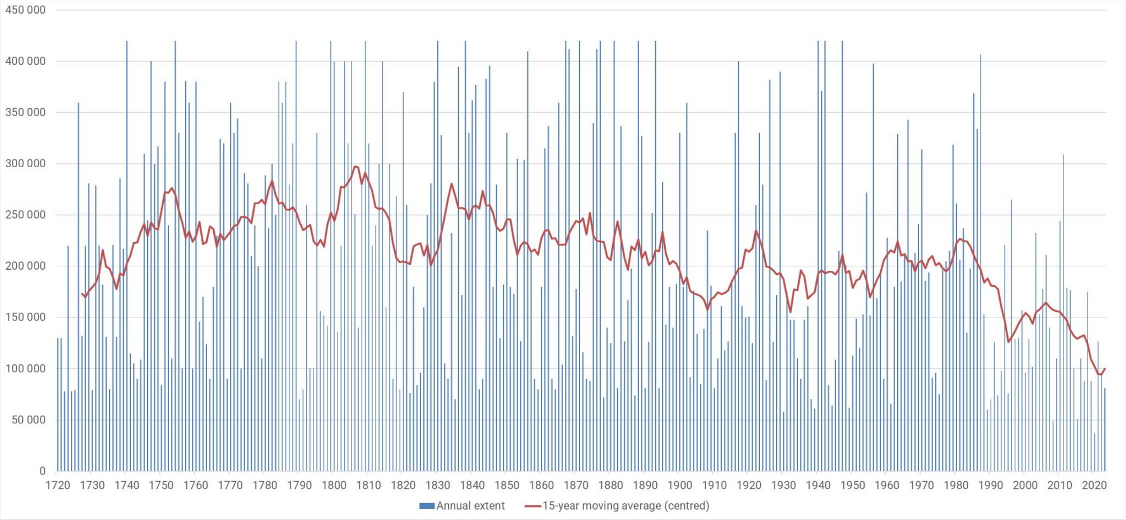


Figure 7.16 Maximum extent of ice cover in the Baltic Sea in the winters 1719/20–2022/23 (blue bars) and 15 year moving average (red line). Source: Jouni Vainio, Finnish Meteorological Institute (updated from Seinä and Palosuo 1996; Seinä *et al*. 2001).

Lagoons

Baltic Sea lagoons and estuaries are playing an important, buffering role between terrestrial and marine ecosystems. These complex, dynamic, and diverse water bodies are under huge anthropogenic pressure due to their productivity and location at the coastline. Lagoons have restricted water exchange with the open sea and thus create specific brackish water conditions and are prone to eutrophication effects. Macrophytes and benthic invertebrates create excellent feeding, spawning, and nursery conditions for numerous fish species as well as feeding and breeding areas for waterbirds. However, there is a pronounced impact of alien species on different ecosystem components.

Lagoons traditionally provide numerous goods and services as e.g. transportation, fisheries, and aquaculture. Especially in summer, they are hot spots for tourism. Management is a complicated challenge as all three large Baltic lagoons i.e. Szczecin Lagoon, Vistula Lagoon, and Curonian Lagoon are transboundary water bodies and, moreover, two of them are shared between EU and non-EU countries. The areas under EU jurisdiction are all designated Natura 2000 areas.

Fish

Coastal fish

Coastal fish communities (waters < 20 metres deep) often show a greater species diversity than open-sea fish communities, due to the addition of freshwater species (e.g. perch *Perca fluviatilis*, pikeperch *Sander lucioperca*, pike *Esox lucius*, whitefish *Coregonus lavaretus*, gobies and cyprinids). The coastal communities have a more local population structure and response to environmental signals. Changes in the species composition of coastal fish communities in past decades are linked to an increasing water temperature, shorter ice cover period and decreasing salinity. In many areas, the increasing trend in the abundance of cyprinids and a concurrent decrease in piscivorous fish indicate a deteriorating ecosystem status, although this trend has shown some signs of improvement in more recent years. Increased levels of nutrients favour cyprinids and pikeperch and impede whitefish, pike and burbot *Lota lota*. Indications of an overall temporal decline of pike populations have been found (Olsson *et al*. 2023). The abundance of the three-spined stickleback *Gasterosteus aculeatus*, an important species for the coastal ecosystem functioning and a resource competitor with other pelagic fish, has increased in the past decade (Olin *et al*. 2022). Flounder are key benthic fish in the central and southern Baltic Sea, particularly in coastal areas. Some non-indigenous species e.g. round goby *Neogobius melanostomus* (Kruze *et al*. 2023) and chinese sleeper *Perccottus glenii* (Orlova *et al*. 2006) have increased in recent years with negative effects on native species and ecosystems.

Demersal fish

In the Baltic Sea, demersal fish play a crucial role in the ecosystem by occupying the bottom layers of the sea. They are an essential component of the foodweb, preying on invertebrates and small fish while serving as a food source for larger predators, including seals and harbour porpoises. However, their populations are under threat due to overfishing, habitat degradation, and hypoxic conditions caused by nutrient enrichment and organic matter decomposition.

The group of demersal fish in the Baltic Sea includes Atlantic cod (*Gadus morhua*), European flounder (*Platichthys flesus*), the endemic Baltic flounder (*Platichthys solemdali*), Baltic plaice (*Pleuronectes platessa*), turbot (*Scophthalmus maximus*), brill (*Scophthalmus rhombus*), dab (*Limanda limanda*) and sole (*Solea solea*). The status of demersal fish was not satisfactory in any sub-basin where it was assessed (HELCOM 2023a). The western Baltic cod stock biomass has been below the limit reference point (Blim) since 2008, which has led to a reduced reproduction. An increase was seen in later years because of one strong year class in 2016, which was insufficient to ensure a healthy status of this population. The eastern Baltic cod stock is also decreasing, and the stock size in 2018 was the lowest observed since 2003. The SSB is below the spawning-stock biomass where specific and appropriate management actions are taken (MSY Btrigger), although the stock status is uncertain. The eastern Baltic cod population structure has deteriorated in recent years and shows no improvement. Since 2017, especially, the biomass of the length groups larger than 40 cm has decreased. The declining eastern Baltic cod condition has been linked to hypoxia, which also causes a reduction in food resources, selective fishing pressure, and parasite infestation (the liver worm *Contracaecum osculatum*). Conservation efforts are essential to maintain the ecological balance and ensure the sustainability of demersal fish stocks in the region.

Migratory fish

Salmon *Salmo salar* and sea trout *Salmo trutta* have been exploited in coastal and open waters of the Baltic Sea. The harvest rate of salmon has decreased considerably since the beginning of the 1990s. Since 1997, total wild smolt production has increased tenfold in the Bothnian Bay. This area is the largest contributor to the overall smolt production in the Baltic Sea. Despite the overall increase in wild smolt production, there was a decline in post-smolt survival from the late 1980s until the mid-2000s. In the last ten years, the number of spawners and smolt production in the northern large salmon rivers Tornionjoki and Simojoki has been relatively high. In 2023, however, the number of spawners in the rivers collapsed, and the EU Commission has strictly restricted the salmon fishery. European eel *Anguilla anguilla* is anadromous and critically endangered worldwide and the numbers of migrating eel have also collapsed in the Baltic Sea. The EU Commission has proposed to ban all fishing for eel in the Baltic Sea.

Open sea pelagic fish

The composition and diversity of the open-sea pelagic fish community is structured along the salinity and temperature gradient, with a higher diversity in the west compared to the east and north. Up to 80% of the biomass in the open-sea fish communities of the main basin is shared between three species: cod, herring, and sprat. In the late 1980s and early 1990s the regime shift in the open-sea pelagic ecosystem was evident by a shift from a cod-dominated system to one dominated by sprat and herring.

