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Ecosystem Health of the Baltic Sea – HELCOM Initial Holistic Assessment

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Baltic Sea Environment Proceedings No. 122

Ecosystem Health of the Baltic Sea

HELCOM Initial Holistic Assessment

Helsinki Commission

Baltic Marine Environment Protection Commission

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Ecosystem Health of the Baltic Sea 2003–2007

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The HELCOM Initial Holistic Assessment is a new and innovative approach, using existing and new tools of HELCOM. The results produced with the new tool HOLAS and the Baltic Sea Pressure/Impact Indices (BSPI/BSII) should be considered preliminary results which in the future need further elaboration and improvement. The same is valid for the status classifications (especially as far as they concern the indicators used in HEAT, BEAT and CHASE). Discrepancies between national WFD assessments and HOLAS results arise due to differences in spatial and temporal scaling as well as due to the use of different parameters.

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Preface

Eleven years remain for the nine countries sharing the Baltic Sea to reach their common goal to restore the health of the Baltic marine environment, as agreed by the adoption of the Baltic Sea Action Plan in 2007. Although 2021 seems a long time from now, looking at the challenges to be addressed and presented in this report, time is likely to fly rapidly.

This report is an essential document for the environmental managers and decision-makers in the Baltic region and it is novel in several respects. For the first time an attempt has been made to assess the ecosystem health of an entire regional sea, including the associated costs and benefits to society.

Clear and concise maps and texts demonstrate how the Baltic Sea is potentially affected by individual and cumulative pressures—and how far and how fast we need to go to reach our common management goals. Sea areas are portrayed on a scale as small as five by five kilometres. In order to deliver helpful guidance to identify the most effective remedial measures, pressures are ranked for the entire Baltic Sea as well as for individual sea basins.

The assessment is based on quality-assured data and expert knowledge gathered between 2003 and 2007; it provides a good basis to enable a comparison to the status before the implementation of the Baltic Sea Action Plan adopted by HELCOM in 2007. By comparing the future status of the sea to this baseline, it will be possible to demonstrate how our measures are improving the health status of the Baltic ecosystem and how the pressures we are exerting are changing, hopefully to the better.

This Initial Holistic Assessment of the ecosystem health of the Baltic applies existing and newly developed assessment tools and an economic cost-benefit overview and yields important conclusions: getting started and solving the environmental problems of the Baltic will also safeguard great economic, cultural and social values of the societies in the countries around the Baltic Sea. Postponing urgently needed investments, however, would put these values at stake.

The assessment gives the clear message that none of the open-water basins currently is in a 'good environmental status'. Most sea areas are affected by eutrophication, hazardous substances or an unfavourable conservation status. The human-induced pressures on the Baltic Sea have compromised the health of the Baltic Sea ecosystem, including the human communities linked to it. Given the current impaired status of ecosystem health, we urgently need to manage our pressures intelligently, especially pressures caused by agriculture, fisheries, industries, and the maritime sector, but also by ordinary people, because after all it is our lifestyle which is the root cause of all pressures affecting the marine environment.

Executive Summary

The Baltic Sea is a small sea on a global scale, yet it is one of the world's largest semi-enclosed bodies of brackish water. Very unusual for a sea, the Baltic is almost entirely land-locked and the water exchange is very limited. Its special geographical, oceanographic, and climatological characteristics render the Baltic ecosystem highly susceptible to the environmental impacts of human activities at sea and in its catchment area, which is home to over 85 million people.

The Baltic presents a challenging showcase of environmental management of a sea. No other sea so clearly demonstrates our mediocre performance in balancing the uses and the protection of natural marine resources. As depicted on the maps included in this report, the human pressures are so powerful that they are altering the marine ecosystem, depleting the renewable resources beyond safe biological limits, and jeopardizing the future uses of the Baltic ecosystem goods and services. Obviously, our environmental remedial measures so far have not been sufficient to prevent the alarming ecosystem shift taking place today.

However, tools have been developed to assess the state and find cost-efficient solutions to restore the marine ecosystem and improve its unacceptable status.

Status

This HELCOM Initial Holistic Assessment shows that the environmental status of the Baltic Sea is generally impaired (**Chapter 2**). None of the open basins of the Baltic Sea has an acceptable environmental status at present. The integrated assessment of the 'ecosystem health' has revealed that only very few coastal areas along the Gulf of Bothnia can be considered healthy. To reach the commonly agreed aim of a healthy Baltic Sea in 2021 at the latest, the Baltic Sea Action Plan urgently needs to be implemented to its full extent.

Eutrophication, caused by nutrient pollution, is a major concern in most areas of the Baltic Sea. The Bothnian Bay and the northeastern parts of the Kattegat are the only open areas of the Baltic Sea not affected. The only coastal areas not affected by eutrophication are confined to the Gulf of Bothnia. Despite significant reductions of the nutrient inputs over the past, all other open basins and coastal waters are classified as 'areas affected by eutrophication'. HELCOM has been very successful in reducing the inputs of nitrogen and especially phosphorus to the Baltic Sea. During the decade from 1990 to 2000, the direct point-source inputs of phosphorus and nitrogen decreased by 68% and 60%, respectively. From 1990–2006, the total inputs to the Baltic Sea were reduced by 45% for phosphorus, but only 30% for nitrogen. For atmospheric nitrogen deposition, the picture is different: There was a much smaller decrease since the mid-1990s and an increase in the period from 2003 to 2007. Shipping in the Baltic Sea is an important contributor to the atmospheric nitrogen deposition, and will significantly increase in the future.

Living organisms and bottom sediments are affected by hazardous substances in all parts of the Baltic Sea. Despite targeted abatement strategies, measures, and also significant reductions of inputs of hazardous substances, only very few coastal sites presently seem undisturbed by hazardous substances. At present, the key substances of concern include PCBs, heavy metals, TBT, dioxins, DDT/DDE, PAHs and alkylphenols. However, several management actions have proved to be successful, for example, reducing atmospheric inputs of mercury, lead, and cadmium, and reducing the inputs of certain persistent organic pollutants, such as DDT, PCBs and TBT, by banning their use in the Baltic Sea region. Concentrations of radioactive substances originating from the Chernobyl fallout are still high in the northern, eastern, and central parts of the Baltic Sea, but the concentrations of the radionuclide cesium-137 are decreasing in all areas of the Baltic Sea.

The status of biodiversity appears to be unsatisfactory in most parts of the Baltic Sea. According to the preliminary results of the biodiversity assessment, 82% of the coastal areas assessed exhibit an unfavourable status. Environmentally alarming shifts and unbalances appear in many habitats and at all levels of the food chain, particularly at the level of large fish. Promising signs of successful remediation measures include an improvement in the status of top predators such as grey seals and white-tailed eagles during recent decades.

The results of this HELCOM Initial Holistic Assessment are based on HELCOM's thematic assessments of the 'eutrophication status', the 'biodiversity status' and the 'hazardous substances status'. As an added value, these thematic assessments have been integrated to assess the 'ecosystem health', thereby setting a baseline for evaluating the effectiveness of the implementation of the HELCOM Baltic Sea Action Plan.

Pressures

For the first time in an assessment of a regional sea, all the relevant pressures and their impacts have been identified and ranked by a special index, the Baltic Sea Pressure Index and the Baltic Sea Impact Index (**Chapter 3**). The further development of the Baltic Sea Impact Index should be seen as a process in which the data layers and the index need to be continuously improved. Ultimately, the goal is to develop an index for decision support as well as solution targeting, which can take into account regional differences.

Most prominently, the marine environment is under pressure by anthropogenic loads of nitrogen, phosphorus, organic matter, and hazardous substances. But commercial fishing is also a strong and widespread pressure, which severely impacts the Baltic Sea ecosystem. Especially bottom trawling is a very destructive fishing technique which affects large areas of the sea. The seabed is also disturbed by construction works, dredging and the disposal of dredged material, which can have large impacts on local marine environments.

Comparing the pressures on a Baltic Sea-wide scale, it is obvious that pressures are high in the western, southern and eastern parts of the Baltic Sea. Coastal areas are affected mainly by pollution stemming from point sources as well as the disturbed seabed. The open-sea areas are mainly affected by fishing, riverine pollution, and atmospheric nitrogen deposition. It can be concluded that the cumulative impact of human activities is high in all areas except the open-sea areas of the Gulf of Bothnia.

Pressures causing eutrophication are mainly related to inputs of nutrients from external sources, whether via water or air, and to a lesser extent internal sources such as sediments that have retained anthropogenic inputs from the past.

Pressures causing contamination and pollution effects by hazardous substances are either related to the inputs of synthetic or natural compounds from external sources, whether via water or air, or to inputs from contaminated bottom sediments caused by physical disturbance of the seabed following, for example, construction activities, dredging or disposal of dredged material. Releases of oil to the marine environment represent a continuous pressure on the Baltic Sea. Releases of oil not only cause pollution effects, but can also directly harm biodiversity. For example, seabirds are highly susceptible to oil pollution.

Pressures including the selective extraction of species by commercial fisheries and by hunting of seals and seabirds directly disturb biodiversity. The greatest concern in this respect relates to the elimination of top predators. Biodiversity is also impaired by numerous types of physical disturbances which take place in most, if not all, coastal zones and also in large areas of the open sea. These disturbances include smothering of benthic organisms from disposal of dredged materials, abrasion of the sea bottom caused by bottom trawling and dredging, and changes in salinity or temperature regimes. Underwater noise and marine litter are forms of physical disturbance which also have the potential to disturb life in the Baltic Sea, but with effects that are less well known.

Solutions

Solutions and associated actions to restore the health of the marine ecosystem are offered in **Chapter 4**. Solutions providing multiple positive effects are recommended for prioritization. Their cost-effectiveness can in many cases be increased through multiple positive effects.

It is vital to reduce all types of anthropogenic pressures. The greatest emphasis should be placed on reducing nutrient inputs and the environmentally negative impact of fishing activities. Inputs of hazardous substances and oil pollution should be reduced as well.

To prioritize actions in a targeted way, the spatially explicit status analyses regarding eutrophication, pollution by hazardous substances, and biodiversity need to be combined with the basin-wide ranking of pressures. However, getting the sub-basin priorities and actions

right is one of the future challenges for implementing the ecosystem approach to the management of human activities.

In addition, physical disturbance to habitats and species should be reduced, for example, by planning, controlling and reducing construction activities, operation of maritime structures (such as wind farms, oil refineries or platforms), commercial bottom trawling and noise (from shipping, wind farms and other sources).

Nature restoration is a useful, but currently not widely used, tool. For example, the re-establishment of the top levels of the marine food chains should be promoted by ensuring the recovery of the populations of cod, harbour porpoises, seals, predatory birds, as well as pike and pikeperch in the coastal areas. Natural habitats should be restored more widely, especially in areas where important or protected marine habitats have been lost.

Nature restoration should not be restricted to the marine territory, but should also extend to coastal wetlands, which provide indispensable ecosystem services by filtering out nutrients and potentially also hazardous substances, increasing biodiversity and enhancing sequestration of carbon dioxide. Furthermore, the restoration of river habitats, river water quality and their hydromorphology could contribute to reducing the flow of nutrients and hazardous substances into the Baltic Sea. At the same time, this would improve the state of the spawning populations of migratory fish.

A key priority in this respect is the establishment of an ecologically coherent network of well-managed marine protected areas (MPAs). Coherence alone is not enough, especially if the management and enforcement of programmes of measures for MPAs are weak and restrictions on human activities poor. Banning or strictly regulating commercial fishing within MPAs should be the first step in the process of enhancing nature protection and restoring fish stocks. The current governance issues, or rather lack of governance, should be addressed without delay and also linked to the upcoming implementation of maritime spatial planning. Noting that the Baltic Sea Action Plan is based on the ecosystem approach to the management of human activities, it should be evident that Baltic Sea Maritime Spatial Planning should apply the same principles, including the ecosystem approach as one of the main principles to ensure cross-sectoral policy integration as outlined in the EU Maritime Policy (Anon. 2007) and attaining good environmental status of the marine environment.

Ecosystem goods and services

Chapter 5 indicates that environmental gains are economic gains, too. The Baltic Sea provides us with many valuable services including transport, energy, food, mineral resources, recreational facilities and cultural heritage. Of the 24 marine ecosystem services identified in the Baltic Sea, only ten are operating properly and seven are under severe threat. The seven threatered ecosystem services are: the food web, biodiversity, habitats, Baltic Sea resilience (the capacity of the sea to resist and recover from disturbances), food, genetic resources, and aesthetic values. Eutrophication and overfishing have been identified as the main threats to ecosystem services in the Baltic Sea.

There are huge economic values at stake in the Baltic Sea today. From an economic perspective, we cannot afford to wait. Actions will be costly and constitute a severe challenge to the leadership skills of the Baltic Sea nations, but there is an undeniable risk that it will be much more costly not to take actions immediately, due to potentially serious effects on highly valuable ecosystem services.

Chapter 1: Introduction

The Baltic Sea is a small sea on a global scale, but as one of the world's largest and most isolated bodies of brackish water, it is ecologically unique.

Due to its special geographical, climatological, and oceanographic characteristics, the Baltic Sea is highly sensitive to the environmental impacts of human activities in its sea area and in its catchment area, which is home to over 85 million people.

Economic, social and cultural characteristics and conditions vary within the Baltic Sea region and impact the ecosystem status of the associated marine areas in different ways.

The human activities in the catchment area and at sea affect the health status of the Baltic Sea. Hence, the aim of this Initial Holistic Assessment is simply to assess the current health status of the Baltic Sea as an ecosystem and to try to answer the questions "Is the Baltic Sea in a good shape or not?" and "How far are we from achieving the environmental visions and objectives?"

1.1 Holistic Assessment of the state of the Baltic Sea

This assessment report, referred to as the HOLAS report, is the first attempt to conduct a Holistic Assessment of the ecosystem health of the Baltic Sea. It is a product of the Helsinki Commission (HELCOM), the intergovernmental body composed of the Baltic Sea coastal states and the EU, to implement the Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992 (the Helsinki Convention). The assessment serves two key purposes. Firstly, it presents an integrated assessment of the ecosystem health of the Baltic Sea as well as thematic assessments of 'eutrophication status', 'biodiversity status' and 'hazardous substances status'. Secondly, it sets a baseline for evaluating the effectiveness of the implementation of the measures of the HELCOM Baltic Sea Action Plan that was adopted in 2007. Furthermore, the Initial Holistic Assessment is also a regional contribution to the initial assessment according to the Marine Strategy Framework Directive (MSFD) for those HELCOM Contracting Parties that are also EU Member States.

This assessment also covers a number of aspects of Good Environmental Status, as described by the qualitative descriptors of Annex III of the MSFD, including eutrophication, contamination by hazardous substances and biodiversity aspects. It will facilitate the work of the EU Member States of HELCOM in implementing the requirements of the Directive that are related to those descriptors, especially the development of the initial assessment, targets and associated indicators for Good Environmental Status that are due in June 2012. Moreover, it provides input to the overall requirement of the Directive for coordination and cooperation among the countries within a marine region.

Due to the fact that the assessment is partly based on new tools (HOLAS, see **Section 2.1** and BSPI/BSII, see **Section 3.2**) and to some extent preliminary targets and indicators (especially the biodiversity assessment tool BEAT), the results should be interpreted with care and results produced with the new tools and BEAT should be considered preliminary. HELCOM will further develop and improve the methodologies and the data compilation.

How does this HELCOM Initial Holistic Assessment differ from previous assessments of the state of the Baltic Sea? It primarily differs from the previous assessments by being concerned with the entire Baltic Sea and its catchments. It also concerns complete systems rather than the analysis or treatment of individual parts or issues. Hence, the HELCOM Initial Holistic Assessment is 'ecosystem-based' and it addresses the key vision of the Baltic Sea Action Plan, which is to have "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 human economic and social activities" (HELCOM 2007a, Backer et al. 2009).

The present ecosystem health assessment links the status of the ecosystem to the pressures and human activities impacting the Baltic Sea. Hence, it is 'ecosystem-based'.

1.2 A sea like no other

The Baltic Sea is a unique sea and certainly one of the most fascinating sea areas in the world. Looking at its horizon makes you feel that the Baltic is as wide and endless as an ocean, but this is an illusion. From their cockpit, pilots—crossing the sea on their daily shuttle trips between the Baltic countries—can see the borders of this sea at almost any time.

In fact, the Baltic is small, and what is even more important, it is almost entirely closed in by the lands of nine nations (**Fig. 1.1**). Only through the bottle neck of the narrow and shallow Danish straits is the Baltic connected to the rest of the marine world. That is why the Baltic waters are rather isolated from the world's oceans, turning the Baltic into a test case of ecological adaptation, but also a test case of environmental protection and management.

The Baltic Sea is not a uniform sea area, but instead it is actually a sequence of sub-basins divided by sills. The sub-basins have varying physico-chemical and biological characteristics which affect their response to the human-induced pressures. On average, the water—and all the contaminants discharged from the catchment area with 85 million people—remains in the Baltic for decades.

The input of freshwater from the catchment is larger than the inflow of saline water from the North Sea. This causes strong stratification of the water column which at times leads to hypoxia or anoxia at the sea floor. Nevertheless, the occasional inflows of saline water bring along well-oxygenated water which breathes life into the deeps of the Baltic Sea.

The most crucial feature of the Baltic Sea is revealed to any swimmer tasting a drop of sea water: the salinity is low, making the Baltic the world's second largest brackish-water basin after the Black Sea. The salinity decreases with every mile travelled farther eastward and northward into the Baltic, where a multitude of rivers dilute the salty waters so much that it tastes like fresh water in the Bothnian Bay.

The low salinity is of tremendous importance to life in the Baltic and is the key to understanding and managing the sensitive marine ecosystem. Only a few marine animals and plants are able to tolerate the low salinity, rendering them irreplaceable in the Baltic ecosystem (**Fig. 1.2**). A system made up of so few species is not very stable, and is very susceptible to such pressures as fishing, habitat destruction, and pollution. In fact, the Baltic ecosystem is immature and still evolving since it reached its current form and salinity level only 2000 years ago, and changes such as land uplift still continue, particularly in the northern areas (Leppäranta and Myrberg 2009). Certainly it has not been capable of living up to the collective pressure caused by the people living in its watershed.

The current large anthropogenic pressures, including climate change, on the Baltic Sea ecosystem have endangered the ecosystem functions. The provisioning of goods and services by the Baltic Sea to the Baltic societies now and hopefully in the future has also been endangered.

Figure 1.1 The Baltic Sea with its sub-basins, largest rivers and catchment area.

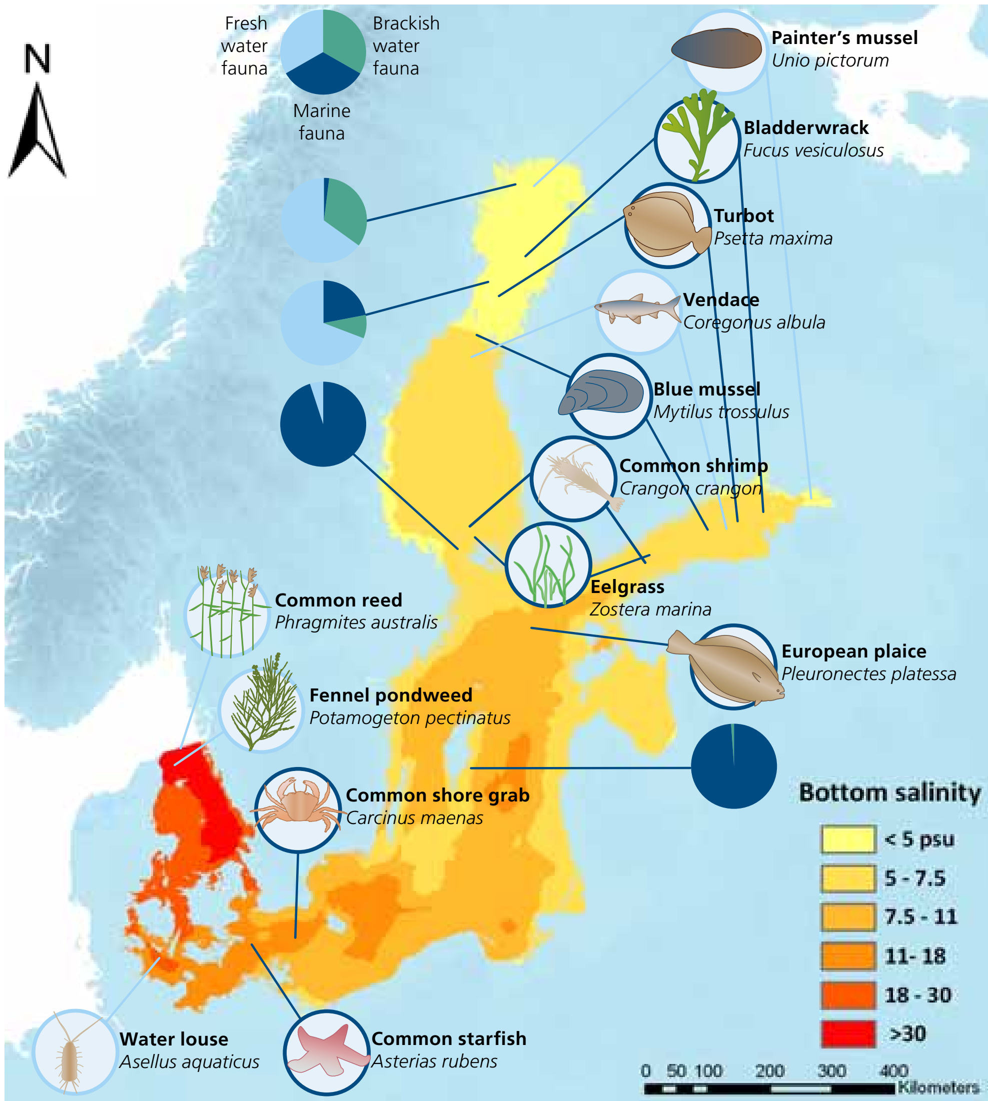


Figure 1.2 Distribution limits of some marine (dark blue) and freshwater (light blue) species due to salinity, as well as bottom salinity (Al-Hamdani and Reker 2007). Based on Fuhrman et al. (2004).

1.3 The economics of ecosystem goods and services at stake in the Baltic Sea

Nature provides humans with many valuable services. Marine ecosystem services can be divided into provisioning, supporting, regulating and cultural services, following the classification used in the UN Millennium Ecosystem Assessment (MEA 2005). Of the 24 marine ecosystem services identified in the Baltic Sea region and listed in **Table 1.1**, only ten are operating properly and seven are under severe threat: the food web, biodiversity, habitats, Baltic Sea resilience (the capacity of the sea to resist and recover from disturbances), food, genetic resources and aesthetic values (for details, see Swedish EPA 2009a). Eutrophication and overfishing have been identified as the main threats to ecosystem services in the Baltic Sea.

Societies need to make rational choices in using and managing the environment. Actions targeted at the problems causing ecosystem destruction involve a cost. Cost-benefit analysis is one tool for evaluating the trade-offs. By collecting information on all the positive (benefits) and negative (costs) impacts a project, policy, etc., will lead to, and comparing these, it can be concluded whether the benefits exceed the costs. This kind of economic information is one important piece in the decision-making puzzle regarding the Baltic Sea environment. Other pieces are of an ecological, social, or cultural nature.

Actions to restore ecosystem services may be costly, but non-action may lead to even higher costs in the future due to the loss of highly valued services. Actions are an insurance against future losses in welfare and, from this perspective, action-taking is also in line with the Precautionary Principle prescribed by Article 3 of the Helsinki Convention and the European policies (European Treaty, Article 174, paragraph 2).

Economic analyses are important when considering the choice and timing of actions. One important task when conducting economic analyses is to identify the groups of individuals or sectors in society that are affected by a project or policy, i.e., who wins and who loses. The 'winners' of action in the Baltic Sea would be the general public, the fisheries sector, and the tourism sector. However, the winners and losers may differ in different parts of the Baltic Sea. Each group depends, in one way or another, on the quality of the sea and the ecosystem services it provides.

- For the general public, the sea provides food such as fish (provisioning ecosystem service), recreational opportunities such as swimming and walking along the beach (cultural ecosystem service), and also existence values (values that people attach to healthy ecosystems regardless of whether they use the ecosystem services directly or not).
- Commercial as well as sport fisheries are highly dependent on the health of the Baltic Sea ecosystems. As an example, in order for the sea to produce fish, nursery areas such as seagrass meadows need to be protected. Furthermore, the future of the fisheries sector is highly dependent on existing policies. There has been a large overcapacity within Baltic Sea fisheries. Some improvement has taken place, but in certain fisheries the overcapacity still remains.
- Tourism in the coastal areas of the Baltic depends on the state of the sea. Many water-related recreational activities (swimming, diving, sailing, etc.) are much more attractive if the water is clear and safe and the beaches are clean.

The 'losers' of action are those groups of individuals or sectors bearing the costs of actions. The geographical and sectoral distribution of costs and benefits might be uneven and is dependent on policy choices. This fact has to be taken into account by decision-makers in the Baltic nations.

Scientific findings point to the conclusion that there are great economic values at risk if no actions are taken.

This Initial Holistic Assessment presents a number of examples of costs and benefits related to the environmental state of the Baltic Sea. **Chapter 5** provides an insight into the results of economic research in the area so far. Where feasible, aggregated monetary values for the Baltic Sea as a whole have been presented; in cases for which large-scale figures were unavailable, examples are given instead.

Table 1.1 Ecosystem services provided by the Baltic Sea, with those most severely threatened marked with an asterisk (*) and the well-functioning ones marked with "√". Modified from Swedish EPA (2009a).

Provisioning ecosystem services	Supporting ecosystem services
Food* Inedible goods √ Energy √ Space and waterways √ Chemicals, e.g., blue pharmacy Ornamental resources √ Genetic resources*	Biogeochemical cycles Primary production √ Food web dynamics* Biodiversity* Habitats* Resilience*
Regulating ecosystem services	**Cultural ecosystem services**
Impact on climate and air quality, e.g., absorption of CO_2 √ Sediment retention, e.g., prevention of erosion Reduction of eutrophication, e.g., retention, recycling and removal of nutrients √ Biological regulation, e.g., remedy of perturbations of the ecosystem √ Regulation of pollutants, e.g., by sediment burial of toxins	Recreation Aesthetic value* Science and education √ Cultural heritage Inspiration √ The legacy of the sea

1.4 Human pressures on the Baltic Sea—activities and impacts

The societies along the Baltic shores are rich in history, culture and economy. They have grown and prospered thanks to the services that the Baltic marine ecosystem was able to offer during the past centuries. But today these ecosystem services and goods are no longer available in the quantity and quality former generations relied on for their economic, social and cultural well-being.

The 85 million people living along the shores and in the vast catchment area have exerted so many pressures on the Baltic ecosystem that impacts can be observed over the entire sea area.

It is not only harmful impacts from cities or large industries or the overexploitation of certain marine resources that are turning the Baltic into one of the most used and polluted seas in the world, but the marine environment is also experiencing significant pressures from the diffuse pollution from the densely populated catchment area, agriculture, tourism along the coasts and maritime transport.

One of the key threats to the well-being of the Baltic Sea ecosystem is the waterborne transport and discharges and airborne emissions of excessive amounts of nutrients and hazardous substances. The greatest source of eutrophication-causing nutrients and a significant source of hazardous substances are land-based inputs, most notably by agriculture, municipal wastewaters, industry, and poorly managed old dump sites. Another source of pollution can be the disposal of contaminated dredged material to the seabed, which is an activity exempted from the general prohibition of dumping, but requires special permits according to the Helsinki Convention of 1992.

The Baltic also experiences pressures from industrial activities at sea. Marine foodstuffs and mineral resources, such as fish and other marine products, as well as sand and gravel have been exploited extensively for a long time in the sea area, as modern technology is no longer limited to shallow waters or coastal areas. The hunting of seals reached an unsustainable level already in the early 20th century, followed by commercial fisheries in the mid-20th century, whereas the disturbance of the seabed by sand, gravel, and boulder extraction as well as the dredging of sea lanes spread further seawards only a few decades ago. Today, dredging, fishing and hunting require permits in all countries around the Baltic Sea.

The sea and the associated seabed are not only a resource or a sink for pollutants, but also a communications link for passengers, materials, information, and energy. The intensity of shipping, particularly the transportation of oil and chemicals, is increasing rapidly in the Baltic Sea. Although oil spills have become fewer and smaller, the Baltic Sea environment is burdened by a wide array of shipping-related wastes, emissions, noise and physical disturbance. The sea area also offers other means of transportation: pipelines and cables on the sea bottom transfer energy and information over the sea basin to neighbouring countries. It is well documented that the construction of cables and pipelines disturbs the sediments, whereas it is less well understood whether, for example, the magnetic fields of high voltage cables disturb ancient migration routes of fish to feeding and spawning areas. Increasing numbers of energy cables also transfer energy from the offshore wind farms that are a relatively new human pressure in the marine environment.

All of these pressures accumulate in the Baltic marine ecosystem, causing it to shift in an unfavourable direction.

1.5 Visions and objectives for the Baltic Sea

The need for international regulation of human activities harming the marine environment was recognized in the 1970s and the Helsinki Convention was first signed in 1974 to protect the Baltic Sea.

In order to protect the marine environment of the Baltic Sea, including the provisioning of goods and services for the surrounding societies, and to specify and implement the ecosystem approach to the management of human activities affecting that sea, HELCOM has developed a vision for the Baltic Sea as well as a set of associated goals and objectives (see **Table 1.2**, Backer and Leppänen 2008).

The vision, goals and objectives are embedded in the HELCOM Baltic Sea Action Plan (BSAP), which aims to achieve and maintain the good ecological status of the Baltic marine environment by 2021 at the latest (HELCOM 2007a). Implementation of the agreed actions is seen as an important step towards realizing the HELCOM vision. The Action Plan is a crucial stepping-stone for wider and more efficient actions to combat the continuing deterioration of the marine environment resulting from human activities and ultimately to improve the environmental conditions. With the adoption of the new environmental strategy, HELCOM has strengthened its role in marine environmental protection, incorporating the best available scientific knowledge and novel management approaches into strategic policy implementation, and stimulating goal-oriented multilateral cooperation around the Baltic Sea region. As the first overarching scheme to implement the ecosystem approach to the management of human activities in a regional sea, the Baltic Sea Action Plan is leading to significant changes in the ways adaptive management of the Baltic Sea environment is being implemented.

Although HELCOM has worked for nearly four decades to reduce anthropogenic impacts on the Baltic Sea, the Baltic Sea Action Plan is different from the previous plans or programmes undertaken by HELCOM. The plan is based on a clear set of 'ecological objectives' defined to reflect a jointly agreed vision of "a healthy Baltic Sea environment". Each of the objectives has been designed to reflect and further specify one of the four Strategic Goals (**Table 1.2**).

Table 1.2 Vision and goals of the HELCOM Baltic Sea Action Plan (HELCOM 2007a).

Vision	Goals	Ecological objectives (or Management objectives)
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 human economic and social activities	**Eutrophication:** The Baltic Sea unaffected by eutrophication	Concentrations of nutrients close to natural levels Clear water Natural level of algal blooms Natural distribution and occurrence of plants and animals Natural oxygen levels
	Hazardous substances: The Baltic Sea life undisturbed by hazardous substances	Concentrations of hazardous substances close to natural levels All fish safe to eat Healthy wildlife Radioactivity at pre-Chernobyl level
	Maritime activities: Maritime activities in the Baltic Sea carried out in an environmental friendly way	Enforcement of international regulations: no illegal discharges Safe maritime traffic without accidental pollution Efficient emergency and response capability Minimum sewage pollution from ships No introductions of alien species from ships Minimum air pollution from ships Zero discharges from offshore platforms Minimum threats from offshore installations
	Biodiversity: Favourable conservation status of Baltic Sea biodiversity	Natural marine and coastal landscapes Thriving and balanced communities of plants and animals Viable populations of species

The Ecological Objectives for eutrophication are:
- Clear water;
- Concentrations of nutrients close to natural levels;
- Natural level of algal blooms;
- Natural distribution and occurrence of plants and animals; and
- Natural oxygen levels.

These eutrophication objectives are being interpreted and converted into operational targets in which the desired objectives are expressed by a number, e.g., a Secchi depth water transparency of 6.0 metres in the Gulf of Finland representing the objective 'Clear water'. The BSAP targets for 'good ecological status' are in general based on the best available scientific knowledge.

The HELCOM objectives with regard to hazardous substances are:
- Concentrations of hazardous substances close to natural levels;
- All fish safe to eat;
- Healthy wildlife; and
- Radioactivity at pre-Chernobyl level.

The objective with regard to 'Concentrations of hazardous substances close to natural levels' is in practice equivalent to the so-called Generation Target. The aim of the Generation Target is the continuous reduction of discharges, emissions, and losses of hazardous substances thereby moving towards the target of their cessation by 2020, with the ultimate aim of reducing the concentrations in the environment to near background values for naturally occurring substances and close to zero concentrations for man-made synthetic substances (HELCOM 1988). Fulfilling the Generation Target would, in principle, also result in fulfilment of the objectives 'All fish safe to eat' and 'Healthy wildlife'.

The HELCOM objectives in regard to maritime activities are management-oriented. They are:
- Enforcement of international regulations – No illegal discharges;
- Safe maritime traffic without accidental pollution;
- Efficient emergency and response capability;
- Minimum sewage pollution from ships;
- No introductions of alien species from ships;
- Minimum air pollution from ships;
- Zero discharges from offshore platforms; and
- Minimum threats from offshore installations.

These action-oriented management objectives focus on specific activities that have an environmentally negative impact on the marine ecosystem. Some of these maritime activities affect the 'eutrophication status' and 'hazardous substances status', whilst the majority create pressures on 'biodiversity status'.

The HELCOM objectives with regard to biodiversity are:
- Natural marine and coastal landscapes;
- Thriving and balanced communities of plants and animals; and
- Viable populations of species.

The biodiversity objectives can be characterized as being 'downstream' and thus integrating the cumulative effects from eutrophication, inputs of hazardous substances and maritime activities.

With the application of the ecosystem approach, the protection of the marine environment is no longer seen as an event-driven pollution reduction approach to be taken sector-by-sector. Instead, the starting point is the ecosystem itself, and a shared concept of a healthy sea with a good ecological status. Hence, measures are targeted based on best available monitoring data and scientific knowledge, and implemented in a coordinated manner by the Baltic Sea countries aiming at a cost-effective process.

1.6 Data and assessment tools

One of the key objectives for HELCOM is to produce targeted and timely assessments. Previously, the environmental status of the Baltic Sea has been assessed by so-called Periodic Assessments of which a total of four have been published (HELCOM 1987, 1990, 1996, 2002). The adoption of the new HELCOM Monitoring and Assessment Strategy in 2005 substantially changed and refocused the way assessments are to be carried out (HELCOM 2005). This new strategy is hierarchical and the HELCOM Initial Holistic Assessment is at the top (see **Fig. 1.3**). According to this strategy, a holistic assessment should assess how HELCOM strategies and environmental objectives have been met, link environmental changes to pressures, and to the extent possible provide advice for subsequent decision-making, such as advice for the formulation of supplementary regional policies and measures.

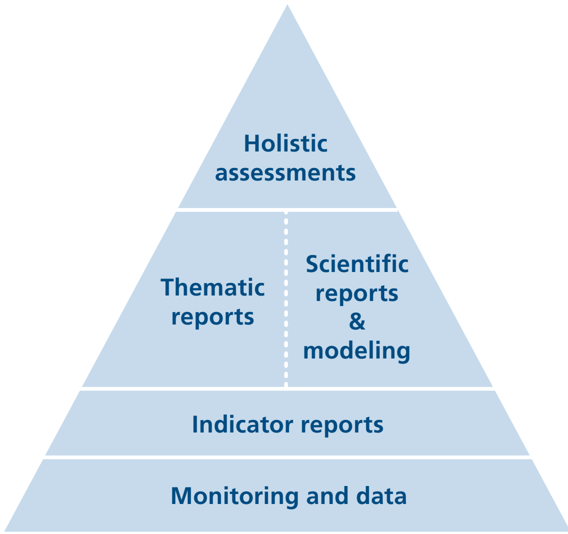


Figure 1.3 The HELCOM monitoring and assessment hierarchy (HELCOM 2005).

The engine of the assessment work is the monitoring activities carried out by the Baltic Sea countries within the HELCOM framework in the Cooperative Monitoring in the Baltic Marine Environment (COMBINE) programme for the monitoring of eutrophication and hazardous substances in the marine environment (HELCOM 2007b), monitoring of pollution loads (inputs) in the Compilation of Airborne Pollution Loads (PLC-Air) and Compilation of Waterborne Pollution Loads (PLC-Water) programmes and radioactive substances in the Monitoring of Radioactive Substances (MORS-PRO) programme as well as coastal fish within the HELCOM FISH project activities. In addition, the annually updated HELCOM Indicator Fact Sheets published on the HELCOM website channel a large amount of valuable data and information that can be used for the thematic as well as the Holistic assessments.

Over the past few years, HELCOM has developed a suite of indicator-based assessment tools, which have been used for the production of the thematic assessments in 2009 and 2010:
- The HELCOM Eutrophication Assessment Tool (HEAT), which was used for the classification of 'eutrophication status' in 189 areas including all open areas of the Baltic Sea in an integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea region (HELCOM 2006, 2009a);
- The HELCOM Biodiversity Assessment Tool (BEAT), based on HEAT, has been used for the preliminary classification of 'biodiversity status' in 22 areas including all open basins of the Baltic Sea in an integrated thematic assessment of biodiversity and nature conservation in the Baltic Sea (HELCOM 2009b);

• The HELCOM Hazardous Substances Status Assessment Tool (CHASE) was used for classification of the status of hazardous substances in 144 areas including all open areas of the Baltic Sea in an integrated thematic assessment of hazardous and radioactive substances in the Baltic Sea (HELCOM 2010a).

The Initial Holistic Assessment builds on the above-mentioned thematic assessments, which in some cases have been updated and supplemented with data and information from other sources. The assessment criteria (or target values) in this assessment, all of which originate from the HELCOM thematic assessments, were derived from existing targets, for example, in the Baltic Sea Action Plan, European Directives, or international or national agreements or regulations. None of the target values used in this report was developed specifically for this assessment.

The assessment principles used for eutrophication status and biodiversity status are summarized in **Figure 1.4**.

For hazardous substances, the assessment of 'hazardous substances status' differs slightly from the assessment principles described above, cf. **Figure 1.5**.

This Initial Holistic Assessment provides for the first time an assessment of the 'ecosystem health' of the Baltic Sea. Ecosystem health is a concept which reflects the capacity of an ecosystem to resist an external pressure. A healthy ecosystem is defined as having the ability to maintain its structure and function over time while facing an external pressure (Costanza and Mageau 1999). In other words, a healthy ecosystem is able to recover from stress by maintaining an appropriate level of productivity, metabolism and biodiversity, as well as a number and diversity of interactions. This definition relates the concept of ecosystem health to the carrying capacity of an ecosystem.

In this assessment, the ecosystem health has been assessed via two separate routes. The first route involves a merger of the results provided by the HEAT, BEAT and CHASE classifications. The main advantage of this route is that it is directly linked to the HELCOM integrated thematic assessments and, hence, the segments of the Baltic Sea Action Plan. The second route is based on the use of an integrative indicator-based assessment tool termed HOLAS ('tool for the Holistic Assessment of Ecosystem Health Status').

As a precautionary note, it should be mentioned that the HELCOM assessment methodologies differ from the assessments of 'ecological status' and 'chemical status' produced by EU Member States under the Water Framework Directive (WFD).