The herring in the Baltic Sea has several separate spawning populations. The spawning-stock biomass (SSB) of Central Baltic herring has fluctuated around Blim since 1995 and has been below Blim for the last four years. Fishing mortality has been above FMSY since 2015, but decreased to below FMSY in 2022. In the Gulf of Riga, the herring population is classified as having a full reproduction capacity. In the Gulf of Bothnia, the spawning stock of herring has been declining after a peak in 1994. In 2010 the SSB had a small peak, after which the spawning stock decreased again and in 2021-2022 is estimated to be below Btrigger. The reasons for low SSB are the change in the food chain, which causes deteriorated body condition and even starvation, especially in larger herring. In addition, fishing mortality was at a high level in 1994-2016, after which fishing mortality has in general decreased without increasing the SSB. During winter of 2022 and 2023, the condition of even the largest herring specimens recovered to the levels of the 2010's, but the proportion of larger herring size groups had decreased from the levels that were found before 2020. The SSB of the western Baltic spring-spawning herring attained in the last years its lowest historical levels. Catch and fishing pressure are at an all-time low but not zero, as advised by ICES. Recruitment is historically low.

The spawning-stock biomass of sprat reached the maximum observed SSB in 1996–1997 due to the combination of strong recruitments and declining natural mortality, which was the effect of a quickly decreasing cod biomass. High catches in the following years and five successive below-average year classes (2009–2013) led to a stock decline. Sprat population biomass trends fluctuate and strong year classes are followed by 4-5 weaker ones. The spawning-stock biomass has been above precautionary levels for over 30 years, while the fishing mortality has been slightly above present F_{MSY} in 2021–2022. During the recent two decades, the stock distribution has been changing with a tendency to an increased density in the northeastern Baltic, especially in autumn.

Marine Mammals

Three seal species occur regularly in the Baltic Sea: grey seal *Halichoerus grypus*, harbour seal *Phoca vitulina*, and ringed seal *Phoca hispida*. Grey seals occur throughout the Baltic Sea and the population has increased steadily and now is above 40 000 individuals; however, population growth rates have slowed in the last 10 years (HELCOM 2023f). Harbour seals mainly occur in the southern Baltic Sea and the population in this area had an estimated growth rate of 8.4% between 2002 and 2014. The neighbouring Kalmarsund population had a lower growth rate. The population of ringed seals in the Gulf of Finland is low, at around 100 animals, and is listed as vulnerable by IUCN. This is probably due to the recent lack of ice for breeding during winter, which has also made estimating population size and growth rates difficult since 2012. The Bothnian Bay population of ringed seals exceeds 10 000 animals (HELCOM 2023h). The only cetacean species to occur regularly in the Baltic Sea is the harbour porpoise *Phocoena phocoena*. East of the Transition Area, a large population decline has occurred in the past 50–100 years. With an estimation of 447 individuals (95% CI: 90–997), this population is listed as critically endangered by the IUCN. The Belt Sea population has a much higher abundance, estimated at 40 475 (95% CI: 25 614–65 041).

Seabirds

The seabird community of the Baltic Sea is highly variable, depending on the season. Some waterbird species are present throughout the year but many migrate to the Baltic Sea to breed or winter. A variety of species groups with different habitat preferences are found in coastal areas during the breeding period. In winter, the community is dominated by species that breed in arctic freshwater habitats, which use ice-free areas of the Baltic Sea as wintering areas. In all, the Baltic Sea is an important area for around 80 species of waterbirds.

The abundance of waterbirds in the Baltic Sea is strongly influenced not only by prey availability but also by a variety of human activities, with much impact generated by fishing, shipping and the use of wind energy at sea. Pressures include mortality caused by oil spills, incidental bycatch in fisheries, hunting as well as human-induced eutrophication affecting the foodweb structure and function. Many human activities have a cumulative impact on waterbird populations, even effects on species only wintering in the Baltic Sea can carry over to the breeding season (e.g. affecting breeding success). Migratory waterbirds passing the Baltic can be influenced by human activities during migration.

The overall status of wintering waterbirds for 29 species was poor, although there is variability between groups with different feeding behaviour (HELCOM 2023i). In the entire Baltic Sea the status of the breeding bird community is considered as good, but there are diverging results for the species groups. While surface feeders, pelagic feeders, benthic feeders and grazing feeders achieved the threshold value indicating a good status, wading feeders failed to achieve good status (HELCOM 2023j). An example of foodweb effects on birds is the breeding success of common guillemot linked to overfishing of cod, leading to an abundance of small pelagic fish available as a food source (HELCOM 2023j).

Foodwebs

The open Baltic Sea foodweb is characterized by low vertebrate species richness as relatively few fish species are tolerant of its brackish water conditions. In offshore sea areas the fish fauna are typically characterised by a single predatory fish (cod) and its pelagic prey (herring and sprat), and also by three-spined stickleback. In contrast, the coastal foodwebs are more complex and species rich. In the late 1980s and early 1990s, the open central Baltic ecosystem went through a regime-shift primarily due to eutrophication and overfishing, where cod biomass collapsed and that of sprat increased steeply (Tomczak *et al.* 2022). Simultaneously, changes were observed in the zooplankton composition. In the last decade, declines in herring abundance due to high fishing pressure have led to further changes in foodweb dynamics in the Central Baltic, Bothnian Sea and Gulf of Finland. In the western Baltic Sea, the continued overfishing of western Baltic cod and western Baltic spring-spawning herring contributed to a shift in dominance that favoured flatfish and sprat, respectively (Scotti *et al.* 2022). Concurrent worsening of environmental conditions (e.g. eutrophication and ocean warming) impairs the chances of cod and herring stocks to recover (Möllmann *et al.* 2021, Polte *et al.* 2021). Due to its shallow nature, benthic-pelagic coupling is an important mechanism in transferring energy within the Baltic Sea foodweb, with mysid and amphipod taxa serving as important links between the benthic and pelagic foodwebs (Kiljunen *et al.* 2020). However, declines in mysids and amphipods and increases in hypoxic zones may disrupt this coupling. The Bay of Bothnia is nutrient poor compared to other parts of the Baltic Sea, with a large part of the energy transferring to higher trophic levels coming from the microbial loop.

Trends in non-indigenous species

Seventy-six non-indigenous and cryptogenic aquatic species have been recorded in the Baltic Sea from 1980 to 2021 (Zenetos *et al.*, 2022). The annual rate of new species records has been increasing since the late 1990s (Figure 7.17).

The main introduction pathway has been transport–stowaway, as shipping vectors (primarily ballast water and hull fouling) have contributed to more than 40% of the introductions, although some reports have estimated that the contribution of shipping is even higher (HELCOM, 2023j). Unaided introductions, species that have been anthropogenically introduced to adjacent water bodies and have further spread to the Baltic Sea accounted for nearly 20% of the introductions, while 14% of the newly recorded species had an unknown mode of transport. The significance of these pathways has steadily increased in the past four decades, and there is increasing uncertainty among the most recent introductions, since the proportion of unknown introductions has remarkably increased since 2010 (Figure 7.18).

Several established non-indigenous species (NIS) have had significant impacts on the population and community structures of the native species within the Baltic Sea (Ojaveer *et al.*, 2021). In particular, widespread invaders, such as the round goby (*Neogobius melanostomus*), fish hook water flea (*Cercopagis pengoi*), and the red-gilled mudworm (*Marenzelleria* spp.) have impacts on native species population sizes, their diet, performance as well as functioning of local foodwebs (Nõomaa *et al.*, 2022; Outinen *et al.*, 2024).