Differences from the WFD methodology to be highlighted in regard to HEAT and BEAT are:
(1) There may be differences with regard to spatial and temporal resolution of the Ecological Quality Ratios (EQR) of HEAT and BEAT in comparison to WFD-related assessments.
(2) The indicators to assess biological features are still preliminary in the HELCOM biodiversity assessment.
(3) The HELCOM classifications are, as a first step, based on a weighted average of the EQR values and good-moderate boundaries within a group of indicators (i.e., quality element) and, as a second step, classification into five classes for each group of indicators according to Annex V of the WFD. Some countries are using particular methods for combining the indicators in their WFD assessments according Annex V. They use, e.g., a classification system in which single indicators are used for obtaining a status classification with a subsequent harmonization of EQR-based indicator-wise status classifications to derive the status classification for the quality element (group of indicators).

The calculation and classification methods used in the thematic assessments as well as in this assessment are described in HELCOM (2009a) and Andersen et al. (2010a, b).

An added value of the application of the HEAT and BEAT tools is the utilization of Baltic Sea-wide coastal and offshore data, which provides a unique possibility to compare across sub-regions. However, the spatial distribution of data varies over the regions. The HELCOM tools utilize all information made available to the process in order to make the final classification as confident as possible; in some cases, this information differs from the information used for WFD assessments. However, the tools need further development in order to substitute expert judgement with more sophisticated statistical analysis. In addition, the indicators currently being used need to be further elaborated in order to optimize the use of the assessment tools. For existing indicators, focus should be placed on further development of target values. Furthermore, supplementing the existing indicators with additional food-web indicators and biodiversity indicators would be an important step forward.

The differences in regard to CHASE (HELCOM 2010a) are:
(1) The CHASE tool includes a suite of matrices (biota, sediments, water, as well as biological effects), while the WFD-related assessments do not necessarily use all matrices.

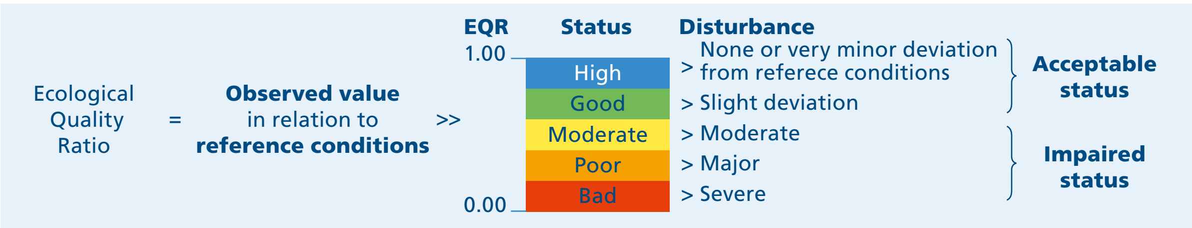


Figure 1.4 The assessment of 'eutrophication status' and 'biodiversity status' is based on the use of the Ecological Quality Ratio (EQR) and classifications are made for groups of indicators, not for single indicators. See Section 1.6 and HELCOM (2006) for details.

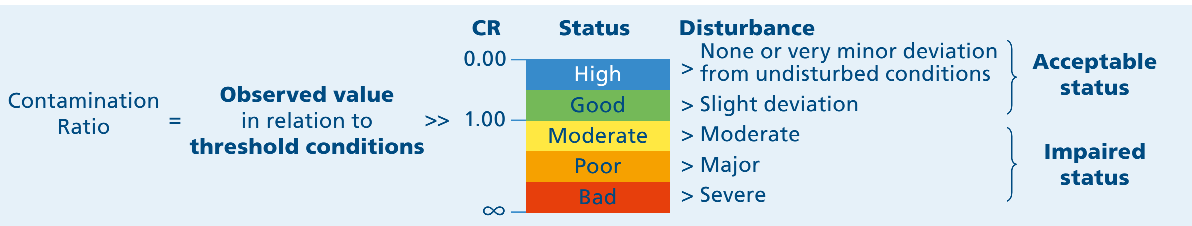


Figure 1.5 The assessment of 'hazardous substances status' is based on the use of the so-called Contamination Ratio (CR). The classifications of 'hazardous substances status' are made for groups of indicators, not for single indicators. See Section 1.6 and HELCOM (2010a) for details.

(2) CHASE gives equal importance to all available data regarding hazardous substances and radioactive substances following the HELCOM Baltic Sea Action Plan, while the WFD tends to focus on so-called Priority Substances, which include a total of 33 substances identified to be of special interest. However, some WFD-related data may have been omitted from this assessment due to the focus of WFD assessments on the water matrix and unsuitable locations of the sampling sites in relation to CHASE assessment units.
(3) CHASE uses five classes while the WFD-related assessments use two classes.
(4) CHASE applies transnational assessment principles across the entire Baltic Sea, while the WFD-related assessments are conducted from a river-basin perspective which in certain cases also involves the transnational aspect.

It should be noted that the substances, matrices and threshold values may differ between the assessment units and there were no fixed sets of threshold values, indicators or matrices used in CHASE. Hence, the set of matrices and substances, as well as the threshold values need to be further developed and harmonized on a Baltic Sea-wide scale. Similarly, further development is still needed to improve the method for classification into the five status classes, as well as to improve the use of statistical analysis for the confidence rating.

The results from the use of the newly developed HOLAS assessment tool should be regarded as a demonstration of one means for the classification of 'ecosystem health status'. The current structure of the HOLAS tool employs three categories: biological indicators, hazardous substances indicators and supporting indicators. The demonstration of the HOLAS tool is based on the same indicators and data as used for the HEAT, BEAT and CHASE classifications as well as the same principles contained in these tools. Future development of the HOLAS tool will depend on the improvements suggested for the HEAT, BEAT and CHASE assessments as well as the guidance for assessing 'Good Environmental Status' *sensu* the EU Marine Strategy Framework Directive. However, the use of the tools should be seen as a first step to enable an initial assessment of 'ecosystem health' based on harmonized Baltic Sea-wide principles and hence the results should be considered preliminary.

Table 1.3 **Anthropogenic pressures in the HELCOM Baltic Sea Pressure Index (grouped according to the EU MSFD, Anon. 2008a).**

Physical loss of the seabed	Smothering of the seabed Sealing of the seabed
Physical damage to the seabed	Changes in siltation Abrasion of seabed Selective extraction of seabed
Other physical disturbance	Underwater noise Marine litter
Interference with hydrological processes	Changes in thermal regime Changes in salinity regime
Contamination by hazardous substances	Introduction of synthetic compounds Introduction of non-synthetic compounds Introduction of radionuclides
Systematic and/or intentional release of substances	Introduction of other compounds[1]
Nutrient and organic matter enrichment	Inputs of fertilizers (nutrients) Inputs of organic matter
Biological disturbance	Introduction of microbial pathogens Introductions and translocations of non-indigenous species[1] Selective extraction of species

[1] No pressure layer from this category.

Table 1.4 **The data layers representing biological ecosystem components in the Baltic Sea Impact Index.**

	Data layer	Remarks	Source
Benthic biotope complexes	Photic sand		Al-Hamdani and Reker 2007; EUSeaMap project[1]
	Non-photic sand		
	Photic hard bottom	Including bedrock and hard bottom complex	
	Non-photic hard bottom		
	Photic soft bottom	Including mud and clay	
	Non-photic soft bottom		
Pelagic biotope complexes	Photic water column	Photic and non-photic layers delimited by the boundary of 1% light availability	
	Non-photic water column		
Benthic biotopes	Mussel beds	Relative density (only >10%) of blue mussels	MOPODECO project
	Zostera meadows	Observational data of the occurrence of *Z. marina* and *Z. noltii*.	Compiled by HELCOM
Species-related distribution data	Distribution of harbour porpoise		ASCOBANS-HELCOM harbour porpoise database
	Distribution of three seal species	Ringed seal, grey seal and harbour seal	Finnish Game and Fisheries Research institute 2010.
	Wintering grounds of seabirds		Skov et al. 2007
	Spawning and nursery areas of cod		Bagge et al. 1994

[1] EUSeaMap project website: http://www.jncc.gov.uk/page-5020

A confidence assessment was also produced for each indicator-based assessment with HEAT, BEAT, CHASE and HOLAS. The confidence assessments of the HEAT and CHASE classifications were based on harmonized scoring by experts of the underlying data, reference levels, and threshold levels. The confidence assessments of the BEAT and HOLAS tools were based on the same principles. The confidence was scored as low, acceptable or high for each indicator. The final confidence was taken as an average of the scores. In addition, a classification received a lower confidence if it consisted of too few indicators or was based on one quality element only. Details of confidence assessments are presented in Andersen et al. (2010a) and in Annex 3 in HELCOM (2010a).

The assessments and classification results from the HEAT, BEAT, CHASE and HOLAS tools seem to be generally accurate according to current standards. These confidence ratings imply that approximately 85% of the classifications can be regarded as having a high or acceptable confidence, while fewer than 15% of the classifications appear to have a low and hence unacceptable confidence. The confidence assessment should be regarded as interim, but still useful for improving both the monitoring activities and future assessments.

The HELCOM and WFD approaches are directly comparable as both rely on the 'good-moderate boundary', meaning the binomial classification scheme determining whether an area has an 'acceptable' or an 'unacceptable' status. However, given the differences outlined above, the HELCOM assessment tools sometimes arrive at a classification that is not directly comparable to the results of EU Member States in regard to the assessment of the 'ecological status', 'conservation status' and/or 'chemical status' of their coastal and transitional waters. It should therefore be remembered that HELCOM assessments have been conducted on a Baltic Sea-wide scale, while WFD assessments have been done for coastal water bodies included in WFD river-basin districts, involving an intercalibration at a Baltic level. Moreover, the data used for the assessments were not identical.

In this Initial Holistic Assessment, for the first time in the Baltic Sea, an estimation of potential anthropogenic cumulative pressures and impacts is presented for the entire Baltic Sea area (**Chapter 3**). The spatial distribution and magnitude of potential cumulative pressure and impacts have been estimated by the Baltic Sea Pressure Index (BSPI) and the Baltic Sea Impact Index (BSII). The methods have been developed based on an article by Halpern et al. (2008).

The prototype tools, HELCOM BSPI and BSII, differentiate 18 different kinds of pressures resulting from human activities (**Table 1.3**). The grouping of the pressures follows the Annex III, Table 2 of the EU Marine Strategy Framework Directive (Anon. 2008a). Altogether 52 data layers of various pressures and human activities have been used to describe the 18 pressure types. Any one human activity may cause several different pressures. Constructing wind farms, for example, causes noise, the abrasion of the seabed, smothering by disposed sediments, siltation and visual disturbance. Generally, the pressures can be divided into those disturbing the seabed, causing hydrographic changes, polluting the sea by nutrients, hazardous substances, litter and noise or exploiting the living resources of the sea.

The Baltic Sea Impact Index (BSII) is calculated for 5 km × 5 km squares for the whole Baltic Sea area (**Fig. 1.6** and background paper HELCOM 2010b). The index value consists of three components: intensity of the anthropogenic pressure (A, normalized to 0–1

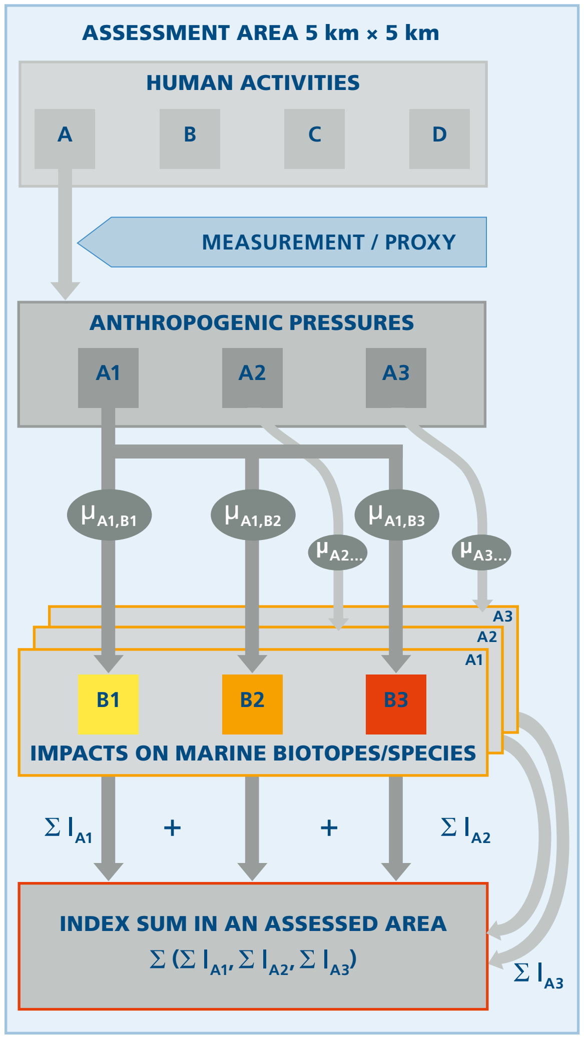


Figure 1.6 **Conceptual model of the Baltic Sea Impact Index (BSII), which takes into account the sensitivity of different biological ecosystem components. The index value is assessed for an area of 5 km × 5 km. The value is the sum of all impacts (I) on all biotopes or species (B) in the assessment area. Impacts are transformed from anthropogenic pressures by weighting scores (μ), which are based on expert opinions. In this figure, there are four activities (A–D) in the assessment area, but only one of them (A) has been shown in further steps. For each of the three biotopes/species in the assessment area (B1, B2 and B3), the activity A causes three pressures (A1, A2 and A3) which are weighted by specific scores ($\mu_{A1,B1}$, $\mu_{A1,B2}$, $\mu_{A1,B3}$, $\mu_{A2,B1}$, ..., $\mu_{A3,B3}$). Each of the weighted pressures is multiplied by 0 or 1, depending on the presence of B, resulting in impacts (I). Finally, the impacts I_{A1}–I_{A3} are summed up, resulting in a sum of nine impact values. See the text and HELCOM 2010b for details.**

scale), presence of a species/ biotope/ biotope complex (0 or 1, hereafter 'biotope', B) and an expert-opinion weighting score (μ, 0–4 scale). The number of available data layers tends to set the upper limit for the number of As and Bs. For any A×B combination, a specific μ has been defined. All three components are multiplied by each other: A×B×μ. In each 5 km × 5 km square, all A×B×μ results are summed up to give the index value. Thus, the larger the number of pressures and 'biotopes', the higher the BSII score. Therefore, the 'biological ecosystem components' must be representative for the region. In the BSII, there were six benthic and two water column biotope complexes, two benthic biotopes and four species-related data layers, which are representative for the whole region (**Table 1.4**).

The weighting scores were produced by experts in the HELCOM Contracting Parties through a questionnaire and a separate workshop. The weighting scores primarily take into account the biotope resilience to and recovery from a pressure but also whether the pressure affects one or several species, one or several trophic levels, or the whole community. The final μ for any A×B combination is a median value of all the expert values.

The Baltic Sea Pressure Index (BSPI) is a simpler approach because it does not take into account ecosystem components but sums up the pressures (represented by 0–1 normalized values) for each 5 km × 5 km square. However, it was recognized that anthropogenic pressures are not directly comparable to each other and therefore also the BSPI requires a weighting score. A median of all the expert μ scores over all 'biotopes' for each pressure was used to obtain the BSPI weighting score.

The use of both approaches is demonstrated for the first time in this assessment and should be further elaborated, in particular regarding the utilization of expert judgement in the weighting procedures. They should therefore be seen as first steps towards a better understanding of the magnitude and spatial distribution of anthropogenic pressures in the marine environment at a Baltic Sea-wide scale. The indices are presented in **Section 3.2** and a more detailed presentation of the data layers and methodology is included in a background document on BSPI and BSII (HELCOM 2010b).

Chapter 2: What is the status?

None of the open basins of the Baltic Sea has an acceptable ecosystem health status at the present time.

The Baltic Sea ecosystem is degraded to such an extent that its capacity to deliver ecosystem goods and services to the people living in the nine coastal states is hampered. The resilience of the marine ecosystem has been undermined by the inputs of contaminants from 85 million people living in the catchment area.

Eutrophication, caused by nutrient pollution, is of major concern in most areas of the Baltic Sea. The Bothnian Bay and the northeastern parts of the Kattegat are the only open-sea areas of the Baltic Sea not affected. The only coastal areas not affected by eutrophication are restricted to the Gulf of Bothnia.

The entire Baltic Sea area is disturbed by hazardous substances and the status was mainly classified as being moderate. Only at very few coastal sites and in the western Kattegat is the water still undisturbed by hazardous substances. Key substances of concern are PCBs, heavy metals, DDT/DDE, TBT, dioxins and brominated substances.

The biodiversity status was classified as being unfavourable in most of the Baltic Sea since only the Bothnia Sea and some coastal areas in the Bothnian Bay were classified as having an acceptable biodiversity status. The results indicate that changes in biodiversity are not restricted to individual species or habitats; the structure of the ecosystem has also been severely disturbed.

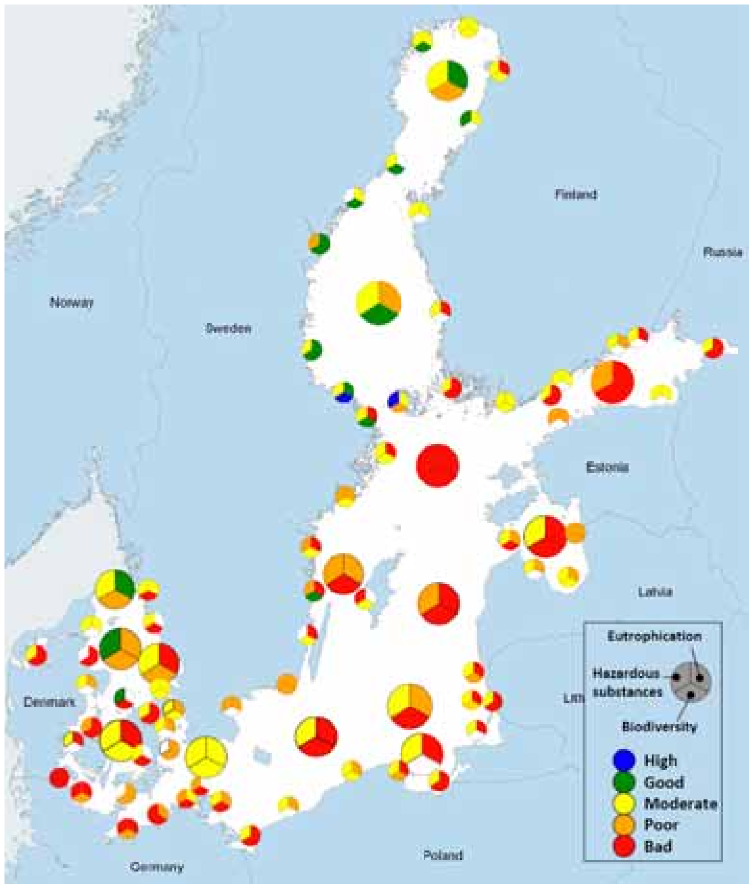


Figure 2.1 **Presentation of the 'eutrophication status' from HEAT classifications, the 'hazardous substances status' from CHASE classifications and the 'biodiversity status' from BEAT classifications. See Section 1.6 for details. White areas in the pie charts denote a lack of classification; large pie charts represent assessments of open sea areas and small pie charts of coastal areas.**

2.1 Integrated and Holistic Assessments

Arriving at an all-inclusive classification of the 'ecosystem health status' is useful for assessing whether the vision of a healthy Baltic Sea has been achieved or how far we still are from reaching this vision.

In the Initial HELCOM Holistic Assessment, ecosystem health has been assessed using two methods. The first approach is a straightforward combination of the results provided from the classifications made by the eutrophication assessment tool (HEAT, see **Section 2.2**), the biodiversity assessment tool (BEAT, see **Section 2.3**), and the assessment tool of chemical status (CHASE, see **Section 2.4**). The second approach is based on the use of an indicator-based assessment tool termed HOLAS, an abbreviation of 'tool for the Holistic Assessment of Ecosystem Health status'. The advantages of this approach are twofold: firstly, the indicators used in regard to the thematic assessments are integrated into a Holistic Assessment of 'ecosystem health'; secondly, the HOLAS tool is flexible in the sense that future assessments of 'ecosystem health' can be based on this tool and make use of indicators developed in the future.

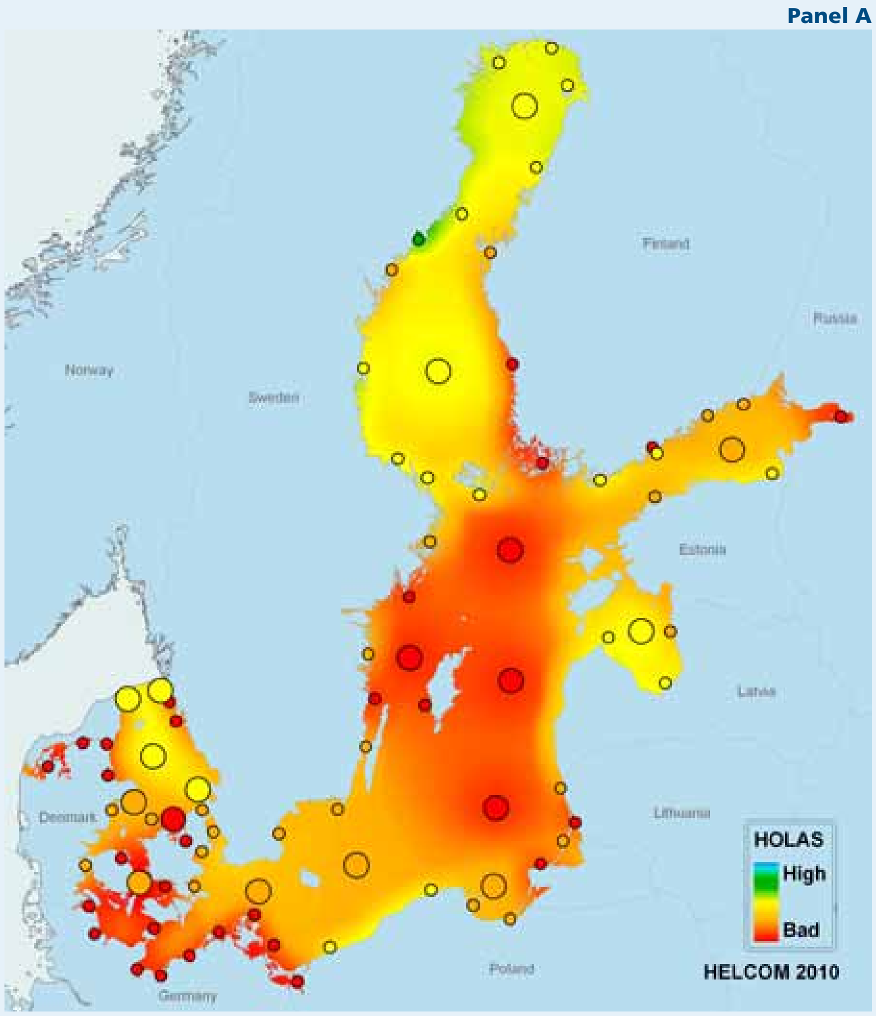
The results of the combination of HEAT, BEAT and CHASE classifications of 'eutrophication status', 'biodiversity status' and 'chemical status', respectively, are presented in **Figure 2.1**. Impaired conditions, here represented by yellow, orange or red colours indicating respectively a 'moderate', 'poor' or 'bad' status, can be found all over the Baltic Sea. Basins such as the Gulf of Finland, Northern Baltic Proper, Western Gotland Basin, Eastern Gotland Basin, Gulf of Riga, Bornholm Basin, Arkona Basin, and Danish Straits were all classified as impaired. Some positive signs, represented by the green colour, were however found in the Bothnian Bay, Bothnian Sea and parts of the Kattegat. If the lowest classification were to determine the final classification, not a single area would be classified as having an acceptable environmental status.

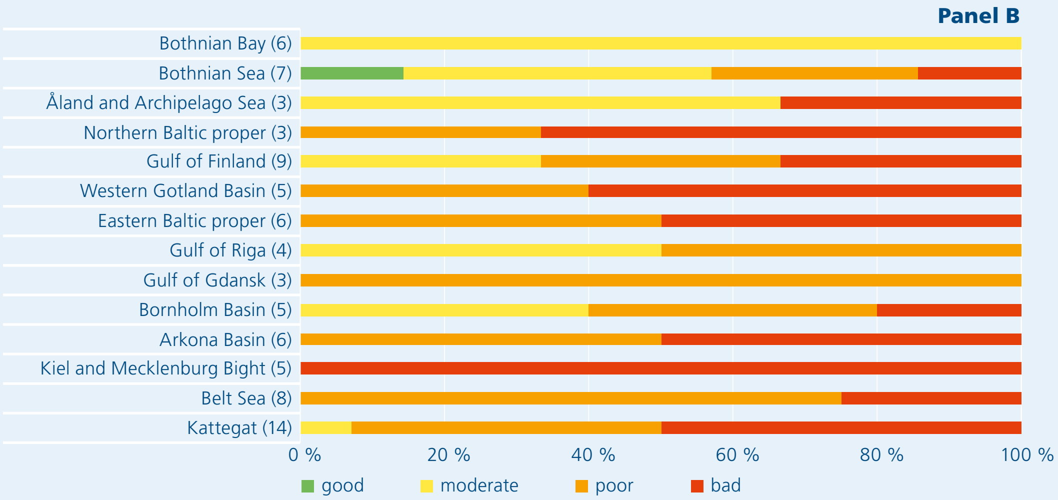
The preliminary results of the integrated assessment of the health of the Baltic marine ecosystem are presented in **Figure 2.2.** The integration is based on the interim assessment tool HOLAS. None of the open basins in the Baltic Sea were classified as having a 'good ecosystem health status'. The only areas close to having 'good ecosystem health status', for example, being classified as 'moderate', include the Bothnian Bay, the Bothnian Sea and parts of the northern Kattegat. In all other open areas, the status substantially deviated from reference conditions, in particular, the open parts of the Gulf of Finland, the Northern Baltic Proper, the Eastern Gotland Basin, as well as the coastal water in the Kattegat, Danish Straits, and the Arkona Basin.

However, there may be coastal 'pockets' fulfilling the vision of having a 'good ecosystem health status'.

In this assessment, only a single coastal area in the entire Baltic Sea was identified with 'good ecosystem health status': the Örefjärden area in the northwestern coastal area of the Bothnian Sea. Further isolated pockets may exist in other coastal waters. The identification of such areas will require detailed, site-specific analysis.

Nonetheless, the confidence assessment reveals that the assessment results generally are reliable, as shown in **Figure 2.2, Panel C**. Areas with low confidence are only found in the Gulf of Finland and in the Archipelago Sea, indicating a need for improved monitoring activities.





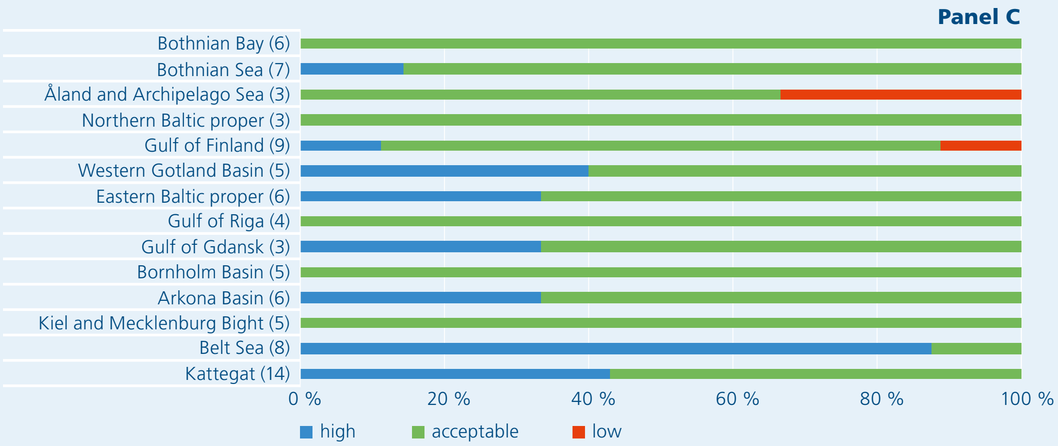


Figure 2.2 Panel A: Interim assessment and classification of 'ecosystem health' in the Baltic Sea, based on the assessment tool HOLAS. See Section 1.6 for a description of the general assessment principles. The interpolated map has been produced in three steps: 1) coastal assessment units have been interpolated along the shores, 2) open basins have been interpolated, and 3) the coastal and open interpolations have been combined using a smoothing function. The larger circles indicate the open-sea assessment units and the smaller circles the coastal assessment units. Panel B: Summary of the integrated classifications of 'ecosystem health' presented as the proportion of the assessment units per sub-basin (see the locations of the sub-basins in Fig. 1.1). Colour key as in Panel A. Panel C: Interim confidence rating of the 'ecosystem health' classifications presented as the proportion of assessment units per sub-basin. Colours: blue represents 'high confidence', green represents 'acceptable confidence' and red represents 'low confidence'.

2.2 Eutrophication

Eutrophication has its roots in Greek: 'eu' meaning 'well' and 'trope' meaning 'nourished', but the translation trivializes the impact of this very serious and expensive ecological syndrome gripping the Baltic. Algal blooms, turbid waters, loss of submerged aquatic vegetation, and dead zones spreading on the sea floor – the consequences of nutrient inputs and nutrient enrichment in the Baltic are manifold. They have changed the structure and functioning of the marine ecosystem and continue to impair our uses of the ecosystem services.

Eutrophication is triggered by excessive amounts of nutrients washed into the sea. Although nutrient chemicals are themselves harmless, in large quantities they cause eutrophication. The nutrients come from our farmlands, homes and gardens, cars, cities and industries. In the sea, the nutrients first foster the production of planktonic algae forming algal blooms, which in the worst case are so large and dense that they are visible even to astronauts in space.

This increased production of organic matter often has secondary and drastic negative consequences: the water becomes murkier and less transparent, the sedimentation of organic material to the sea floor increases, decomposition of organic matter increases and oxygen is consumed, thus depleting the bottom waters of oxygen. Benthic communities such as meadows of submerged aquatic vegetation are deprived of light, and benthic invertebrate communities and fish are affected by oxygen depletion, ultimately suffocating (**Fig. 2.3**).

Over the years, HELCOM has put considerable efforts into monitoring and assessment of the eutrophication status of the Baltic Sea. Special focus has been on indicators in the following groups: (1) phytoplankton, (2) submerged aquatic vegetation, (3) benthic invertebrates, and (4) supporting features, e.g., nutrient concentrations and water transparency. HELCOM has also focused on the development of tools for the assessment of eutrophication status (HELCOM 2006, 2009a). Combining indicators into a final classification of 'areas unaffected by eutrophication' and 'areas affected by eutrophication' is carried out using the HELCOM Eutrophication Assessment Tool (HEAT, see **Section 1.6**, HELCOM (2009a) and Andersen et al. (2010b) for details). HEAT calculates the integrated classification of 'eutrophication status'. HEAT also calculates a secondary assessment of the confidence in the eutrophication assessment.

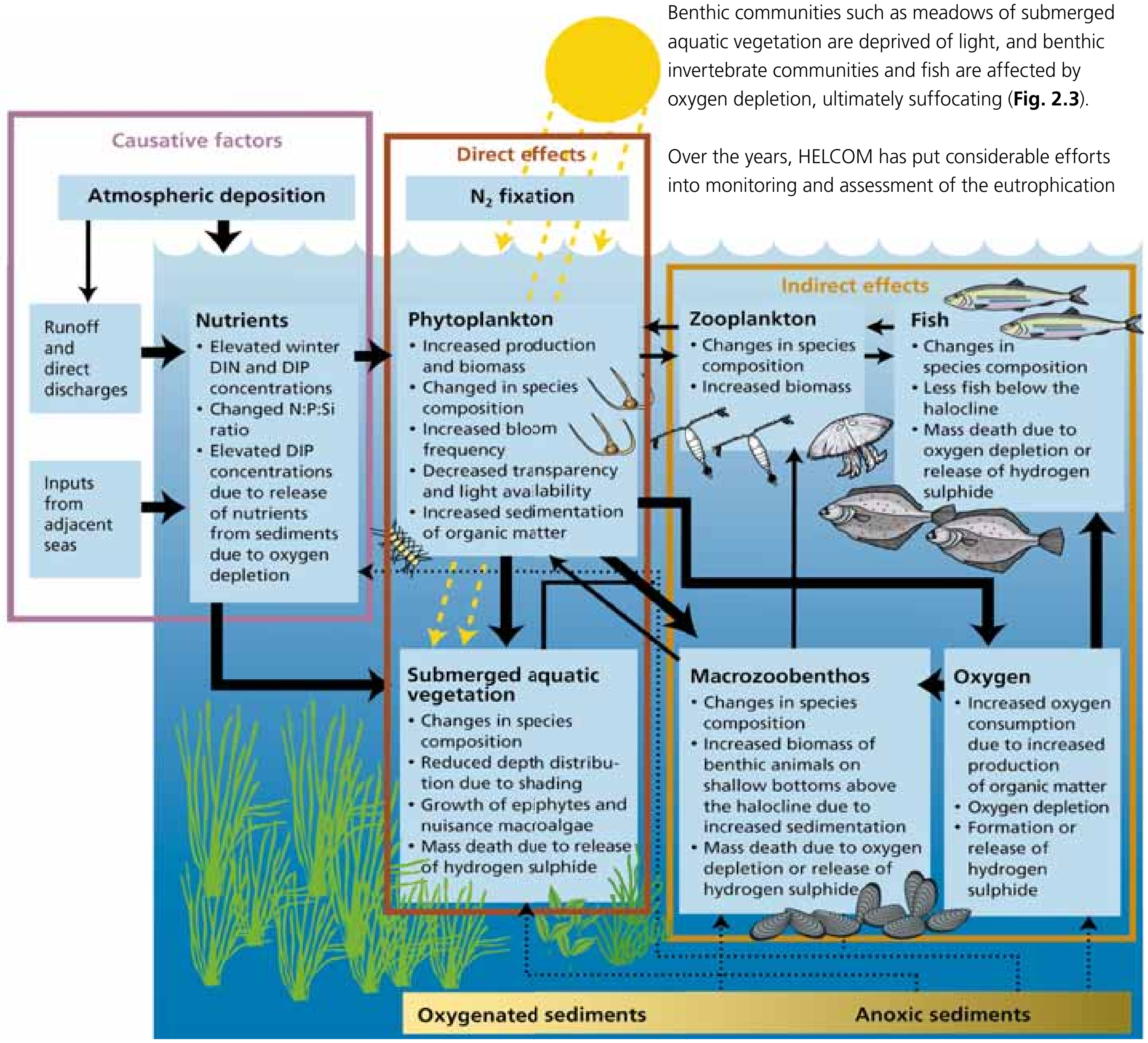


Figure 2.3 Conceptual model of eutrophication. The arrows indicate the interactions between different ecological compartments. A balanced coastal ecosystem in the Baltic Sea is supposedly characterized by: (1) a short pelagic food chain (phytoplankton > zooplankton > small fish > large fish), (2) natural species composition of plankton and benthic organisms, and (3) a natural distribution of submerged aquatic vegetation. Nutrient enrichment results in changes in the structure and function of marine ecosystems, as indicated with bold lines. Dashed lines indicate the release of hydrogen sulfide (H_2S) and phosphorus, which both occur under conditions of oxygen depletion. Abbreviations: N = nitrogen; P = phosphorus; Si = silicon; DIN = dissolved inorganic nitrogen; DIP = dissolved inorganic phosphorus.

To determine the current status of eutrophication in the Baltic marine ecosystem, the conditions at 17 open-water areas and 172 coastal areas were assessed using data collected between 2001 and 2006.

All open waters in the basins of the Baltic Sea, including the open parts of the Bothnian Sea, were found to be 'affected by eutrophication'. The only open-water areas 'not affected by eutrophication' included the open waters of the Bothnian Bay and the Swedish parts of the northeastern Kattegat, the latter being renewed by oxygen-rich Atlantic waters (**Fig. 2.4**). The open parts of the Bothnian Sea were labelled 'affected' due to increased chlorophyll-a concentrations (see HELCOM 2009a for details).

In most of the coastal waters, nutrient concentrations and chlorophyll-*a* concentrations generally are elevated compared to both target values and reference conditions. In most open basins, mussels, clams, crustaceans and other invertebrates living at the sea floor are outside the range of what is considered as being in a 'good status'.

Only 11 out of 172 coastal areas were found to be 'unaffected by eutrophication'; all of these were located in the Gulf of Bothnia. Outside the Gulf of Bothnia, not a single coastal area in the Baltic achieved this status. Thus, all 161 coastal areas assessed outside the Gulf of Bothnia received the classification 'affected by eutrophication'. The impaired conditions included elevated levels of nutrients and chlorophyll-*a*, loss of submerged aquatic vegetation, as well as periods of oxygen depletion particularly affecting benthic invertebrates.

The accuracy of the classification results was generally good, although there is some room for improvement. This has been documented indirectly by the rating of confidence, in which the data on which the classification was based was scored in terms of accuracy. 145 of 189 areas had an acceptable confidence level, while the remaining 44 areas had low confidence. Low confidence is generally a consequence of mediocre monitoring activities or the use of too few or low quality indicators or targets. The interim assessment of confidence is summarized in **Figure 2.4, Panel C**. The areas with low confidence are generally found in the southeastern or northern parts of the Baltic Sea.

Assessing the eutrophication status in an integrated manner for the whole Baltic Sea provides a good basis for evaluating the effectiveness of the implementation of the eutrophication segment of the HELCOM Baltic Sea Action Plan. The assessment clearly documents that nutrient inputs need to be further reduced, even though the Baltic Sea countries have successfully reduced nutrient inputs to a certain degree (see **Section 3.1.7** and HELCOM 2009a). The eutrophication status of the Baltic Sea will only improve if inputs of both nitrogen and phosphorus are significantly further reduced (Conley et al. 2009b, HELCOM 2009a).

The limited water exchange with the North Sea and the long residence time of water are the main reasons for the sensitivity of the Baltic Sea to eutrophication. High nutrient loads in combination with a long residence time means that nutrients discharged to the sea will remain in the basin for a long time. In addition, the vertical stratification of the water masses increases the vulnerability of the Baltic Sea to eutrophication. The most important effect of stratification in terms of eutrophication is that it hinders or prevents ventilation and oxygenation of the bottom waters and sediments by vertical mixing of the water, a situation that often leads to oxygen depletion. Furthermore, hypoxia and anoxia worsen the situation by affecting nutrient transformation processes, such as nitrification and denitrification, as well as the capacity of the sediments to bind phosphorus. In the absence of oxygen, reduced sediments release significant quantities of phosphorus to the overlying water.

Large parts of the Baltic marine ecosystem are trapped in a vicious circle that encourages algal blooms, although the inputs of nitrogen and phosphorus to the sea have been reduced in significant amounts since the late 1980s. In fact, the widespread anoxia which facilitates the release of phosphorus from the sea floor sediments fuels the growth and blooms of certain planktonic algae that are capable of utilizing dissolved nitrogen (N_2) gas. These algae, termed nitrogen (N_2) fixing blue-green algae or cyanobacteria, are capable of fixing nitrogen dissolved in the surface layers, thus transforming it into a form that can be used by other organisms. Large quantities of nitrogen compounds available for the growth of other planktonic algae are introduced to the ecosystem by cyanobacteria especially during their bloom period in the late summer. This state is sometimes called a state of repressed recovery (Vahtera et al. 2007).