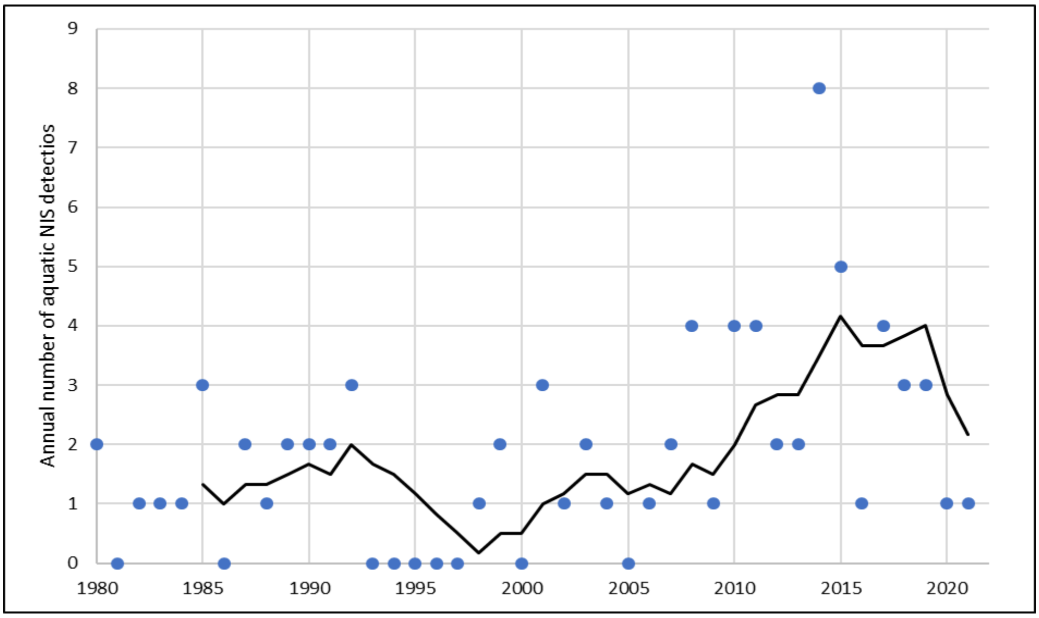


Figure 7.17 Annual rate of new aquatic non-indigenous species (NIS) and cryptogenic species detections from 1980 to 2021. Annual numbers of new detections are marked with blue dots, and the black line represents a six-year moving average as the trendline (which is in line with HELCOM HOLAS 3 assessment and 6-year assessment periods used by the EU MSFD reporting). The records do not include species recorded from Russian waters within the Baltic Sea.

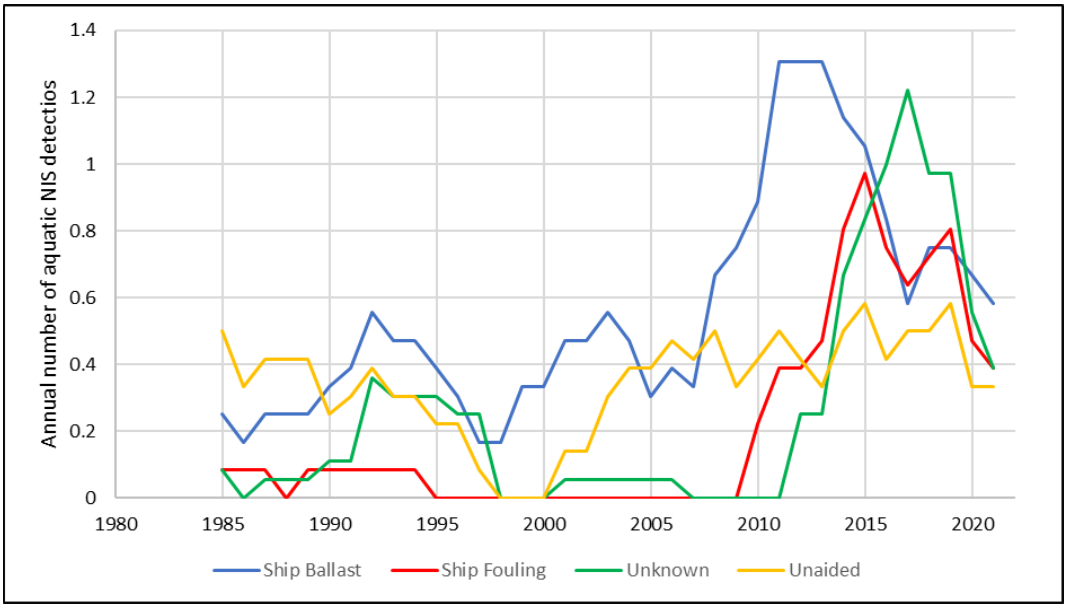


Figure 7.18 Annual rate of new aquatic non-indigenous species (NIS)and cryptogenic species detections from 1980 to 2021 by four most highly suspected or observed pathways: Ship Ballast (n = 21), Ship Fouling (8), unknown (10), and unaided (13). NIS associated with more than one pathway were assigned for the pathways using a weighted approach. Trendlines are showing six-year moving averages. The records do not include species recorded from Russian waters within the Baltic Sea.

Threatened and declining species and habitats

The HELCOM Red List assessment for the Baltic Sea considered nearly 2800 species or subspecific assessment units among which 1750 were evaluated using IUCN Red List criteria and 4% were categorized as threatened. Three species are regionally extinct: the American Atlantic sturgeon, common skate, and gull-billed tern. Eight taxa are classified as Critically Endangered (all vertebrates), 18 Endangered and 43 Vulnerable, and 36 Near Threatened (HELCOM 2023k). Red-listed fish, birds, and mammals taxa are evenly distributed across regions and have experienced dramatic overall declines (HELCOM 2023k). Red-listed macrophytes and benthic invertebrates are often rare (restricted by salinity) and declining (HELCOM 2023k; Table 7.1). The main pressures are eutrophication (especially in shallow sheltered habitats), human activities such as tourism, construction, aquaculture, fishing, bycatch, and recreational fishing while climate change is a growing concern for the future (HELCOM 2023k).

Complex interactions between pressures increase the risk of threatened and declining species and habitats. HELCOM assessments of coastal and marine habitats Red List includes 53 habitats in the Baltic Sea. One was categorized as Critically Endangered, 11 as Endangered, five as Vulnerable, and 42 as Near Threatened (HELCOM 2023e). The proportion of red listed habitats was highest for aphotic biotopes compared to the photic or the pelagic zone. Of the red-listed biotopes, the Baltic aphotic muddy sediment dominated by ocean quahog, was designated as Critically Endangered. Additionally, all biotope complexes were red-listed (HELCOM 2023k; Table 7.2).

Table 7.1 Threatened and declining species in the Baltic Sea according to HELCOM 2023e. The assessment of the Baltic Sea Ecosystem is seen in the last column, with these abbreviations: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Near Threatened (NT).

Species scientific name	Species name in English	Species group	Threat status
Alisma wahlenbergii		Macrophytes	VU

Chara braunii	Braun`s stonewort	Macrophytes	VU
Hippuris tetraphylla	Fourleaf Mare’s Tail	Macrophytes	EN
Lamprothamnium papulosum	Foxtail stonewort	Macrophytes	EN
Nitella hyalina	Many-branched stonewort	Macrophytes	VU
Persicaria foliosa		Macrophytes	EN
Zostera noltii	Dwarf eelgrass	Macrophytes	VU
Abra prismatica		Invertebrates	VU
Atelecyclus rotundatus	Circular crab/Old man’s face crab	Invertebrates	VU
Clelandella miliaris		Invertebrates	VU
Cliona celata	Yellow boring sponge	Invertebrates	VU
Deshayesorchestia deshayesii		Invertebrates	VU
Epitonium clathrus	Common wentletrap/European wentletrap	Invertebrates	VU
Haploops tenuis		Invertebrates	EN
Haploops tubicola		Invertebrates	VU
Hippasteria phrygiana	Rigid cushion star	Invertebrates	VU
Hippolyte varians	Chamaeleon prawn	Invertebrates	VU
Lunatia pallida	Pale moonsnail	Invertebrates	VU
Macoma calcarea	Chalky macoma	Invertebrates	VU
Modiolus modiolus	Northern horsemussel	Invertebrates	VU
Nucula nucleus	Common nut clam	Invertebrates	VU
Parvicardium hauniense	Copenhagen cockle	Invertebrates	VU
Pelonaia corrugata		Invertebrates	VU
Scrobicularia plana	Peppery furrow shell	Invertebrates	VU
Solaster endeca	Purple sun star	Invertebrates	VU
Stomphia coccinea	Spotted swimming anemone	Invertebrates	VU
Acipenser oxyrinchus	American Atlantic sturgeon	Fish	RE
Anguilla anguilla	European eel	Fish	CR
Coregonus maraena	Whitefish	Fish	EN
Dipturus batis	Common skate	Fish	RE
Gadus morhua	Atlantic cod	Fish	VU