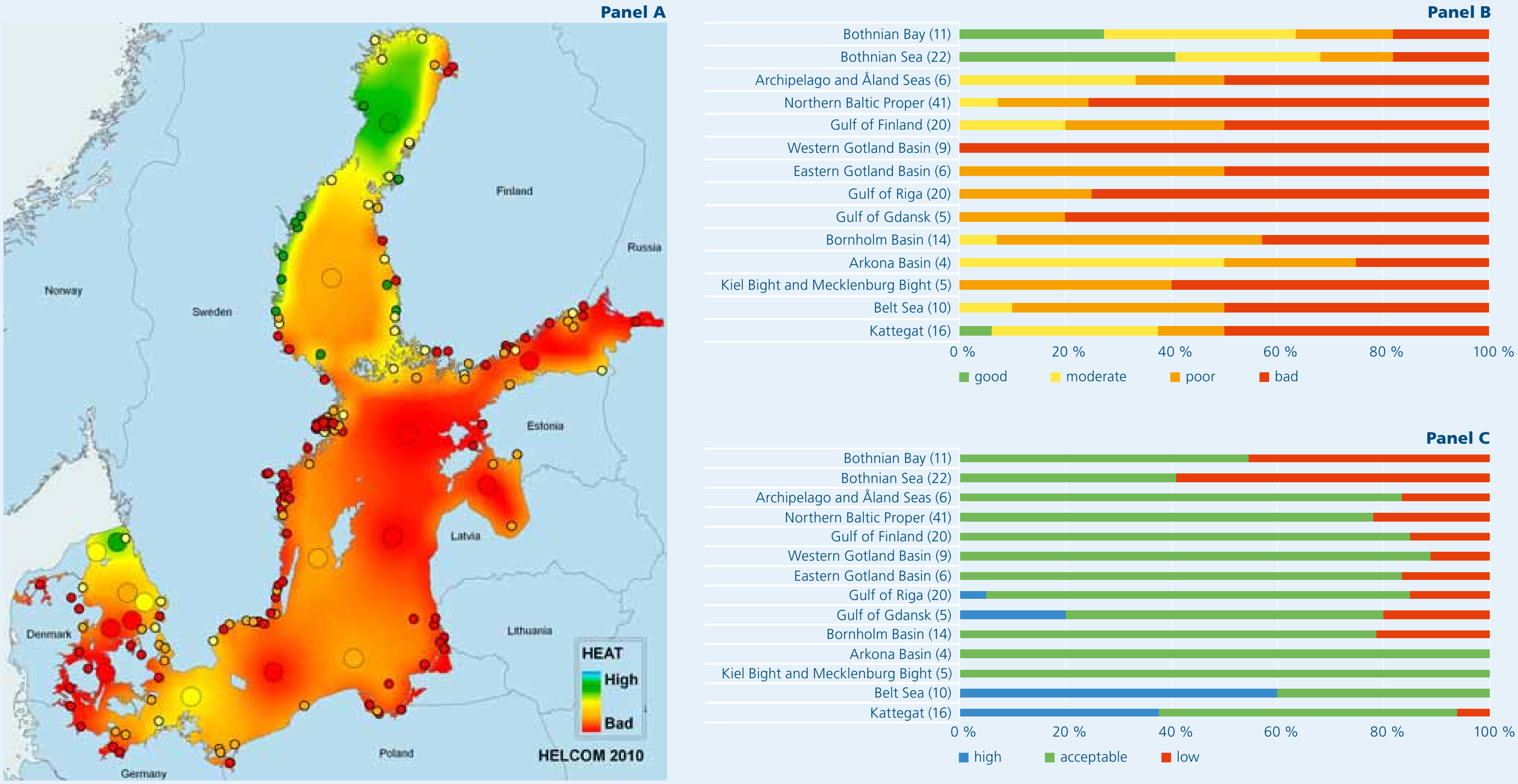


Figure 2.4 Panel A: Integrated classification of eutrophication status in the Baltic Sea (see Fig. 2.2 for an explanation of the interpolation method). Areas in green represent 'areas unaffected by eutrophication', while areas in yellow, orange and red represent 'areas affected by eutrophication', from Andersen et al. (2010a), based on HELCOM (2009a). Large circles represent assessment sites in open basins and small circles represent coastal assessment sites. Panel B: Summary of the integrated classifications of 'eutrophication status' presented as the proportion of assessment units per sub-basin, from Andersen et al. (2010a), based on HELCOM (2009a). The colour key is same as in Panel A. Panel C: Interim confidence ratings of the eutrophication classifications presented as the proportion of assessment units per sub-basin. Colours: blue represents high confidence, green represents acceptable confidence and red represents a low and hence unacceptable confidence, from Andersen et al. (2010b), based on HELCOM (2009a).

2.3 Hazardous substances

Hazardous substances include compounds – either synthetic or natural – which cause adverse effects on the ecosystem and human health by being toxic, persistent and bioaccumulating. Heavy metals such as mercury, cadmium, and lead are toxic to organisms at high concentrations, whereas persistent organic pollutants (POPs), such as polychlorinated biphenyls (PCBs), DDTs, polybrominated diphenylethers (PBDEs) and organotin compounds (TBT and TPT) may be toxic even at low concentrations. Concentrations of the radionuclide cesium-137 were also assessed to evaluate whether the HELCOM Ecological Objective for radioactivity had been reached.

The overall status of hazardous substances, presented in **Figure 2.5**, has been assessed using the HELCOM Hazardous Substances Status Assessment Tool CHASE. CHASE employs indicators related to four ecological objectives of the hazardous substances segment of the Baltic Sea Action Plan (see **Section 1.5**). At present, there is no jointly agreed fixed set of assessment criteria for hazardous substances for the Baltic Sea, meaning that different areas may have been assessed using different assessment criteria (e.g., different sets of substances, threshold values, or matrices).

During 1999–2007, the Baltic Sea was an area with high contamination by hazardous substances, as shown by the Integrated Thematic Assessment of Hazardous Substances in the Baltic Sea (HELCOM 2010a). All open-sea areas of the Baltic Sea except the western Kattegat were classified as being 'disturbed by hazardous substances'. Similarly, 98 of the 104 coastal assessment units were classified as being 'disturbed by hazardous substances'. Altogether, only seven out of the 144 assessment units were considered to be 'undisturbed by hazardous substances' (**Fig. 2.5, Panel A**). The majority of the Baltic Sea was classified as having a moderate status.

The main basin of the Baltic Sea (Northern Baltic Proper, Western and Eastern Gotland Basins) together with certain parts of the Kiel and Mecklenburg Bights were the areas most disturbed by hazardous substances (**Fig. 2.5, Panel B**). Although status classifications of coastal areas were highly variable, there was a certain tendency for the waters near larger cities (e.g., Tallinn, Rostock, St. Petersburg, Helsinki, Gdansk and Stockholm) to be classified as having a 'moderate', 'poor' or sometimes even 'bad' status.

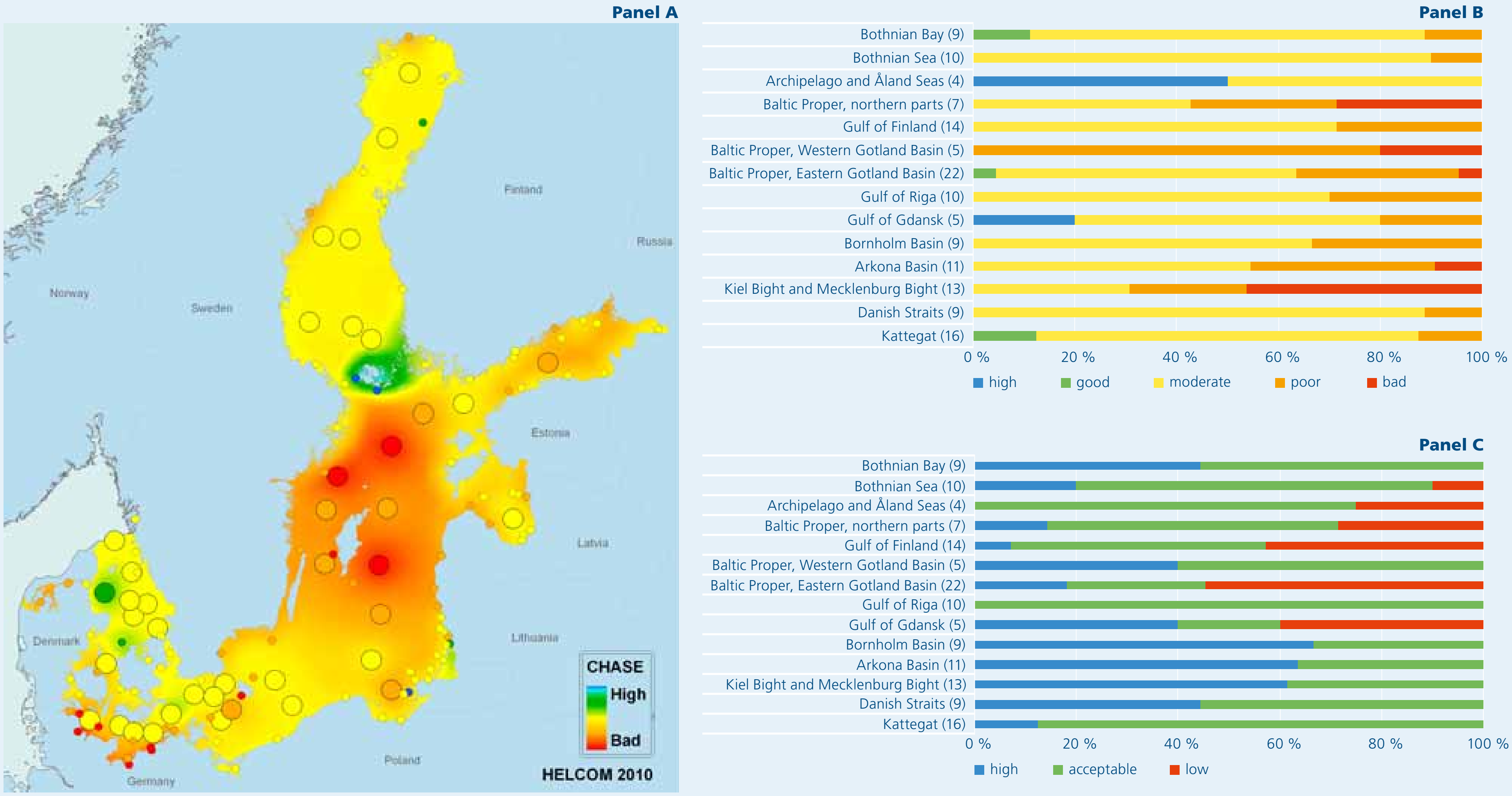


Figure 2.5 Panel A: Integrated classification of the 'status of hazardous substances' in 144 assessment units. Blue = 'high' status, green = 'good', yellow = 'moderate', orange = 'poor', and red = 'bad' status. 'High' and 'good' status (blue and green) are equivalent to 'areas not disturbed by hazardous substances', while 'moderate', 'poor', and 'bad' status (yellow, orange and red) are equivalent to 'areas disturbed by hazardous substances'. Large dots represent open basins; small dots represent coastal assessment units. See Section 1.6 and HELCOM (2010a) for details of the assessment method and Fig. 2.2 for an explanation of the interpolation method. Panel B: Summary of the integrated classifications presented as the proportion of assessment units per sub-basin (HELCOM 2010a). The colour code is the same as in Panel A. Panel C: Interim confidence ratings of the hazardous substances status classifications presented as the proportion of assessment units per sub-basin. Colors: blue represents high confidence, green acceptable and red represents a low and hence unacceptable confidence (HELCOM 2010a).

The integrated assessment was based mainly on measurements from biota (mussels and fish), but several open-sea areas were assessed on the basis of sediment measurements. Water measurements were used only rarely and none of the classifications was based solely on the water data.

The accuracy of the CHASE classifications was generally considered to be good using the CHASE confidence assessment (**Fig. 2.5, Panel C**).

In the Baltic Sea, substances such as polychlorinated biphenyls (PCBs), lead, DDE (a degradation product of DDT), cadmium, mercury, tributytin (TBT), and dioxins as well as brominated substances, for example, polybrominated diphenylethers, appear as contaminants with the highest concentrations in relation to the threshold levels (**Fig. 2.6,** HELCOM 2010a). In the main basin, the eight open-sea areas with 'bad' or

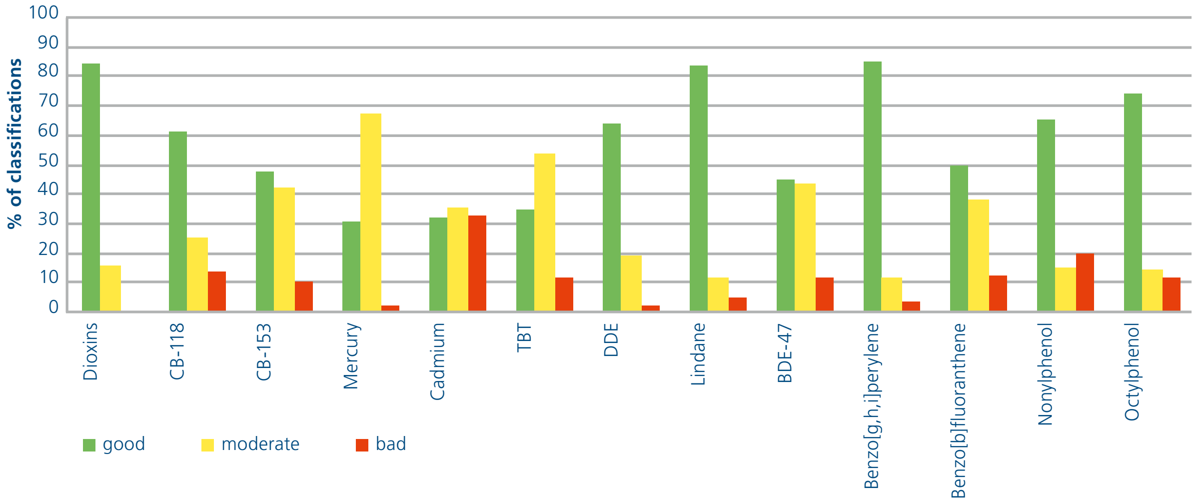


Figure 2.6 Percent distribution of the status classification categories ('good' = green, 'moderate' = yellow, 'bad' = red) of the different substances in the Integrated Thematic Assessment of Hazardous Substances in the Baltic Sea (HELCOM 2010a). The three status classes are based on the substance-specific status maps in the thematic assessment (HELCOM 2010a). CB-118 and CB-153 represent two congeners of polychlorinated biphenyls and BDE-47 is a congener of polybrominated diphenylether.

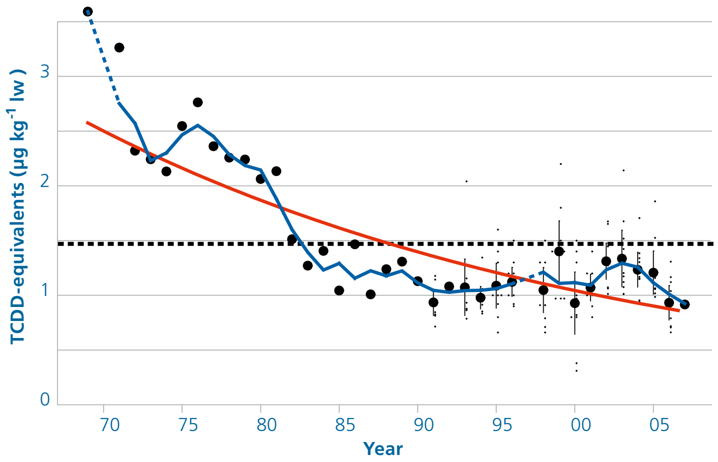


Figure 2.7 **Decreasing trends of dioxins (measured as TCDD-equivalents, µg kg^{-1} lipid weight) in common guillemot (*Uria aalge*) eggs from Stora Karlsö in the Western Gotland Basin (HELCOM 2010a).**

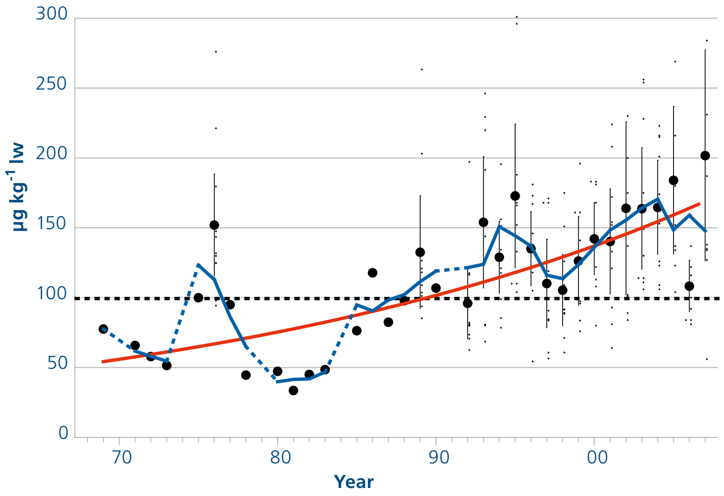


Figure 2.8 **The increasing temporal trend of HBCDD concentrations (µg kg^{-1} lipid weight) in eggs of the common guillemot from Stora Karlsö, Western Gotland Basin. The red line is the trend line and the blue line is the smoothed average of the measurements. The horizontal line is the geometric mean of the time series. Source: HELCOM (2010a).**

'poor' status were most contaminated with PCBs, TBT, lead, cadmium and octylphenol (HELCOM 2010a). The Kiel and Mecklenburg Bights had several coastal sites with either 'bad' or 'poor' status. In those sites, substances with the highest concentrations in relation to threshold levels were PCBs, lead, hexachlorocyclohexane (HCH) and metabolites of polycyclic aromatic hydrocarbons (PAHs).

There are positive signals of decreasing trends of persistent organic pollutants (POPs) in the Baltic Sea. In many cases, the declines can be directly related to bans or restrictions on the production or use of the substances. Dioxins, measured as TCDD-equivalents in common guillemot (*Uria aalge*) eggs from Stora Karlsö in the Western Gotland Basin since the end of the 1960s, are decreasing (**Fig. 2.7**). The temporal trend of DDE, a degradation product of DDT, measured in herring muscle has been declining since the end of the 1970s. PCBs show significant declining trends for herring, perch and blue mussels in several regions in the Baltic Sea and TBT, which has entered the marine environment primarily due to its use in anti-fouling paints on ship hulls, has declined at least in Danish and German waters (HELCOM 2010a).

The primary HELCOM target of decreasing trends of the radionuclide cesium-137 in water, sediment, and fish muscle has been reached in all parts of the Baltic Sea and for all compartments of the ecosystem (HELCOM 2010a). The levels of long-lived man-made radionuclides in the Baltic Sea sediments are low and not expected to cause harmful effects to man or wildlife. In addition, there are no particular management measures that could be taken to reduce the levels and they will decline naturally over time.

Despite the declining trends of POPs, their concentrations in the marine environment are still of concern. PCBs are clearly the most widespread and problematic group of pollutants in the Baltic Sea (HELCOM 2010a). TBT levels in sediments and blue mussels are still of concern in most areas of the Baltic Sea. The concentrations of dioxins and furans also still exceed the safety criteria for seafood in the northern and northeastern parts of the Baltic Sea, although the levels in the more southern areas were classified as being 'good' according to environmental standards. Exceedances of the threshold values for cadmium and mercury concentrations in fish and mussels were found in almost all areas of the Baltic Sea (HELCOM 2010a).

There are also signs of increasing concentrations of some hazardous substances. The concentration of a brominated substance, hexabromocyclododecane (HBCDD) which is used, for example, as a flame retardant in polystyrene-based insulation products in the building and construction industry, increased approxi-

mately 3% per year in guillemot eggs from Stora Karlsö between the late 1960s and 2007 (**Fig. 2.8**) and is already now of high concern in many of the western Baltic Sea areas. Perfluorooctane sulphonate (PFOS) concentrations have also been found to increase in eggs of the common guillemot since 1968 without signs of levelling off (HELCOM 2010a). There are also indications of an increase in heavy metal concentrations (e.g., nickel, copper, arsenic, chrome) in sediments in the Baltic Sea during the 2000s. Cadmium and mercury concentrations in biota do not show any consistent temporal trends in the Baltic Sea area; both increasing and decreasing trends have been found.