Galeorhinus galeus	Tope shark	Fish	VU
Lamna nasus	Porbeagle	Fish	CR
Merlangius merlangus	Whiting	Fish	VU
Molva molva	Ling	Fish	EN
Petromyzon marinus	Sea lamprey	Fish	VU
Raja clavata	Thornback ray	Fish	VU
Salmo salar	Salmon	Fish	VU
Salmo trutta	Trout	Fish	VU
Squalus acanthias	Spurdog / Spiny dogfish	Fish	CR
Thymallus thymallus	Grayling	Fish	CR
Anser fabalis fabalis (wintering)	Taiga bean goose	Birds	EN
Arenaria interpres (breeding)	Ruddy turnstone	Birds	VU
Aythya marila (breeding)	Greater scaup	Birds	VU
Calidris alpina schinzii (breeding)	Southern dunlin	Birds	EN
Cepphus grylle arcticus (wintering)	Black guillemot	Birds	VU
Charadrius alexandrinus (breeding)	Kentish plover	Birds	CR
Clangula hyemalis (wintering)	Long-tailed duck	Birds	EN
Gavia arctica (wintering)	Black-throated diver	Birds	CR
Gavia stellata (wintering)	Red-throated diver	Birds	CR
Gelochelidon nilotica (breeding)	Gull-billed tern	Birds	RE
Hydroprogne caspia (breeding)	Caspian tern	Birds	VU
Larus fuscus fuscus (breeding)	Lesser black-backed gull	Birds	VU
Larus melanocephalus (breeding)	Mediterranean gull	Birds	EN
Melanitta fusca (wintering EN, breeding VU)	Velvet scoter	Birds	EN
Melanitta nigra (wintering)	Common scoter	Birds	EN
Mergus serrator (wintering)	Red-breasted merganser	Birds	VU
Philomachus pugnax (breeding)	Ruff	Birds	VU
Podiceps auritus (breeding VU, wintering NT)	Slavonian grebe	Birds	VU
Podiceps grisegena (wintering)	Red-necked grebe	Birds	EN

Polysticta stelleri (wintering)	Steller's eider	Birds	EN
Rissa tridactyla (breeding EN, wintering VU)	Black-legged kittiwake	Birds	EN
Somateria mollissima (wintering EN, breeding VU)	Common eider	Birds	EN
Xenus cinereus (breeding)	Terek sandpiper	Birds	EN
Phoca hispida botnica	Baltic ringed seal	Mammals	VU
Phoca vitulina (Kalmarsund population)	Harbour seal	Mammals	VU
Phocoena phocoena (Baltic Sea population)	Harbour porpoise	Mammals	CR
Phocoena phocoena (Western Baltic population)	Harbour porpoise	Mammals	VU

Table 7.2 Threatened and declining habitats in the Baltic Sea

n/a

Emerging Issues

Due to the energy crisis, priority for planning new and expanding existing offshore wind farms, including the linked technical infrastructure is evident. In the majority of countries around the Baltic Sea, this is creating a lot of competition for space with other, "more traditional" sectors such as e.g. fisheries, transportation or environmental protection. Setting of new priorities in the process of Marine Spatial Planning will change the way ecosystem goods and services are being utilized in the nearest future.

Extreme climate-related events such as heatwaves are increasing in frequency and magnitude in the Baltic Sea. Warming generates stratification of the sea surface, halting the water mixing and imposing anoxic conditions in the layers adjacent the seabed. Therefore, besides coping with temperature rise, marine organisms will have to endure low oxygen conditions during extreme heatwave episodes, which may lead to high mortality rates and decrease biodiversity. However, little is known about how heatwave events affect marine ecosystems in the Baltic Sea (Pansch *et al*. 2018, Ito *et al*. 2024). Further studies should be conducted to assess the impacts of heatwaves and reveal adaptive management strategies to be applied in the region.

Military activities due to the unstable political situation after Russia's attack on Ukraine have caused an increased alertness in the Baltic Sea. This situation has resulted in more military rehearsals and there is a risk of increased military activity in the area. These actions are largely classified and the resulting pressures and their ecosystem impacts are unknown.

Sources and acknowledgements

n/a

8 Reference list

Bełdowski, J., Klusek, Z., Szubska, M., Turja, R., Bulczak, A.I., Rak, D., Brenner, M., Lang, T., Kotwicki, L., Grzelak, K. and Jakacki, J., 2016. Chemical munitions search & assessment—an evaluation of the dumped munitions problem in the Baltic Sea. Deep Sea Research Part II: Topical Studies in Oceanography, 128:85-95. https://doi.org/10.1016/j.dsr2.2015.01.017

Białowąs, M., Jonko-Sobuś, K., Pawlak, J., Polak-Juszczak, L., Dąbrowska, A. and Urban-Malinga, B., 2022. Plastic in digestive tracts and gills of cod and herring from the Baltic Sea. Science of the Total Environment, 822: 153333. https://doi.org/10.1016/j.scitotenv.2022.153333

Blenckner, T., Möllmann, C., Stewart Lowndes, J., Griffiths, J.R., Campbell, E., De Cervo, A., Belgrano, A., Boström, C., Fleming, V., Frazier, M., Neuenfeldt, S., Niiranen, S., Nilsson, A., Ojaveer, H., Olsson, J., Palmlöv, C.S., Quaas, M., Rickels, W., Sobek, A., Viitasalo, M., Wikström, S.A. and Halpern, B.S. 2021: The Baltic Health Index (BHI): Assessing the social–ecological status of the Baltic Sea. People and Nature, 3: 359-375. https://doi.org/10.1002/pan3.10178

Bregnballe, T., Tofft, J., Kotzerka, J., Lehikoinen, A., Rusanen, P., Herrmann, C., ... and Kouzov, S. A. 2022. Occurrence and behaviour of White-tailed Eagles *Haliaeetus albicilla* in Great Cormorant *Phalacrocorax carbo sinensis* colonies in countries around the Baltic Sea. Ardea, 109(3): 565-582. https://doi.org/10.5253/arde.v109i2.a24

Bryhn, A.C., Bergek, S., Bergström, U., Casini, M., Dahlgren, E., Ek, C., Hjelm, J., Königson, S., Ljungberg, P., Lundström, K. and Lunneryd, S.G., 2022. Which factors can affect the productivity and dynamics of cod stocks in the Baltic Sea, Kattegat and Skagerrak?. *Ocean & Coastal Management*, *223*, p.106154. https://doi.org/10.1016/j.ocecoaman.2022.106154

Carstensen, J., Andersen, J.H., Gustafsson, B.G. and Conley, D.J., 2014. Deoxygenation of the Baltic Sea during the last century. PNAS 111, 5628–5633. https://doi.org/10.1073/pnas.1323156111

Carstensen, J. and Conley, D.J., 2019. Baltic Sea Hypoxia Takes Many Shapes and Sizes. Limnology and Oceanography Bulletin 28, 125–129. https://doi.org/10.1002/lob.10350

Casini, M., Käll, F., Hansson, M., Plikshs, M., Baranova, T., Karlsson, O., Lundström, K., Neuenfeldt, S., Gårdmark, A. and Hjelm, J., 2016. Hypoxic areas, density-dependence and food limitation drive the body condition of a heavily exploited marine fish predator. R. Soc. open sci., 3: 160416. https://doi.org/10.1098/rsos.160416

Cervin, L., Harkonen, T. and Harding, K.C., 2020. Multiple stressors and data deficient populations; a comparative life-history approach sheds new light on the extinction risk of the highly vulnerable Baltic harbour porpoises (*Phocoena phocoena*). Environment International, 144: 106076. https://doi.org/10.1016/j.envint.2020.106076

Conley, D. J., Carstensen, J., Aigars, J., Axe, P., Bonsdorff, E., Eremina, T., Haahti, B. M., Humborg, C., Jonsson, P., Kotta, J., Lännegren, C., Larsson, U., Maximov, A., Medina, M. R., Lysiak-Pastuszak, E., Remeikaitè-Nikienè, N., Walve, J., Wilhelms, S. and Zillén, L. (2011). Hypoxia is increasing in the coastal zone of the Baltic Sea. Environmental Science and Technology, 45(16): 6777–6783. https://doi.org/10.1021/es201212r

EEA Europe data and map service. Accessed 15.5.2024 https://www.eea.europa.eu/data-and-maps/figures/baltic-sea-physiography-depth-distribution-and-main-currents

Eero, M., MacKenzie, B., Koster, F. and Gislason, H., 2011. Multi-decadal responses of a cod (*Gadus morhua*) population to human-induced trophic changes, fishing, and climate. Ecological Applications, 21: 214–226. https://doi.org/10.1890/09-1879.1

Eero, M., Dierking, J., Humborg, C., Undeman, E., MacKenzie, B. R., Ojaveer, H., ... and Köster, F. W. 2021. Use of food web knowledge in environmental conservation and management of living resources in the Baltic Sea. ICES Journal of Marine Science, 78(8): 2645-2663, https://doi.org/10.1093/icesjms/fsab145

Glemarec, G., Königson, S., and Kindt-Larsen, L. 2021. Bycatch in Baltic Sea commercial fisheries: High-risk areas and evaluation of measures to reduce bycatch. HELCOM ACTION (2021). https://helcom.fi/wp-content/uploads/2021/11/Bycatch-in-Baltic-Sea-commercial-fisheries.pdf

Granéli, E., Wallström, K., Larsson, U., Granéli, W. and Elmgren, R. 1990. Nutrient Limitation of Primary Production in the Baltic Sea Area. Ambio, 19: 142–151. https://www.jstor.org/stable/4313680

Gröger, M., Arneborg, L., Dieterich, C., Höglund, A., and Meier, H. E. M. 2019. Summer hydrographic changes in the Baltic Sea, Kattegat and Skagerrak projected in an ensemble of climate scenarios downscaled with a coupled regional ocean–sea ice–atmosphere model. Climate Dynamics, 53: 5945–5966. https://doi.org/10.1007/s00382-019-04908-9

Gustafsson, E., Savchuk, O.P., Gustafsson, B.G. and Müller-Karulis, B. 2017. Key processes in the coupled carbon, nitrogen, and phosphorus cycling of the Baltic Sea. Biogeochemistry, 134: 301–317. https://doi.org/10.1007/s10533-017-0361-6

Gustafsson, B.G., Schenk, F., Blenckner, T., Eilola, K., Meier, H.E.M., Müller-Karulis, B., Neumann, T., Ruoho-Airola, T., Savchuk, O.P. and Zorita, E. 2012. Reconstructing the Development of Baltic Sea Eutrophication 1850–2006. Ambio, 41: 534–548. https://doi.org/10.1007/s13280-012-0318-x

Gustafsson, E. and Gustafsson, B.G. 2020. Future acidification of the Baltic Sea–A sensitivity study. Journal of Marine Systems, 211: 103397. https://doi.org/10.1016/j.jmarsys.2020.103397

Hansson, M. and Viktorsson, L. 2023. Oxygen Survey in the Baltic Sea 2023 - Extent of Anoxia and Hypoxia, 1960-2022 (Report Oceanography No. 74). SMHI. https://www.smhi.se/polopoly_fs/1.196444!/RO_74%20Oxygen%20Survey%20in%20the%20Baltic%20Sea%202022%20-%20Extent%20of%20Anoxia%20and%20Hypoxia%2C%201960-2022.pdf

Harding, K. C., Härkönen, T., Helander, B. and Karlsson, O. 2007. Status of Baltic grey seals: Population assessment and extinction risk. NAMMCO Sci. Publ., 6: 33–56. https://doi.org/10.7557/3.2720

HELCOM 2013. Red List of Baltic Sea underwater biotopes, habitats and biotope complexes. Baltic Sea Environmental Proceedings No. 138. Online. 30.5.2024. https://helcom.fi/post_type_publ/bsep138/

HELCOM 2021. Baltic Sea Action Plan 2021 Update. Online. 30.5.2024. https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf

HELCOM 2022. PLC-7: Assessment of sources of nutrient inputs to the Baltic Sea in 2017. Online. 30.5.2024. https://helcom.fi/wp-content/uploads/2022/12/PLC-7-Assessment-of-sources-of-nutrient-inputs-to-the-Baltic-Sea-in-2017.pdf

HELCOM 2023a. Diatom/Dinoflagellate index. HELCOM pre-core indicator report. Online. 29.5.2024, https://indicators.helcom.fi/indicator/diatom-dinoflagellate-index/

HELCOM 2023b. Chlorophyll-a. HELCOM core indicator report. Online. 29.5.2024, https://indicators.helcom.fi/indicator/chlorophyll/.

HELCOM 2023c. Cyanobacteria bloom index. HELCOM pre-core indicator report. Online. 29.5.2024, https://indicators.helcom.fi/indicator/cyanobacterial-blooms/

HELCOM 2023d. Zooplankton mean size and total stock. HELCOM core indicator report. Online. 20.5.2024, https://indicators.helcom.fi/indicator/zooplankton/

HELCOM 2023e. HELCOM Thematic assessment of biodiversity 2016-2021. Baltic Sea Environment Proceedings 191. https://helcom.fi/post_type_publ/holas3_bio/

HELCOM 2023f. Population trends and abundance of seals. HELCOM core indicator report. Online. 20.5.2024, https://indicators.helcom.fi/indicator/grey-seal-abundance/.

HELCOM 2023g. Population trends and abundance of seals. HELCOM core indicator report. Online. 20.5.2024, https://indicators.helcom.fi/indicator/ringed-seal-abundance/.

HELCOM 2023h. Abundance of waterbirds in the wintering season. HELCOM core indicator report. Online. 30.5.2024, https://indicators.helcom.fi/indicator/waterbirds-wintering-season/.

HELCOM 2023i. Abundance of waterbirds in the breeding season. HELCOM core indicator report. Online. 30.5.2024, https://indicators.helcom.fi/indicator/waterbirds-breeding-season/.

HELCOM 2023j. Trends in arrival of new non-indigenous species. HELCOM core indicator report. Online. 8.5.2024, https://indicators.helcom.fi/indicator/non-indigenous-species/

HELCOM 2023k. Thematic assessment of eutrophication 2016-2021 (No. 192), Baltic Sea Environment Proceedings. Online. 30.5.2024. https://helcom.fi/wp-content/uploads/2023/06/HELCOM-Thematic-assessment-of-eutrophication-2016-2021.pdf

HELCOM 2023l. Inputs of nutrients (nitrogen and phosphorus) to the subbasins 1995-2021. Online. 30.5.2024. https://indicators.helcom.fi/indicator/inputs-of-nutrients/

HELCOM BLUES 2023. A2.3 Pelagic habitats - Main report. Online. 30.5.2024. https://blues.helcom.fi/wp-content/uploads/2023/04/HELCOM-BLUES_Activity-2.3_Main-report.pdf

Herrmann, C., Bregnballe, T., Larsson, K., and Rattiste, K. 2014. Population development of Baltic bird species: Great Cormorant (*Phalacrocorax carbo sinensis*), update 2018. HELCOM Baltic Sea Environment Fact Sheet. Online. 30.5.2024. https://helcom.fi/wp-content/uploads/2020/06/BSEFS-Population-development-of-the-Great-Cormorant.pdf

ICES 2019. EU request to advise on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, sr.2019.25, https://doi.org/10.17895/ices.advice.5742.

ICES 2021a. ICES advice to the EU on how management scenarios to reduce mobile bottom fishing disturbance on seafloor habitats affect fisheries landing and value. In Report of the ICES Advisory Committee, 2021. ICES Advice 2021. sr.2021.08. https://doi.org/10.17895/ices.advice.8191.

ICES 2021b. Working Group on Marine Litter (WGML; outputs from 2020 meeting). ICES Scientific Reports, 3:51. 90 pp. https://doi.org/10.17895/ices.pub.8185

ICES 2022a. Technical guideline document for assessing fishing impact from mobile bottom-contacting fishing gears (version 2, 27 February 2022). within: Report from the working group on Fisheries Benthic Impact and Trade-Offs

ICES 2022b Workshop to evaluate proposed assessment methods and how to set thresholds for assessing adverse effects on seabed habitats (WKBENTH3). https://figshare.com/articles/report/Workshop_to_evaluate_proposed_assessment_methods_and_how_to_set_thresholds_for_assessing_adverse_effects_on_seabed_habitats_WKBENTH3_/21666260.