The health of the Baltic Sea wildlife is improving in terms of the health of predatory birds and seals, but there are no signs of improvement in fish health and lower trophic levels are also still impacted by hazardous substances (HELCOM 2010a). Predatory birds, seals and fish were suggested as indicators of the ecological objective 'Healthy wildlife' in the BSAP. Fish populations of the coastal areas seem to suffer more from pollution than those of the open-sea sites (HELCOM 2010a). In perch (*Perca fluviatilis*), a fourfold increase in EROD activity indicating exposure to compounds such as dioxins, PCBs and PAHs was observed between 1988 and 2008 in Kvädöfjärden, on the Swedish coast of the Western Gotland Basin (HELCOM 2010a). An integrative parameter of the impact of a combination of contaminants and general toxicity, the lysosomal membrane stability test measured in flounder (*Platichthys flesus*), indicated marked impacts in coastal and harbour areas in the southern Baltic Sea and the Baltic Proper, as well as in an open-sea site in the Bornholm Basin (HELCOM 2010a). The poorer status of the coastal sites was confirmed with another indicator of genotoxic damage measured in flounder, the micronucleus test.

Even though there are encouraging signs of decreasing trends of certain substances and improving health status of some top predators, it can be concluded that there is still a great deal of work to be done in order to reach the goal of the Baltic Sea Action Plan of a Baltic Sea with life undisturbed by hazardous substances (HELCOM 2010a). In addition, inputs that primarily took place decades ago are still obvious in the Baltic Sea, as is demonstrated by undesirable concentrations of PCBs, DDT/DDE and TBT.

2.4 Biodiversity

Biodiversity is vital to the functioning of the Baltic marine ecosystem and the delivery of valuable ecosystem goods and services. However, biodiversity in the Baltic is changing in a direction that is weakening the capacity of the ecosystem to provide valuable goods and services.

The term biodiversity embraces the variety of all living species in the sea, the diversity among the various coastal and offshore habitats that form their living environment, and the genetic variation within each species. In order to maintain the biodiversity in the Baltic, it is vitally important to protect not only individual plants and animals, but also their fundamental conditions for growth and evolution.

In the Baltic Sea, marine and freshwater species live in the same habitats and have in many cases genetically adapted to the brackish-water conditions. Compared to other sea regions, biodiversity in the Baltic is low and only a handful of keystone species build the basis for the food web. In the coastal communities, such species are the fucoid alga bladderwrack (*Fucus vesiculosus*), eelgrass (*Zostera marina*) and perhaps the blue mussel (*Mytilus trossulus* and *M. edulis*). In the pelagic community, cod (*Gadus morhua*) and common eider (*Somateria mollissima*) have been mentioned as keystone species. The ecological interactions of the relatively few species make the food web particularly vulnerable to external pressures.

The biodiversity in the Baltic is continuously affected by essentially all human activities at sea, and all land-based activities that reach or directly affect the coastline (see **Chapter 3**).

A direct impact is caused by targeted removal through hunting and fishing, non-targeted removal such as by-catch, direct killing through oil spills, but also by the extraction of physical components of the sea floor such as through sand and gravel extraction. The development of harbours, bridges, and wind farms is also associated with the direct loss of species and habitats in the zone around the structures as well as the potential for severe disturbance during the construction phase through the emission of noise and stirring up of sediments. Artificial structures, however, create a substrate for new habitats, which increases habitat and species diversity.

Many impacts on biodiversity are indirect and caused by eutrophication and the uptake of hazardous substances released from multiple human activities, both at sea and on land. The impacts of eutrophication on phytoplankton, macrophytes and large-scale habitats have been detailed in the Integrated Thematic Assessment on Eutrophication (HELCOM 2009a) and **Section 2.2**. Hazardous substances primarily affect the health and reproduction of biota. Severe effects on fish, birds and mammals have already been witnessed in the Baltic Sea in the 1960s and 1970s (HELCOM 2010a and **Section 2.3**).

Considering the multitude of pressures that act upon the Baltic biodiversity at any one time, the relative impact of an individual pressure is difficult to discern. And importantly, it is the cumulative and synergistic impact of all the pressures that determines the state of biodiversity in the sea. There is, however, strong evidence to suggest that at present eutrophication and fisheries have the most severe impacts on Baltic biodiversity in offshore areas (ICES 2008, HELCOM 2009b), while in the coastal areas physical disturbance adds significant stress to the biodiversity.

Baltic biodiversity is particularly sensitive to changes in salinity and in this way it is easily affected by natural variations in the environmental conditions. During recent decades, large-scale climate fluctuations have influenced the Baltic Sea, which in turn has affected the distribution and abundance of species in the Baltic Sea (Matthäus and Nausch 2003). The natural variability of the climate makes it difficult to quantitatively distinguish the human-induced modifications of the Baltic Sea biodiversity. Over long time spans, the

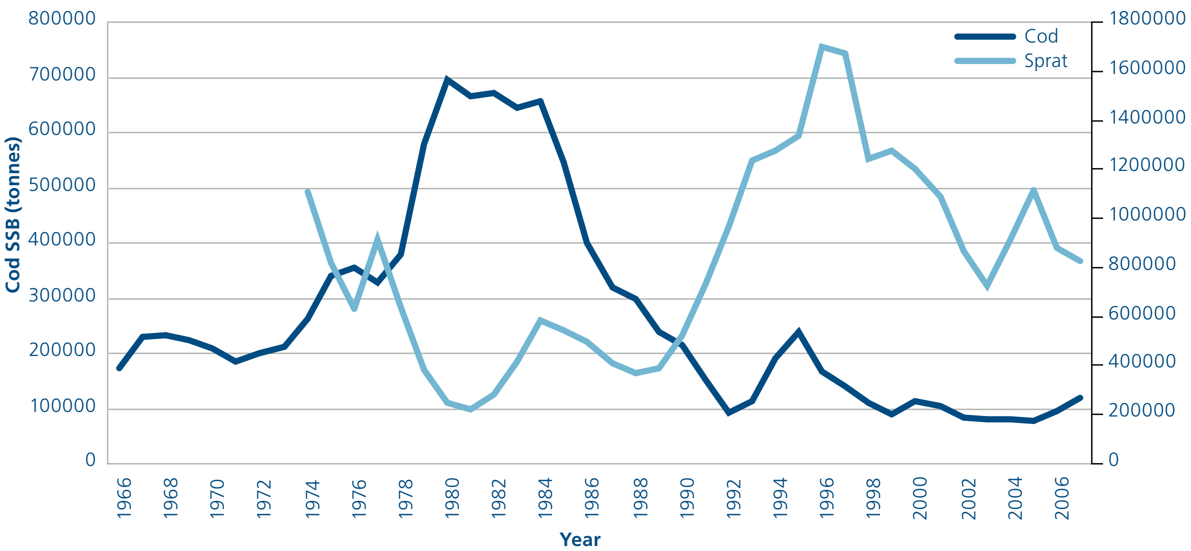


Figure 2.9 Changes in cod and sprat spawning stock biomass (SSB) in the Baltic Sea. The SSB of cod represents the eastern cod population (ICES areas 25–29, the Bornholm Basin and the Baltic Proper, and area 32, the Gulf of Finland), whereas the sprat population is from the whole sea area. Data source: ICES (2009a).

biodiversity of the Baltic Sea is naturally dynamic, but anthropogenic climate change is foreseen to have an impact on these natural and dynamic processes (BACC Author team 2008). As an example, the increasing seawater temperatures will diminish the distribution ranges of cold-water species. Similarly, the predicted decline of pH in the sea due to emissions of CO_2 may change species distributions, as species with calcareous parts will not survive at a low pH (Caldeira and Wickett 2005, Perttilä 2008). But even now there is no doubt that various human pressures have contributed to the observed changes in biodiversity during the past 30 to 40 years (HELCOM 2009a).

At the lower level of the food chain, the composition of the phytoplankton community has changed and in the zooplankton community, dominant species among the copepods—a group of crustacean plankton that is an essential food source for fish—have shifted. At the same time, large plants in the sea (macrophytes) have disappeared in many locally polluted and exploited areas, particularly in the southernmost coastal areas. The number and abundance of species in offshore benthic invertebrate communities have also declined, likely linked to the impacts of eutrophication (HELCOM 2009a). At the same time, the offshore fish community has undergone a regime shift: while it was previously dominated by predatory cod (*Gadus morhua*), it is now dominated by sprat caused by the combined effect of natural, climate-related fluctuations and overfishing (**Fig. 2.9**, see p.37 for changes in the food-web structure). The overfishing of cod was addressed in 2008 by implementation of a management plan (see **Section 4.4**).

Among the bird species populating the Baltic Sea, a long-term population decline is evident for dunlin, as well as a recent decline for eider and wintering long-tailed duck. Regarding mammals, only a few hundred harbour porpoises remain in the Baltic Proper and the status of ringed seals is poor. Overall, 59 species are considered as threatened or declining in the Baltic Sea or in some of its sub-basins and many essential habitats in the coastal sea area are also threatened, as identified in a report by HELCOM (HELCOM 2007c). These species include fish, mammals, plants, birds and invertebrates.

The situation is not entirely discouraging and signs of recovery have been seen during recent decades, primarily related to birds and mammals. Here, dedicated efforts to restore habitats, ban hunting, and reduce

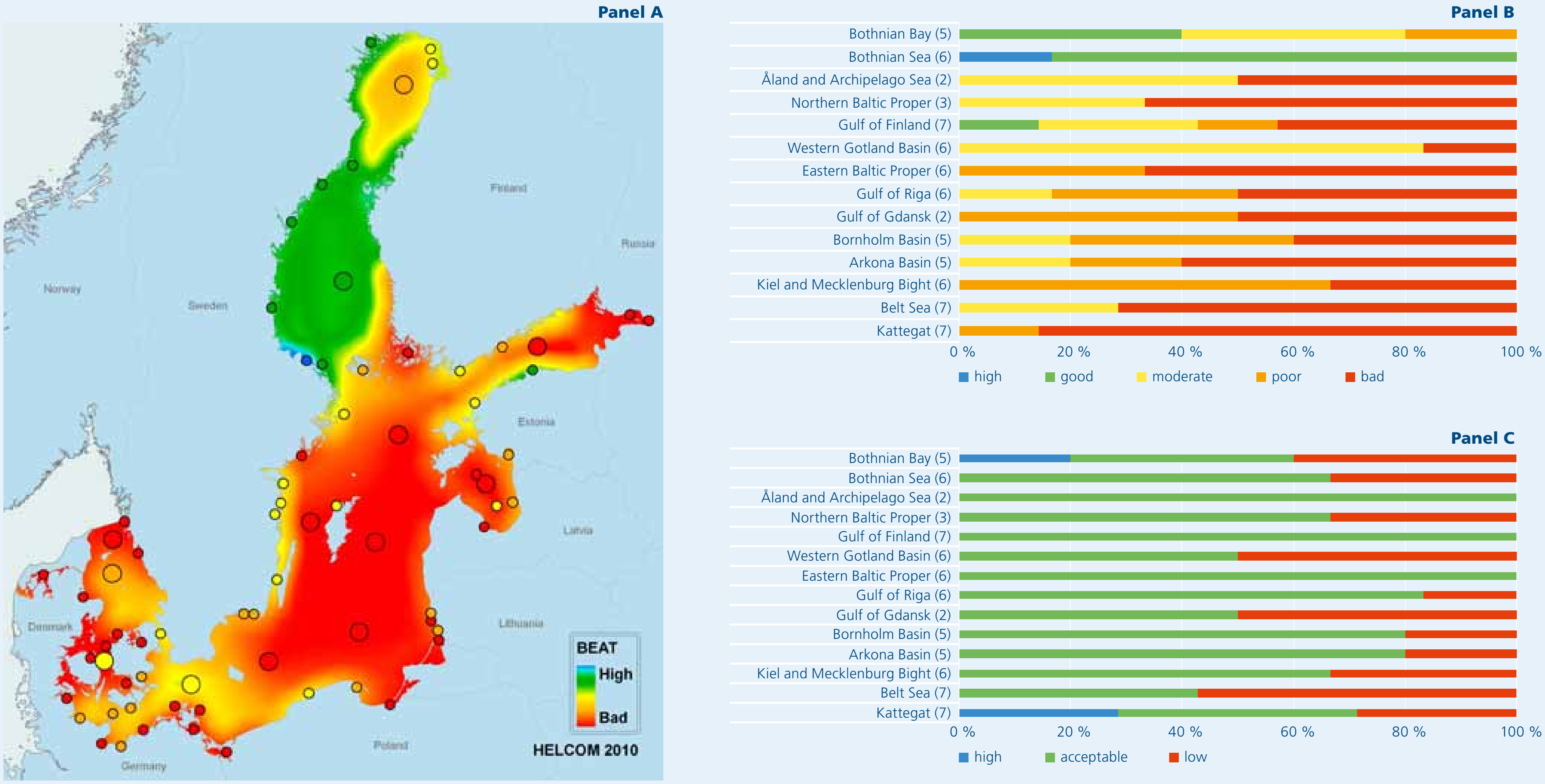


Figure 2.10 Panel A: A preliminary integrated classification of biodiversity status of the Baltic Sea. Areas in blue and green represent areas with an 'acceptable biodiversity status', while areas in yellow, orange and red represent areas with an 'unacceptable biodiversity status', based on HELCOM (2009b). Large circles represent assessment sites in open basins and small circles represent coastal assessment sites. See Section 1.6 for a description of the general assessment principles and Fig. 2.2 for an explanation of the interpolation method. Panel B: Summary of the integrated classifications presented as the proportion of assessment units per sub-basin (HELCOM 2009b). The colour code is the same as in Panel A. Panel C: Interim confidence rating of the biodiversity classifications presented as the proportion of assessment units per sub-basin. Colours: blue represents high confidence, green represents acceptable confidence, and red represents a low and hence unacceptable confidence level (HELCOM 2009b). Please refer to the text for the confidence of the results.

hazardous substances have led to the recovery of the white-tailed eagle, the great cormorant, and the grey seal north of 59°N. In the past few years, macrophytes have also been reported to have recovered in the northwestern and northeastern Baltic Proper.

The overall status of biodiversity, presented in **Figure 2.10**, has been assessed using the HELCOM Biodiversity Assessment Tool BEAT. BEAT groups the indicators according to the three HELCOM Ecological Objectives relevant to biodiversity, namely, landscapes, communities, and species, in line with the structure of the biodiversity segment of the Baltic Sea Action Plan. At present, the tool is still being tested and there is no jointly agreed set of appropriate biodiversity indicators for the Baltic Sea, meaning that different areas may have been assessed by different types, or by a limited number, of indicators. Also, some indicators have gone through rigorous national calibration, while other indicators are still only proposals by experts. Thus, the results presented in **Figure 2.10** should be viewed as preliminary. These results, however, point in the same direction as the HEAT and CHASE assessments: the status of biodiversity in coastal areas is poorest in the southern and eastern parts of the Baltic Sea, while the status is good along the coasts of the Bothnian Bay and the Bothnian Sea.

Altogether, 73 open-sea and coastal areas were assessed using the BEAT tool. According to these preliminary results, 82% of the coastal areas assessed (2003–2007) are in an unfavourable conservation status ('moderate', 'poor' or 'bad'), and only 18% are in a 'good' or 'high' state. In the open waters, the status of biodiversity is worst in the Baltic Proper, the Gulf of Riga and the Gulf of Finland, while it is indicated to be slightly better—although still unfavourable—in the northern and southern-most basins. Only the Bothnian Sea yielded a 'good' status of biodiversity.

It is important to note that a 'bad' status reveals that the biodiversity has changed in a direction that can negatively impact the marine ecosystem, but it does not necessarily mean that the number of species has declined. Some areas with 'bad' status are benthic biodiversity hot spots and are still very important sites as resting, wintering, and feeding grounds for seabirds and temporal hot spots for harbour porpoises.

At present, the indicators most regularly used in the assessments are related to macrophytes, benthic animals and fish, on the level of both communities and species. In a limited number of cases, indicators related to birds, zooplankton and phytoplankton have also been used. On the level of landscapes, indicators related, for example, to the areal distribution of biotopes have been envisioned but data are scarce and so far only a few areas assessed include indicators related to the landscape level. In order to move from preliminary to reliable assessment results, it is necessary to continue a regional development of biodiversity-related indicators as well as to discuss the type of monitoring that is needed to obtain relevant data. Moreover, the results based on BEAT differ in some areas from the assessments of ecological status according to the Water Framework Directive due to differences in the approach (see **Section 1.6**).

Summing up, many components and all levels of Baltic biodiversity have been negatively affected by human activities. Moreover, the changes to biodiversity have not only altered individual characteristics of the Baltic ecosystem, but the structure of the ecosystem has also been severely disturbed, which has had negative consequences far beyond that of individual species or habitats. However, more information and particularly a suitable set of biodiversity indicators are needed in order to verify these results.

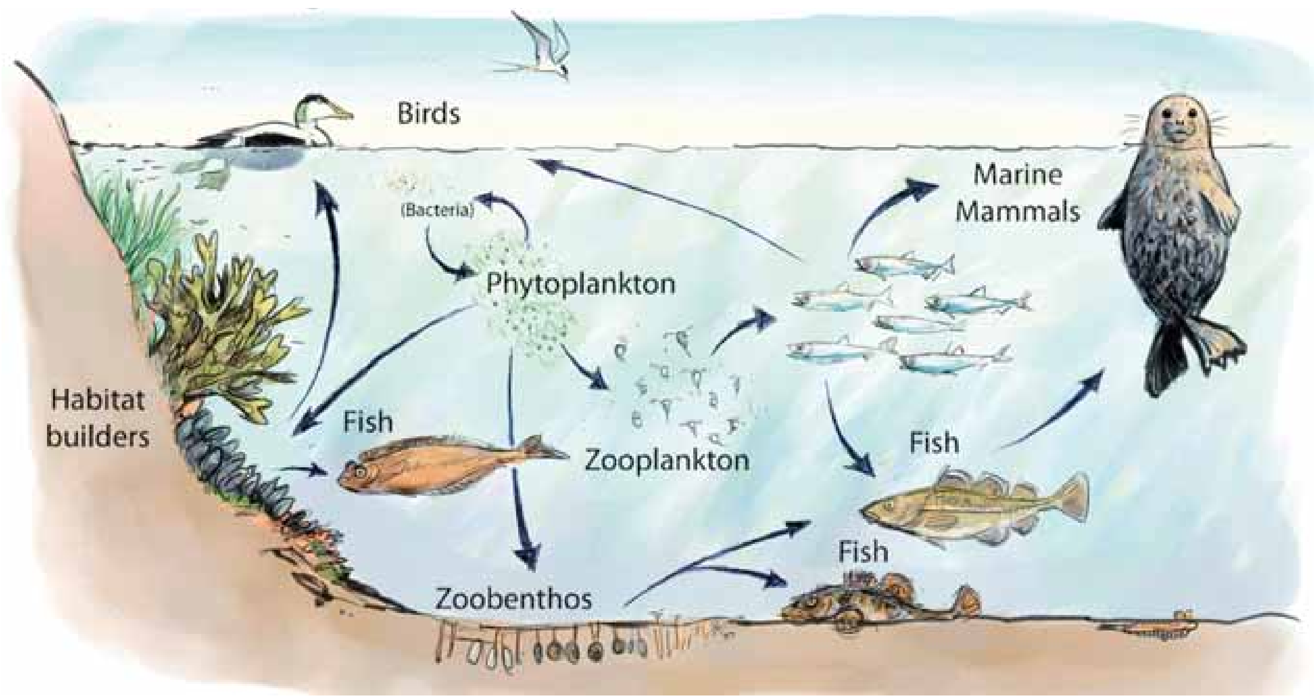


Figure 2.11 A schematic presentation of the simplified food-web structure in the Baltic Sea.