ICES. 2022c. Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT; outputs from 2022 meeting). Online. 30.5.2024. https://ices-library.figshare.com/articles/report/Working_Group_on_Fisheries_Benthic_Impact_and_Trade-offs_WGFBIT_outputs_from_2022_meeting_/22123193

ICES. 2022d. Baltic Sea ecoregion – fisheries overview. In: Report of the ICES Advisory Committee, 2022. ICES Advice 2022, section 4.2. https://doi.org/10.17895/ices.advice.21646934

ICES. 2023a. ICES Ecosystem Overviews Technical Guidelines. Version 4. ICES Guidelines and Policies - Advice Technical Guidelines. 24 pp. https://doi.org/10.17895/ices.pub.22059803

ICES 2023b. Sprat (*Sprattus sprattus*) in subdivisions 22–32 (Baltic Sea). In Report of the ICES Advisory Committee, 2023. ICES Advice 2023, spr.27.22–32. https://doi.org/10.17895/ices.advice.21820581

ICES. 2024. Baltic Sea ecoregion – Ecosystem overview. In Report of the ICES Advisory Committee, 2024. ICES Advice 2024, Section 7.1, https://doi.org/10.17895/ices.advice.27256635

Ito, M., Halouani, G., Cresson, P., Giraldo, C. and Girardin, R. 2023. Detection of fishing pressure using ecological network indicators derived from ecosystem models. Ecological Indicators, 147: 110011. https://doi.org/10.1016/j.ecolind.2023.110011

Ito, M., Guy-Haim, T., Sawall, Y., Franz, M., Buchholz, B., Hansen, T., Neitzel, P., Pansch, C., Steinhoff, T., Wahl, M., Weinberger, F. and Scotti, M. 2024. Responses at various levels of ecological hierarchy indicate acclimation to sequential sublethal heatwaves in a temperate benthic ecosystem. Philosophical Transactions of the Royal Society B, 379: 20230171. https://doi.org/10.1098/rstb.2023.0171

Jaspers, C., Bezio, N. and Hinrichsen H-H. 2021. Diversity and Physiological Tolerance of Native and Invasive Jellyfish/Ctenophores along the Extreme Salinity Gradient of the Baltic Sea. Diversity, 13(2): 57. https://doi.org/10.3390/d13020057

Kiljunen, M., Peltonen, H., Lehtiniemi, M., Uusitalo, L., Sinisalo, T., Norkko, J., Kunnasranta, M., Torniainen, J., Rissanen, A.J. and Karjalainen, J. 2020. Benthic-pelagic coupling and trophic relationships in northern Baltic Sea food webs. Limnology and Oceanography, 65(8): 1706-1722. https://doi.org/10.1002/lno.11413

Koehler, B., Erlandsson, M., Karlsson, M. and Bergström, L. 2022. Species richness and functional attributes of fish assemblages across a large-scale salinity gradient in shallow coastal areas. Biogeosciences, 19(8): 2295-2312, https://doi.org/10.5194/bg-19-2295-2022

Kuliński, K., Rehder, G., Asmala, E., Bartosova, A., Carstensen, J., Gustafsson, B., Hall, P.O.J., Humborg, C., Jilbert, T., Jürgens, K., Meier, H.E.M., Müller-Karulis, B., Naumann, M., Olesen, J.E., Savchuk, O., Schramm, A., Slomp, C.P., Sofiev, M., Sobek, A., Szymczycha, B. and Undeman, E. 2022. Biogeochemical functioning of the Baltic Sea. Earth System Dynamics, 13: 633–685. https://doi.org/10.5194/esd-13-633-2022

Köster, F.W., Huwer, B., Hinrichsen, H.-H., Neumann, V., Makarchouk, A., Eero, M., Dewitz, B.V., Hüssy, K., Tomkiewicz, J., Margonski, P., Temming, A., Hermann, J.-P., Oesterwind, D., Dierking, J., Kotterba, P. and Plikshs, M. 2017. Eastern Baltic cod recruitment revisited—dynamics and impacting factors. ICES J Mar Sci 74: 3–19. https://doi.org/10.1093/icesjms/fsw172

Lehmann, A., Myrberg, K., Post, P., Chubarenko, I., Dailidiene, I., Hinrichsen, H.H., Hüssy, K., Liblik, T., Meier, H.M., Lips, U. and Bukanova, T. 2022. Salinity dynamics of the Baltic Sea. Earth System Dynamics, 13(1): 373-392. https://doi.org/10.5194/esd-13-373-2022

Liljebäck, N., Sørensen, I. H., Sterup, J., Haas, F., Petersen, I. K., Månsson, J., 2023. Prevalence of imbedded and ingested shot gun pellets in breeding sea ducks in the Baltic Sea—possible implications for future conservation efforts. European Journal of Wildlife Research, 69(4): 73. https://doi.org/10.1007/s10344-023-01706-x

MacKenzie, B. R. and Köster, F. W. 2004. Fish production and climate: sprat in the Baltic Sea. Ecology, 85(3): 784-794. https://doi.org/10.1890/02-0780

McCrackin, M.L., Muller-Karulis, B., Gustafsson, B.G., Howarth, R.W., Humborg, C., Svanbäck, A. and Swaney, D.P., 2018. A Century of Legacy Phosphorus Dynamics in a Large Drainage Basin. Global Biogeochemical Cycles, 32: 1107–1122. https://doi.org/10.1029/2018GB005914

Meier, H.E.M., Kniebusch, M., Dieterich, C., Gröger, M., Zorita, E., Elmgren, R., Myrberg, K., Ahola, M. P., Bartosova, A., Bonsdorff, E., Börgel, F., Capell, R., Carlén, I., Carlund, T., Carstensen, J., Christensen, O. B., Dierschke, V., Frauen, C., Frederiksen, M., Gaget, E., Galatius, A., Haapala, J. J., Halkka, A., Hugelius, G., Hünicke, B., Jaagus, J., Jüssi, M., Käyhkö, J., Kirchner, N., Kjellström, E., Kulinski, K., Lehmann, A., Lindström, G., May, W., Miller, P. A., Mohrholz, V., Müller-Karulis, B., Pavón-Jordán, D., Quante, M., Reckermann, M., Rutgersson, A., Savchuk, O. P., Stendel, M., Tuomi, L., Viitasalo, M., Weisse, R., and Zhang, W. 2022. Climate change in the Baltic Sea region: a summary. Earth System Dynamics, 13: 457–593. https://doi.org/10.5194/esd-13-457-2022

Meier, H.E.M., Reckermann, M., Langner, J., Smith, B., and Didenkulova, I. 2023. Overview: The Baltic Earth Assessment Reports (BEAR). Earth System Dynamics, 14: 519–531. https://doi.org/10.5194/esd-14-519-2023

Möllmann, C., Cormon, X., Funk, S., Otto, S.A., Schmidt, J.O., Schwermer, H., Sguotti, C., Voss, R. and Quaas, M. 2021. Tipping point realized in cod fishery. Scientific Reports, 11: 14259. https://doi.org/10.1038/s41598-021-93843-z

Morkūnas, J., Biveinytė, V., Balčiūnas, A., Morkūnė, R., 2021. The broader isotopic niche of Long-tailed Duck *Clangula hyemalis* implies a higher risk of ingesting plastic and non-plastic debris than for other diving seabirds. Marine pollution bulletin, 173: 113065. https://doi.org/10.1016/j.marpolbul.2021.113065

Morkūnas, J., Oppel, S., Bružas, M., Rouxel, Y., Morkūnė, R., & Mitchell, D., 2022. Seabird bycatch in a Baltic coastal gillnet fishery is orders of magnitude larger than official reports. Avian conservation and ecology., 17(1), 1-12. https://doi.org/10.5751/ACE-02153-170131

Möllmann, C., Diekmann, R., Müller-Karulis, B., Kornilovs, G., Plikshs, M. and Axe, P. 2009. Reorganization of a large marine ecosystem due to atmospheric and anthropogenic pressure: a discontinuous regime shift in the Central Baltic Sea. Global Change Biology, 15(6): 1377-1393. https://doi.org/10.1111/j.1365-2486.2008.01814.x

Möllmann, C., Cormon, X., Funk, S., Otto, S.A., Schmidt, J.O, Schwermer, H., Sguotti, C., Voss, R., and Quaas, M. 2019. Tipping point realized in cod fishery. Scientific Reports, 11(1): 14259. https://doi.org/10.1038/s41598-021-93843-z

Neuenfeldt, S. 2002. The influence of oxygen saturation on the distributional overlap of predator (cod, Gadus *morhua*) and prey (herring, *Clupea harengus*) in the Bornholm Basin of the Baltic Sea. Fisheries Oceanography, 11(1): 11-17, https://doi.org/10.1046/j.1365-2419.2002.00183.x

Niquil, N., Scotti, M., Fofack-Garcia, R., Haraldsson, M., Thermes, M., Raoux, A., Le Loc'H, F. and Mazé, C. 2021. The merits of loop analysis for the qualitative modeling of social-ecological systems in presence of offshore wind farms. Frontiers in Ecology and Evolution, 9: 635798. https://doi.org/10.3389/fevo.2021.635798

Nõomaa, K., Kotta, J., Szava-Kovats, R., Herkül, K., Eschbaum, R. and Vetemaa, M. 2022. Novel fish predator causes sustained changes in its prey populations. Frontiers in Marine Science, 9: 849878. https://doi.org/10.3389/fmars.2022.849878

Ojaveer, H., Kotta, J., Outinen, O., Einberg, H., Zaiko, A. and Lehtiniemi, M. 2021. Meta-analysis on the ecological impacts of widely spread non-indigenous species in the Baltic Sea. Science of the Total Environment, 786: 147375. https://doi.org/10.1016/j.scitotenv.2021.147375

Olsson, J., Tomczak, M. T., Ojaveer, H., Gårdmark, A., Pollumäe, A., Müller-Karulis, B., ... and Bergström, L. 2015. Temporal development of coastal ecosystems in the Baltic Sea over the past two decades. ICES Journal of Marine Science, 72(9): 2539-2548. https://doi.org/10.1093/icesjms/fsv143

Olsson, J., Andersson, M. L., Bergström, U., Arlinghaus, R., Audzijonyte, A., Berg, S., Briekmane, L., Dainys, J., Ravn, H. D., Droll, J., Dziemian, Ł., Fey, D. P., van Gemert, R., Greszkiewicz, M., Grochowski, A., Jakubavičiūtė, E., Lozys, L., Lejk, A. M., Mustamäki, N., … and Östman, Ö. 2023. A pan-Baltic assessment of temporal trends in coastal pike populations. Fisheries Research, 260. https://doi.org/10.1016/j.fishres.2022.106594

Otremba, Z., Jakubowska, M., Urban-Malinga, B. and Andrulewicz, E. 2019. Potential effects of electrical energy transmission–the case study from the Polish Marine Areas (southern Baltic Sea). Oceanological and Hydrobiological Studies, 48(2): 196-208. https://doi.org/10.1515/ohs-2019-0018

Outinen, O., Katajisto, T., Nygård, H., Puntila-Dodd, R. and Lehtiniemi, M. 2024. National assessment on the status, trends and impacts of marine non-indigenous species for the European Union marine strategy framework directive. Ecological Indicators, 158: 111593. https://doi.org/10.1016/j.ecolind.2024.111593

Pansch, C., Scotti, M., Barboza, F.R., Al-Janabi, B., Brakel, J., Briski, E., Bucholz, B., Franz, M., Ito, M., Paiva, F., Saha, M., Sawall, Y., Weinberger, F. and Wahl, M. 2018. Heat waves and their significance for a temperate benthic community: A near-natural experimental approach. Global Change Biology, 24: 4357-4367. https://doi.org/10.1111/gcb.14282

Pärn, O., Lessin, G. and Stips, A. 2021. Effects of sea ice and wind speed on phytoplankton spring bloom in central and southern Baltic Sea. PLoS ONE, 16(3): e0242637. https://doi.org/10.1371/journal.pone.0242637

Plikshs, M., 2015. Reproduction of Baltic cod, *Gadus morhua* (Actinopterygii: Gadiformes: Gadidae), in the Gotland Basin: Causes of annual variability. Acta Ichthyol. Piscat., 45: 247–258. https://doi.org/10.3750/AIP2015.45.3.04

Polte, P., Gröhsler, T., Kotterba, P., Von Nordheim, L., Moll, D., Santos, J., Rodriguez-Tress, P., Zablotski, Y. and Zimmermann, C. 2021. Reduced reproductive success of western Baltic herring (*Clupea harengus*) as a response to warming winters. Frontiers in Marine Science, 8: 589242. https://doi.org/10.3389/fmars.2021.589242

Räsänen, T., 2022. Baltic seals and changing marine frontiers in the twentieth century. In Cold Waters: Tangible and Symbolic Seascapes of the North (pp. 35-50). Cham: Springer International Publishing.

Rau, A., Lewin, W. C., Zettler, M. L., Gogina, M., and von Dorrien, C. 2019. Abiotic and biotic drivers of flatfish abundance within distinct demersal fish assemblages in a brackish ecosystem (western Baltic Sea). Estuarine, Coastal and Shelf Science, 220: 38-47. https://doi.org/10.1016/j.ecss.2019.02.035

Rodriguez-Perez, A., Tsikliras, A.C., Gal, G., Steenbeek, J., Falk-Andersson, J. and Heymans, J.J. 2023. Using ecosystem models to inform ecosystem-based fisheries management in Europe: a review of the policy landscape and related stakeholder needs. Frontiers in Marine Science, 10: 1196329. https://doi.org/10.3389/fmars.2023.1196329

Rolff, C. and Elfwing, T. 2015. Increasing nitrogen limitation in the Bothnian Sea, potentially caused by inflow of phosphate-rich water from the Baltic Proper. Ambio, 44: 601–611. https://doi.org/10.1007/s13280-015-0675-3

de los Santos, C.B., Krause-Jensen, D., Alcoverro, T. *et al*. 2019. Recent trend reversal for declining European seagrass meadows. Nat Commun, 10: 3356. https://doi.org/10.1038/s41467-019-11340-4

Safonova, K., Meier, H.M. and Gröger, M. 2024. Summer heatwaves on the Baltic Sea seabed contribute to oxygen deficiency in shallow areas. Communications Earth & Environment, 5(1): 106. https://doi.org/10.1038/s43247-024-01268-z

Scotti, M., Opitz, S., MacNeil, L., Kreutle, A., Pusch, C. and Froese, R. 2022. Ecosystem-based fisheries management increases catch and carbon sequestration through recovery of exploited stocks: The western Baltic Sea case study. Frontiers in Marine Science, 9: 879998. https://doi.org/10.3389/fmars.2022.879998

Siebert, U., Stürznickel, J., Schaffeld, T., Oheim, R., Rolvien, T., Prenger-Berninghoff, E., Wohlsein, P., Lakemeyer, J., Rohner, S., Schick, L.A. and Gross, S., 2022. Blast injury on harbour porpoises (*Phocoena phocoena*) from the Baltic Sea after explosions of deposits of World War II ammunition. Environment international, 159: 107014. https://doi.org/10.1016/j.envint.2021.107014

Soininen, N., Belinskij, A., Vainikka, A. and Huuskonen, H., 2019. Bringing back ecological flows: migratory fish, hydropower and legal maladaptivity in the governance of Finnish rivers. Water international, 44(3): 321-336. https://doi.org/10.1080/02508060.2019.1542260

Thermes, M., Fofack Garcia, R., Scotti, M. and Niquil, N. in press. Qualitative modeling for representing the social-ecological system of the Groix – Belle-île offshore wind farm project. ICES Journal of Marine Science, fsae095. https://doi.org/10.1093/icesjms/fsae095

Thomas, D. N., Kaartokallio, H., Tedesco, L., Majaneva, M., Piiparinen, J. P., Eronen-Rasimus, E., Rintala, J.-M., Blomster, J., Vainio, J., & Granskog, M. A. (2017). Life associated with Baltic Sea ice. in P. Snoeijs-Leijonmalm, H. Schubert, & T. Radziejewska (Editors), Biological Oceanography of the Baltic Sea pp 333-357. Springer-Verlag GmbH. https://doi.org/10.1007/978-94-007-0668-2_9

Tomczak, M.T., Müller-Karulis, B., Blenckner, T., Ehrnsten, E., Eero, M., Gustafsson, B., Norkko, A., Otto, S.A., Timmermann, K., Humborg, C., 2022. Reference state, structure, regime shifts, and regulatory drivers in a coastal sea over the last century: The Central Baltic Sea case. Limnology and Oceanography, 67: S266-S284. https://doi.org/10.1002/lno.11975

Vahtera, E, Conley, D.J., Gustafsson, B.G., Kuosa, H., Pitkänen, H., Savchuk, O.P., Tamminen, T., Viitasalo, M., Voss, M., Wasmund, N. and Wulff, F, 2007. Internal ecosystem feedbacks enhance nitrogen-fixing cyanobaceria blooms and complicate management in the Baltic Sea. Ambio, 36: 186–194. https://doi.org/10.1579/0044-7447(2007)36[186:IEFENC]2.0.CO;2