Changes in food-web structure

The Baltic Sea food web is made up of a small number of species and the trophic levels are interlinked by only a few linkages (**Fig. 2.11**). Hence, changes at the top level are more easily reflected at lower levels and vice versa than in cases with a larger number of species and more interlinkages between the trophic levels.

The models of the Baltic food web predict that top predators at the fourth trophic level, including mammals, large fish and cormorants, control the abundance of small fish species at the third trophic level such as perch, sprat, herring and cyprinid fish. The second level mainly consists of herbivorous invertebrates such as zooplankton and benthic invertebrate fauna (zoobenthos), which control the abundance of primary producers at the first trophic level (phytoplankton, benthic algae and vascular plants).

Currently, however, the long-standing balance among the trophic levels has been disturbed and the zooplankton and benthic fauna at the second trophic level are subject to pressures both from above and from below. On the one hand, the zooplankton and benthic fauna can no longer control the abundance of phytoplankton, benthic algae and vascular plants at the first trophic level in many areas of the Baltic, where excessive nutrients have caused accelerated plant growth and eutrophication. At the same time, the zooplankton and benthic fauna are impacted by growing numbers of hungry perch, sprat and herring. These, in turn, are thriving well because their predators, including larger fish, seals, harbour porpoises and white-tailed eagles (at level four), have been reduced owing to human pressures. Although the abundance of seals has increased in northern parts of the Baltic Sea, the status of the populations of marine mammals is still poor in most of the Baltic Sea south of the Gulf of Bothnia.

Food-web models suggest that the co-occurrence of a weakened predation pressure by fewer mammals and large fish and increased primary productivity at level one have caused a complex series of changes in the Baltic Sea. As many as three regime shifts seem to have occurred in the Baltic Sea during the 20th century (Österblom et al. 2007). Although some of the observed changes are considered to have been influenced by climatic variation, reduced top predation pressure and excessive nutrient loading are likely to be the other causative factors (Möllmann et al. 2007).

The first of the three changes in the Baltic food-web structure took place in the early 20th century, when increasing cod populations signalled the decline of seal and harbour porpoise populations due to hunting. The second change in the food-web structure was caused by increased nutrient loading from the catchment area, which led to an increased productivity in the sea. The development of a large-scale fishing industry in the Baltic in the latter half of the 20th century caused the third change in the food-web structure (**Fig. 2.12**), leading to prospering prey fish populations. During this shift, the cod population plunged and decreased sevenfold, while the sprat population benefited and multiplied eightfold (**Fig. 2.9**).

The cascading effects of decreased predation and increased resources may also bring about eutrophication effects, including blooms of blue-green algae and nuisance short-lived macroalgae (Vos et al. 2004, Heck and Valentine 2007). Support for such a scenario has been recently found in the Baltic marine environment (Casini et al. 2008). The changes in the food-web structure have mainly been seen in the pelagic areas of the Baltic Sea, but increasing evidence shows that similar phenomena can also be observed in the coastal areas (Korpinen 2008, Eriksson et al. 2009).

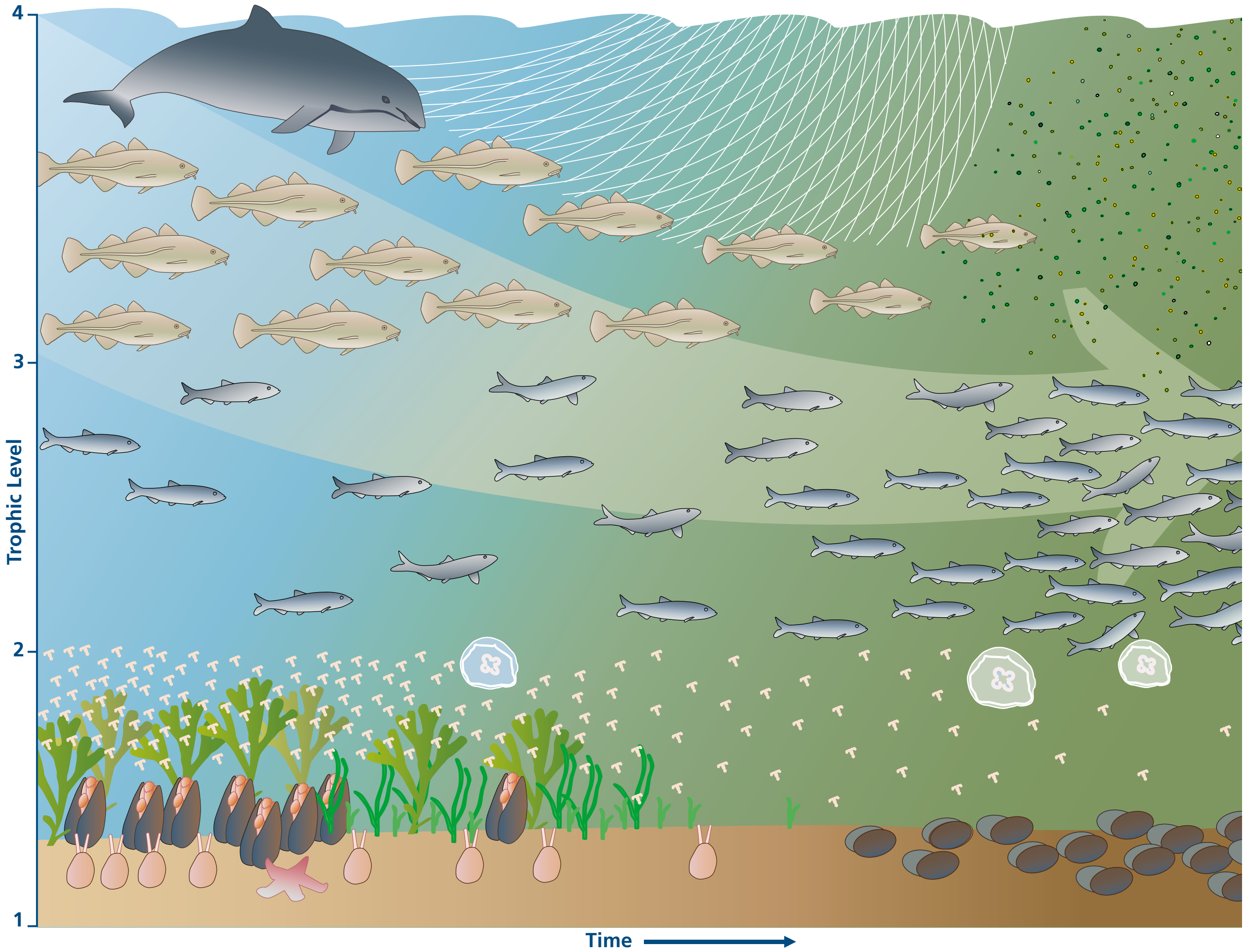
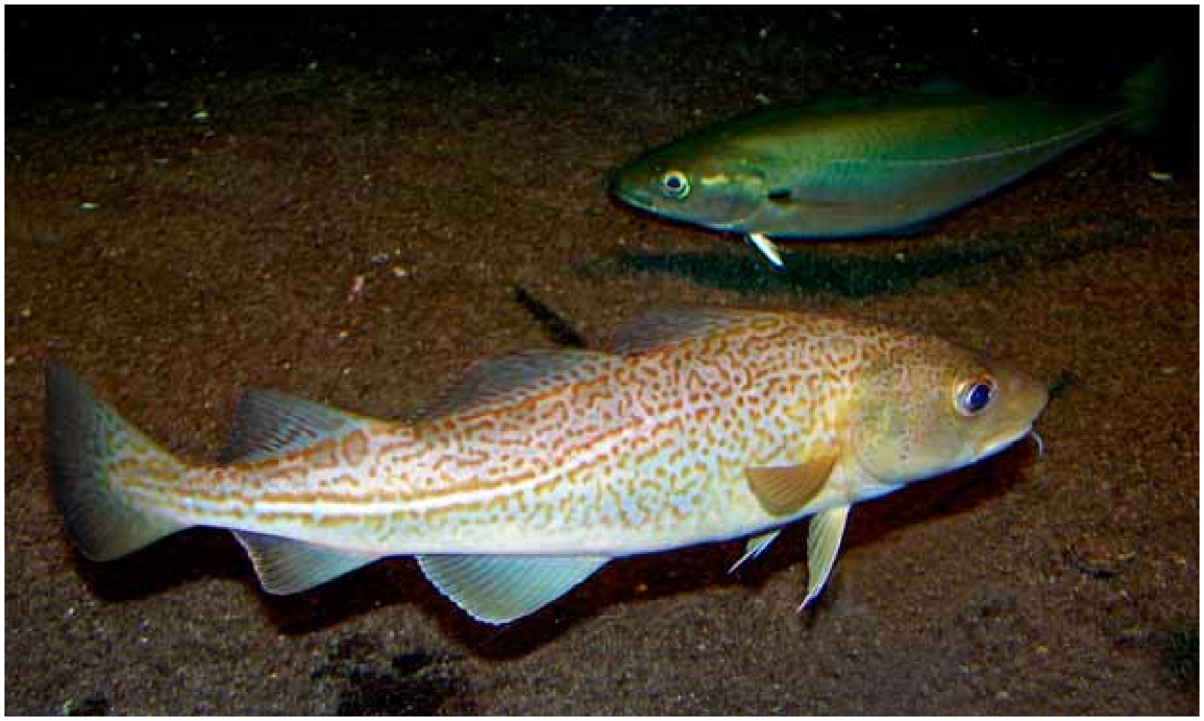
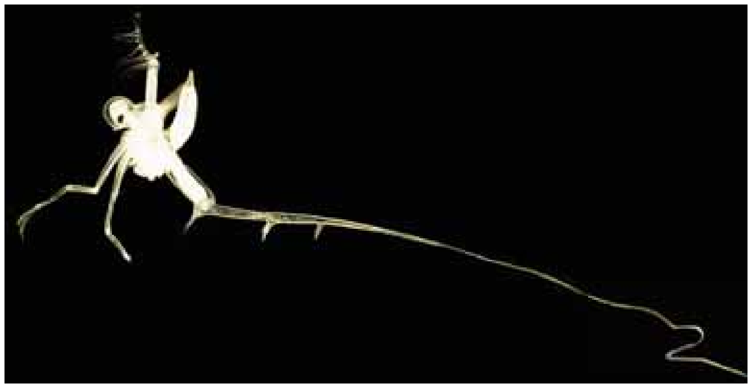


Figure 2.12 Changes in food-web structure due to overfishing and eutrophication in the Baltic Sea. Adapted from Watson and Pauly (2001).



The consequences of increased resource availability and decreased top-down control not only cause altered population abundances, but also changes in species composition and size spectra. The cascading effects of cod predation have been suggested to cause changes in the zooplankton species composition, leading to reduced growth of the Baltic herring (Rönkkönen et al. 2004). The side effects of eutrophication such as reduced water clarity and increased sedimentation of organic matter have benefited some algal species while perennial species such as bladderwrack have declined; this has caused changes in the invertebrate community (Korpinen and Jormalainen 2008). In coastal bays and lagoons, a similar shift from macrophyte dominance to phytoplankton dominance has occurred (Dahlgren and Kautsky 2004).



There are promising signs that the abundance of top predators is increasing in the Baltic Sea. The recovery of seals and predatory birds from hunting and contamination pressures has increased their population sizes during recent decades. The high fishing pressure on cod has been reduced to a sustainable level with the EU long-term management plan for cod (Anon. 2007b) which is expected to further enhance the cod stocks in near future.

For environmental managers, it is important to note that changes in the Baltic food web are caused by forces coming from two directions: from the top and from the bottom. Accordingly, the Baltic Sea food web can only be restored by addressing both forces: by allowing the top levels of the food chains to recover and by reducing the inputs of excessive nutrients that stimulate the lowest level. The mere reduction of nutrient loading will not suffice to restore the food-web structure—an increased abundance of top predators is also needed.

Numbers of alien species in the Baltic Sea basins with moderate or strong impacts

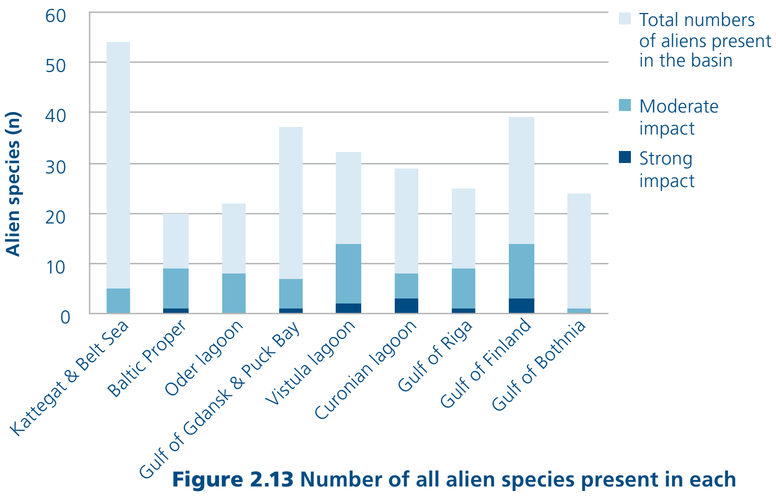


Figure 2.13 Number of all alien species present in each of the Baltic Sea basins and proportion of the species which have shown moderate or strong impacts (Biopollution) on native communities, habitats, and ecosystems (BINPAS Database System 2010).

Alien species

Alien species may be a threat to biodiversity in certain Baltic Sea areas. Although many of the species have not been shown to be harmful, some of the species have caused harm to the Baltic Sea biodiversity. Approximately 120 alien species have been recorded in the Baltic area since the early 1800s, and around 80 of them have become more or less established in some areas. The biological immigrants may influence their new environment and thus alter the Baltic biodiversity, habitats, communities and ecosystem functioning. The degree to which non-native species change the Baltic marine environment depends on their invasiveness.

Non-indigenous species may destabilize existing ecological relationships and in the worst cases may have serious consequences on the local food web (Oguz and Gilbert 2007). Although some superior competitors and predators, for example, the American mink (*Muscula vison*), fish hook water flea (*Cercopagis pengoi*) and American comb-jelly (*Mnemiopsis leidyi*), have found their way to the Baltic Sea, there has not yet been any wide-scale economic or ecological catastrophe following the invasion of a non-indigenous species. However, in some estuarine and coastal areas, non-indigenous species have replaced native species; this is the case with the round goby, *Neogobius melanostomus*, which now dominates the shallow-water zone of the Gulf of Gdansk.

In the most heavily invaded coastal lagoons of the southern Baltic, several food chains and even major parts of sea bottom communities may be based on introduced species (Leppäkoski et al. 2002). Such species include the mollusc *Dreissena polymorpha*, the colonial hydroid *Cordylophora caspia*, three species of the polychaete *Marenzelleria*, the barnacle *Balanus improvisus* and some Ponto-Caspian gammarid species (Olenin and Leppäkoski 1999). The littoral crustacean *Gammarus tigrinus* has become the dominant amphipod species in certain habitats of the northern Baltic Sea (Packalen et al. 2008, Orav-Kotta et al. 2009), although the northern Baltic Sea has so far avoided large changes caused by alien species (BINPAS Database system 2010).

As the first step to an assessment of the alien species in the Baltic Sea area, the actual impacts of alien species in selected ecosystems of the Baltic Sea have been assessed using the Biopollution Index (Olenin et al. 2007, BINPAS Database System 2010). This has been done using the known impacts and abundance estimates to rank the overall impacts on native communities, habitats, and ecosystems on a scale from ‘no impacts’ to ‘massive impacts’. The proportion of alien species in each of the Baltic Sea sub-basins showing moderate or strong impacts is given in **Figure 2.13** (BINPAS Database System 2010).

The Biopollution Index should be considered an example of an approach towards the assessment of alien species based on expert opinion concerning the actual impact of alien species in a specific location or ecosystem. This is a limitation for the practical use of the Biopollution Index approach for management purposes, as this specific knowledge generally needs intense special long-term research in all locations of concern, including port areas, and this is currently lacking for most parts of the Baltic Sea. The Biopollution Index regards all alien species as potentially harmful, although in several countries alien species are assessed as problematic only if they are invasive, i.e., take over ecological functions of native species and replace them. There are also practical differences among countries regarding the monitoring and classification of alien species in the Baltic marine environment. From a practical point of view, the ‘pressure caused by alien species’ is irreversible and thus they should not be considered a pressure similar to other anthropogenic pressures. The only management option is to restrict their further introductions to the region and assess the effectiveness of these measures. The Biopollution Index needs to be elaborated further taking into account the current assessment philosophy according to the WFD and ongoing processes under the Marine Strategy Framework Directive regarding the development of criteria for the descriptor on non-indigenous species.

Alternative approaches to the assessment of aquatic alien species in European inland and coastal waters have recently been developed based on concepts of ‘biological contamination’ (Arbaciauskas et al. 2008, MacNeil et al. 2010) and ‘biological pollution risk’ (Panov et al. 2009). These approaches are also practical and have been tested in many European inland water ecosystems.

Chapter 3: What are the causes?

Anthropogenic loads of nitrogen, phosphorus, organic matter and hazardous substances create a great pressure on the marine environment.

Commercial fishing is a strong and widespread pressure which has a large impact on the Baltic biodiversity.

Disturbance of the seabed by construction, dredging and disposal of dredged material creates large impacts on local environments, whereas bottom trawling affects large areas of the sea.

The cumulative impact of human activities is large in all areas except open-sea areas of the Gulf of Bothnia.

Coastal areas are mainly affected by point-source pollution and open-sea areas by fishing, riverine pollution and atmospheric nitrogen deposition.

The poor environmental status of the Baltic ecosystem is caused by the manner and the intensity with which we use the Baltic Sea and its marine resources, and allow nutrients and hazardous substances to enter the environment from land and at sea. Wherever we are within the vast catchment area of the Baltic Sea, whatever we do on land or at sea, most of our activities create pressures on—and change—the sensitive marine ecosystem.

Out at sea, we accept all the turbulence, pollution and noise accruing from all our busy activities: trawling the bottom for fish, mussels and other creatures, straining the waters for fish, navigating as many as two thousand ships across the waters at any one time, laying cables for communications and pipelines for oil and gas on the sea floor and wind farm foundations for harvesting wind energy.

The dozens of rivers that discharge into the Baltic Sea bring amounts of freshwater more than twice as large as the Niagara Falls every second. The river water arriving at the coast has travelled as far as 1000 kilometres partly underground, partly through lakes, along creeks, ditches, canals and rivers, draining a land area belonging to 14 countries. The water is an attestation to our environmental performance: it carries all the nutrients and hazardous substances released by 85 million people making their living in the catchment area and indulging in daily activities like personal hygiene, washing, heating their houses, driving their cars, fertilizing their farmlands, breeding livestock and running industrial plants.

In addition to the water, the air carries a significant fraction of nutrients and hazardous substances that are deposited onto the Baltic Sea. The air is capable of long-range transport and much of the pollution ending up in the Baltic Sea originates in distant countries outside the Baltic Sea catchment area.

Whether from sea or from land, all the pressures impact and alter the Baltic marine ecosystem in various ways. Chemical elements and compounds are discharged unceasingly, water currents are diverted, keystone species pivotal to the ecosystem are taken away, and nursery grounds of fish are razed to the ground by bottom-trawls.

3.1 Specific pressures and their drivers

The only way to relieve the Baltic from unnecessary stress is to identify and address all the individual pressures. This chapter identifies the various pressures and visualizes their status between 2003 and 2007. They are termed and classified in line with Annex III, Table 2 of the EU Marine Strategy Framework Directive (Anon. 2008a). Whilst some maps of spatial distribution of human activities are shown in this section, all the maps used to assess the anthropogenic pressures are presented in a separate background report (HELCOM 2010b). It is acknowledged that climate change adds further pressure to the Baltic Sea ecosystem and is also likely to exacerbate existing pressures such as inputs of waterborne nutrients. In this assessment, however, climate change has not been assessed as a separate anthropogenic pressure because its management requires global initiatives that are beyond the capacity of a regional organization such as HELCOM.