Viitasalo, M. and Bonsdorff, E. 2022. Global climate change and the Baltic Sea ecosystem: direct and indirect effects on species, communities and ecosystem functioning. Earth System Dynamics, 13: 711–747. https://doi.org/10.5194/esd-13-711-2022

Voss, R., Hinrichsen, H. H., Quaas, M. F., Schmidt, J. O., and Tahvonen, O. 2011. Temperature change and Baltic sprat: from observations to ecological–economic modelling. ICES Journal of Marine Science, 68(6): 1244-1256, https://doi.org/10.1093/icesjms/fsr063

Zenetos, A., Tsiamis, K., Galanidi, M., Carvalho, N., Bartilotti, C., Canning-Clode, J., Castriota, L., Chainho, P., Comas-González, R., Costa, A.C. and Dragičević, B. 2022. Status and trends in the rate of introduction of marine non-indigenous species in European seas. Diversity, 14(12): 1077. https://doi.org/10.3390/d14121077

Žydelis, R. *et al*. (2009) 'Bycatch in gillnet fisheries – An overlooked threat to waterbird populations', Biological Conservation, 142(7), pp. 1269–1281. https://doi.org/10/fwdfxp

Annex 1: List of participants

Name	Institute	Country (of institute)	E-mail
Yosr Ammar	NHRM	Sweden	Yosr.Ammar@nrm.se
Joanna Calkiewizc	MIR	Poland	jcalkiewicz@mir.gdynia.pl
Christian von Dorrien	Thünen institute	Germany	christian.dorrien@thuenen.de
Aleksander Drgas	MIR	Poland	adrgas@mir.gdynia.pl
Carolyn Faithfull	SLU	Sweden	carolyn.faithfull@slu.se
Maysa Ito	GEOMAR	Germany	mito@geomar.de
Katriina Juva	Syke	Finland	Katriina.Juva@syke.fi
Piotr Margonski	MIR	Poland	pmargon@mir.gdynia.pl
Inigo Martinez	ICES	Denmark	inigo@ices.dk
Rasa Morkune	Klaipeda University	Lithuania	rasa.morkune@ku.lt
Monika Normant-Saremba	University of Gdańsk	Poland	monika.normant-saremba@ug.edu.pl
Mikko Olin	Luke	Finland	mikko.olin@luke.fi
Heikki Peltonen	Syke	Finland	heikki.peltonen@syke.fi
Guilherme Pinto	GEOMAR	Germany	guilherme.pinto@idiv.de
Riikka Puntila-Dodd	Syke	Finland	Riikka.puntila-dodd@syke.fi
Ivars Putnis	BIOR	Latvia	ivars.putnis@bior.lv
Jesper Stage	Luleå University of Technology	Sweden	jesper.stage@ltu.se
Marco Scotti	GEOMAR	Germany	mscotti@geomar.de
Maciej Tomczak	SLU	Sweden	maciej.tomczak@slu.se
Andrea Belgrano	SLU	Sweden	andrea.belgrano@slu.se
Lena Bergström	SLU	Sweden	lena.bergstrom@slu.se
Iveta Jurgensone	LHEI	Latvia	iveta.jurgensone@lhei.lv
Astra Labuce	LHEI	Latvia	astra.labuce@lhei.lv
Bärbel Muller-Karulis	SU	Sweden	barbel.muller.karulis@su.se
Okko Outinen	Syke	Finland	okko.outinen@syke.fi
Raisa Turja	Syke	Finland	raisa.turja@syke.fi

Elena Gorokhova	SU	Sweden	elena.gorokhova

Annex 2: Resolutions

2022/WK/IEASG10 A **Workshop for the revision of Ecosystem Overview of the Baltic Sea Ecoregion (WKBALEO)**, chaired by Carolyn Faithfull, Sweden, and Puntila Riikka, Finland, will hold a hybrid workshop 6–8 November 2023 in Gdynia, Poland and work intersessionally online to:

a) Review the content gathered and drafted (intersessionally) by the chairs for the Ecosystem Overview (EO) of the Baltic Sea;
b) Develop a wire diagram informed by a driver - pressure – ecosystem state approach using a linkage framework and pressure assessment process that examines and scores all direct pressures and human activities for the Baltic Sea ecoregion following the ICES technical guidelines methodology;
c) Prepare draft advice on the Baltic Sea EO;
d) List gaps in knowledge for the Baltic Sea and identify operational products to potentially improve the scientific basis of the advice for future iterations of the Baltic Sea EO.

In their work, WKBALEO shall describe the main environmental drivers for the ecoregion and link the main region-specific human activities to pressures on the ecosystem. The workshop will link these pressures to the state/impact of the ecosystem components (ice habitat and associated biota, pelagic habitat and associated biota, benthic habitat and associated biota, cephalopods, fish, reptiles, marine mammals and seabirds). When possible/appropriate temporal trends of each ecosystem component will also be described.

WKBALEO will report for the attention of ACOM and SCICOM by 7 June 2024.

Supporting information

Priority	The overviews are seen as a progression towards operational implementation of the ecosystem approach and as such are aimed at informing expert working groups and assisting Regional Seas Conventions and policy makers. ACOM aims to develop this product for all ICES ecoregions. The EOs should be prepared according to the ICES Technical Guidelines for Ecosystem Overviews. This workshop is an essential step to underpin a sound scientific basis for the management of the Baltic Sea Ecoregion by recording sources of information and discussions on the decisions by the experts. The work of this workshop will feed directly into Advisory process and will allow comparison between different ecoregions. Consequently, these activities are considered to have a very high priority. The ICES EOs are an integral part of ICES strategic plan to implement the Ecosystem Based Management (EBM). The revision of the EO for the Baltic Ecoregion will contribute to implementing EBM in the region and will be aimed at informing both the scientific community as well as states and intergovernmental management authorities and organizations.
Scientific justification	Environments and ecosystems vary over time, sometimes with a trend and sometimes with a step change. The regional ecosystem overviews are intended to provide advisory groups with information on natural variability, trends and step changes in

	the dynamics of their respective ecosystems based on the best available evidence that are expected to influence the advice. They will also summarize the impacts that human activities have on the state of living and non-living resources of the ecosystem components through the main pressures in the region. This information needs to consider both spatial and temporal variability, with priority given to changes that would lead to the most significant modifications to the advice. To support emerging policy developments, those developing advice on the impacts of specific sectors (e.g. fisheries catch options, contaminants, by-catch, seabird abundance, sensitive areas etc.) will need to understand and respond to the implications of their advice for a range of ecosystem components and attributes, with priority given to those impacts that may compromise known management objectives. This development of ecosystem overviews is one of a number of ICES initiatives to integrate the advice on managing the human impacts on marine ecosystems of the ICES area. Risk assessment methods will be used to obtain a better understanding of the distribution and scale of anthropogenic pressures across the marine system and to estimate their impacts. The process will be iterative with a number of phases which will increase the relevance, impact and quality of the ecosystem overviews.
Resource requirements	ICES Data Centre, Secretariat and Advice process.
Participants	The participation should reflect the diverse scientific competence needed to fulfil the objectives of the workshop. Participants join the workshop at national expense. Participation of stakeholders is not committed.
Secretariat facilities	Data Centre, Secretariat support.
Financial	This work will be done at national cost.
Linkages to advisory committees	The EOs are part of the ICES advice and the product of the workshop will enter into the ICES Advisory process to be approved by ACOM.
Linkages to other committees or groups	Several ICES working groups may contribute with text and data to the content of this EO (WGBFAS, WGCEPH, WGDEEP, WGHABD, WGHARP, WGOH, WGSCALLOP, WGPME, JWGBIRD, WGSOCIAL, WGZE, WGECON, etc.) as well as ACOM, SCICOM, IEA, FRSG, HUDISG, HAPISG.
Linkages to other organizations	The work of this group may be used or is closely aligned with work under HELCOM and National Programmes. Organizations with legal mandates to take binding action in the Baltic Ecoregion EO: HELCOM, EU Coastal States. Additional IGOs of interest to this work: NAMMCO, IWC, ICCAT.