3.1.1 Physical loss of the seabed

The seabed is a complex and important part of the Baltic ecosystem, delivering valuable goods and services. One of the greatest concerns in the Baltic, the decline of biodiversity and abundance of species, is directly linked to the physical covering of the seabed and the associated destruction of the natural habitats. Physical loss or covering of the seabed, as considered here, differs from physical damage to the seabed (**Section 3.1.2**) in that it is considered to be permanent or long-lasting, while damage is related to an activity, whether one-off or continuous, that results in a degraded environmental state.

Natural seabed habitats are locally destroyed when constructions seal the sea floor or are altered, e.g., when sediments are dumped onto the sea floor smothering the benthic communities (Powilleit et al. 2006). This occurs at disposal sites of dredged material, when beaches are replenished with new sand, or the seabed is plowed during construction work for wind farms, cables, bridges, or pipelines. Scientific investigations have shown that the species composition at a smothered site is altered by favouring opportunistic species for the next two years (Harvey et al. 1998, Boyd et al. 2000, Martin et al. 2005). Beach replenishment is a common activity in southern Baltic coastal areas, whereas it is rarely or never practiced in northern areas of the Baltic Sea. In contrast, disposal of dredged material is an activity which is widely distributed across the Baltic Sea (**Fig. 3.1**). Disposal sites occur near large harbour projects but also further out at sea. Most Baltic countries dispose of their dredged material at selected sites where special features hinder the dumped material from spreading to larger areas (**Fig. 3.1**). However, the local hydrographic conditions also affect the recovery time of the site.

Harbours, offshore wind farms, cables, bridges, coastal dams, coastal defense structures and oil platforms are distributed along the coasts of the Baltic

Sea, especially on the southwestern shores (**Fig. 3.2)**. They cover the sea floor and have replaced the local habitats. During the assessment period, there were nine offshore wind farms, two oil rigs, 420 harbours, approximately 60 bridges over marine areas, several hundred kilometres of underwater cables and 214 km of coastal defense structures.

In the next few years, additional sea floor areas in the Baltic are likely to be disturbed. Increasingly, sea areas are being reserved for more wind farms, underwater pipelines, data and electricity cables as well as the enlargement of municipalities, harbours, platforms, coastal erosion defense structures, piers and bridges at sea. Whilst the sealing structures destroy natural habitats, they also create new artificial habitats.

3.1.2 Physical damage to the seabed

Physical damage to the seabed constitutes one of the major pressures on the Baltic marine environment (Jones 1992, Jennings et al. 2001). It is caused by the exploitation of mineral resources, dredging, disposal of dredged material, bottom trawling, constructions on the seabed, and coastal shipping.

As land becomes increasingly crowded and more expensive, and mineral resources on land become exhausted, the seabed becomes an attractive alternative and is increasingly being damaged.

The seabed is damaged by different types of activities causing pressures, including abrasion, siltation and selective extraction of mineral resources like sand and gravel. All three types of pressures change the sediment structure and damage the bottom-dwelling communities. When the seabed is left to recover, it should eventually restabilize and at a later stage be able to support a functional community again.

Siltation

Tiny particles of organic or inorganic matter along with all their nutrients and hazardous substances suspended in the water column will eventually sink down and cover the sea floor. In the Baltic, siltation of hard bottoms leads to the disappearance of a biotope which is essential for the attachment and growth of sessile animals and algae. Generally, silted-over biotopes have altered or impaired ecological functions, such as impaired recruitment of larvae and spores, choking of filter-feeding animals and reduced light for photosynthesis, with associated changes at the community and species level (Morton 1996, Eriksson and Johansson 2005). Various activities including dredging, construction, disposal of dredged material, bottom trawling and extraction as well as ship-

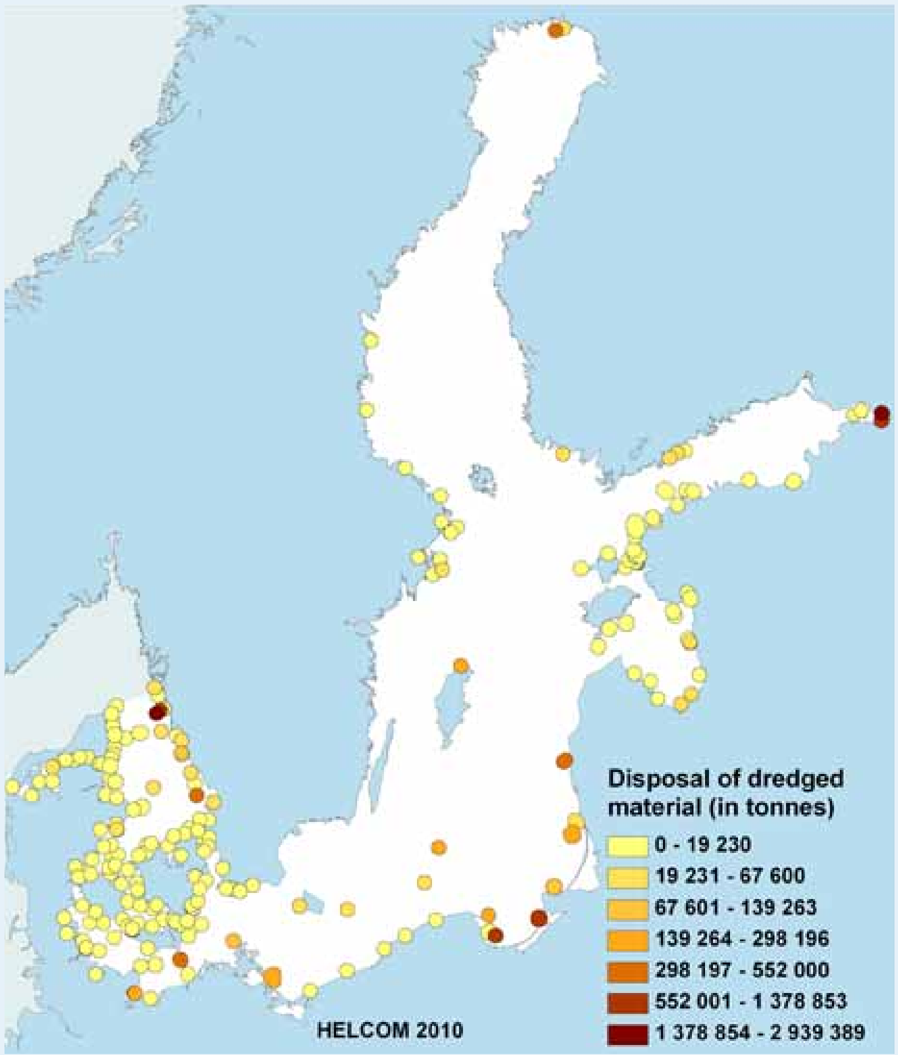


Figure 3.1 **Sites for the disposal of dredged material in 2003–2007, showing the maximum annual amount dumped. The sites have been artificially enlarged to increase their visibility. Data source: HELCOM.**

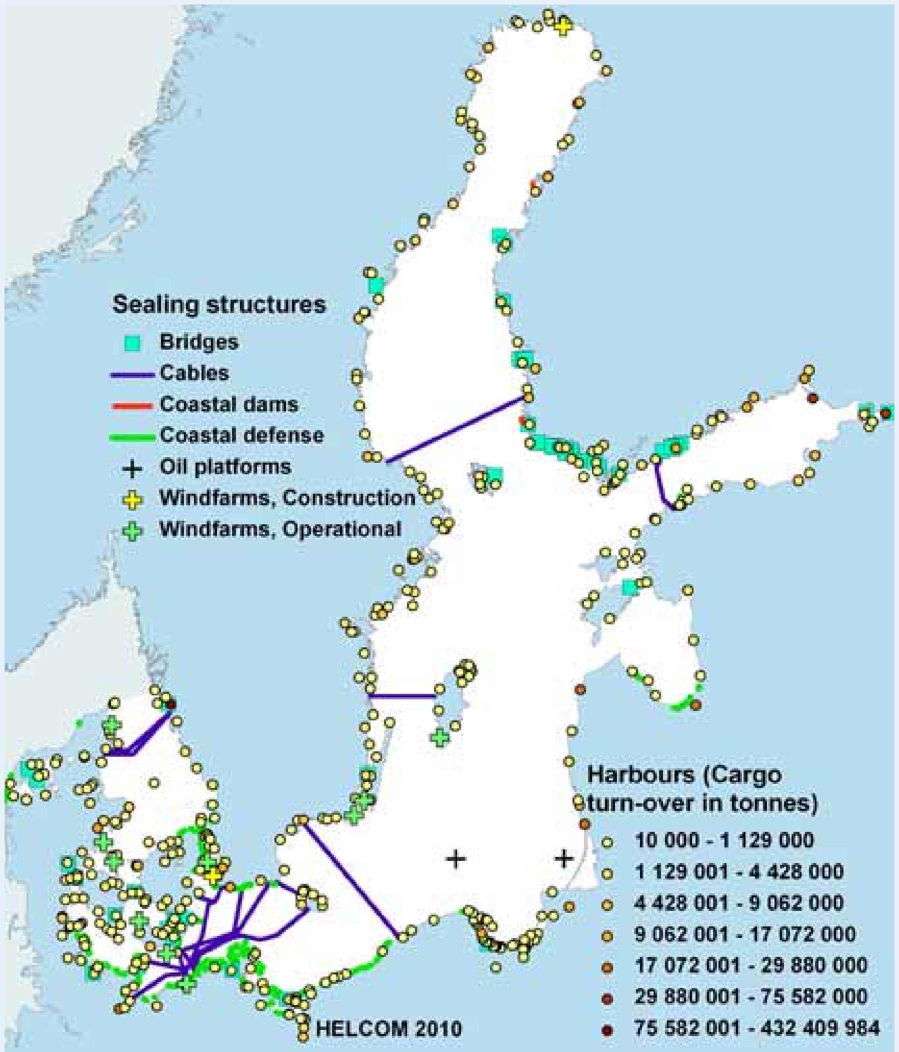


Figure 3.2 **Structures sealing marine biotopes: harbours, bridges, coastal dams, oil platforms, cables and pipelines, coastal defense structures and wind farms. Data sources: Baltic Port Barometer (2009), HELCOM, EEA, EWA.**

ping in shallow coastal waters raise soft mineral and organic particles from the bottom, clouding the water (e.g., Riemann and Hoffman 1991).

Abrasion

Extraction of minerals, dredging, and bottom trawling are the main activities causing the abrasion of the seabed. All nine coastal countries dredge virgin seabed and maintain formerly dredged areas, e.g., harbours and sea lanes (**Fig. 3.3**). This assessment does not cover small-scale dredging—mostly performed by households or neighbourhoods—even though they, too, may have harmful local impacts on the marine environment.

Bottom trawling by fishing vessels razes the seabed along aisles several hundred metres long, trailing wide sediment plumes (Riemann and Hoffmann 1991, Duplisea et al. 2002) and changing the physical and biological characteristics of the seabed (Rosenberg et al. 2003). The impacts depend on the trawling intensity. The highest intensity bottom trawling degrades the status of the seabed for several years (Jennings et al. 2001). This assessment showed that bottom trawling in the Baltic Sea is heavily concentrated in southern sea areas, particularly in the Kattegat, but some bottom trawling also occurs in the Northern Baltic Proper and the Gulf of Bothnia (**Fig. 3.4**). Fish catches and by-catch in the bottom-trawl fishery are presented in **Section 3.1.8**.

Targeted extraction of minerals

Unlike dredging, mineral extraction is targeted at specific seabed types, such as sand or gravel bottoms. The Baltic Sea mineral resources have created an increasing interest in the seabed. However, the sand, gravel, boulder, shell gravel and maerl bottoms are habitats hosting rich animal and plant communities (HELCOM 1998). In the Baltic Sea, Denmark, Germany, Estonia, Poland and Finland have extracted sand or gravel from the seabed during the assessment period 2003–2007. In addition, shell gravel and maerl are extracted in the Kattegat. The spatial distribution of these activities is concentrated in the southwestern sea areas of the Baltic Sea, but activities are increasing in other sea areas as well (**Fig. 3.3**). These activities are of special concern because they may affect biotope types and habitats assessed as being threatened and/or declining in the Baltic Sea area such as reefs, gravel bottoms with Ophelia species and shell gravel bottoms (HELCOM 2007c).

3.1.3 Underwater noise

Underwater noise is currently the least understood pressure on the marine biodiversity in the Baltic Sea.

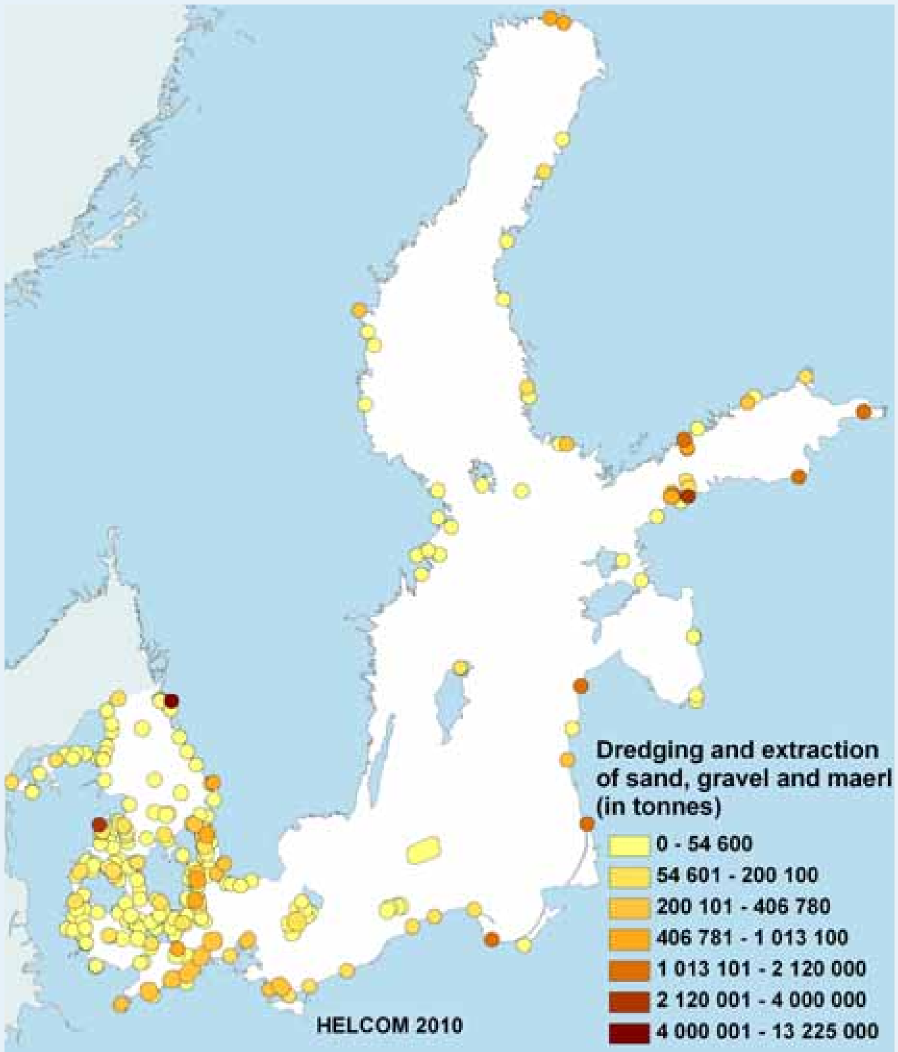


Figure 3.3 Extraction of sand, gravel and maerl and dredging in sea lanes, harbours and various construction projects. Data source: national reporting supplemented with data from private enterprises.

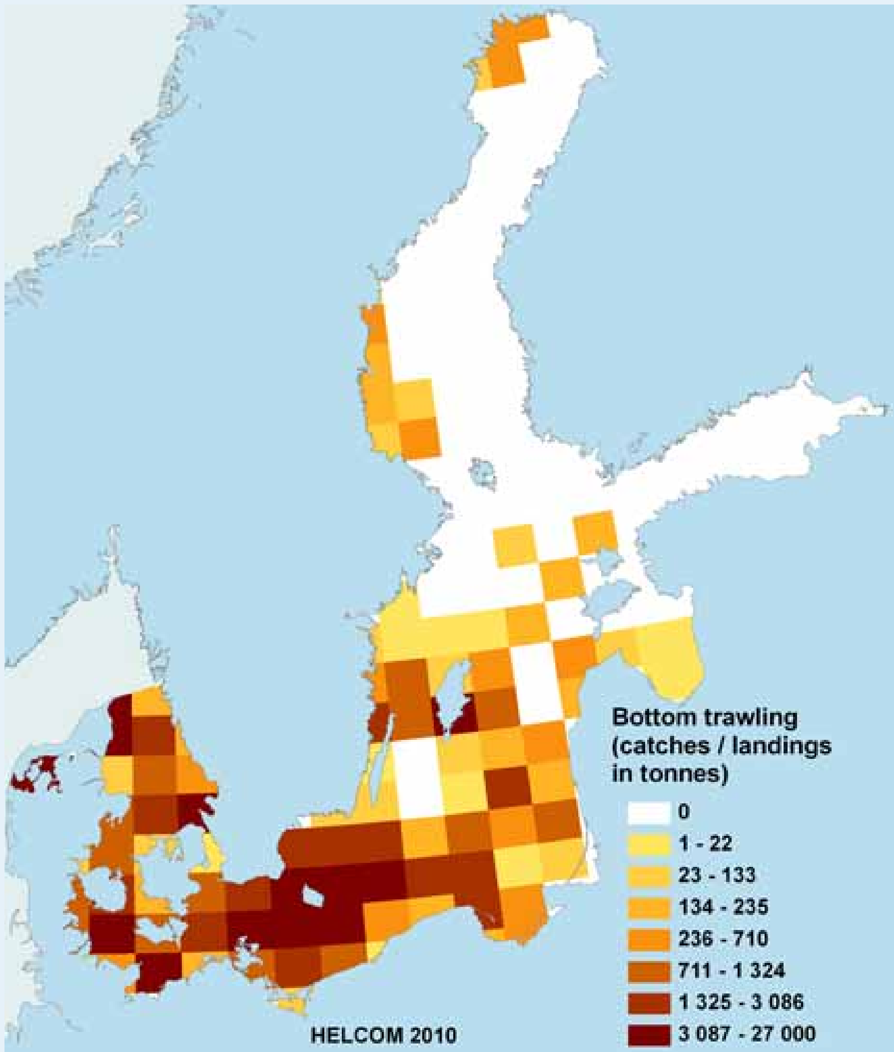


Figure 3.4 Bottom trawling catches/landings in the Baltic Sea. The figure presents all caught and reported fish species in ICES rectangles. Data sources: national fisheries authorities.

The main sources of underwater noise are commercial shipping, fishing, military activities, construction activities, seismic explorations, recreational boating and operational wind farms. The noise may propagate at long distances from known sources and, depending on intensity and frequency, may disturb marine mammals and fish. The current knowledge on underwater noise is comparatively poor and needs to be improved. Underwater noise mapping is strongly recommended.

In general, underwater noise of certain intensity and frequency has been documented to mask the communication of animal species such as harbour porpoise (Lucke et al. 2007), to cause increased stress hormone levels, e.g., in freshwater fish species (Wysocki et al. 2006) or even strandings of whales (Nowacek et al. 2007). Ships produce underwater noise in a wide frequency range (from sonar, motors, gears, resonation, etc.), which may even reach 200 dB. However, the high noise levels attenuate at less than 1 km distance from the ship (Thomsen et al. 2006, Ten Hallers-Tjabbes 2007).

Operational wind turbines are audible in the marine environment, but the sound pressure levels are low compared to levels of construction noise and even to background underwater noise. Construction work associated with impulsive noise has been found to repel marine mammals and fish (Nedwell et al. 2003). Theoretical and observational avoidance distances have been estimated for harbour porpoises, cod, seals and salmon as 7.4–15 km, 5.5 km, 2.0 km and 1.4 km, respectively (Nedwell et al. 2003, Tougaard et al. 2003). Behavioural responses can be detected for harbour porpoise up to 20 km away (Thomsen et al. 2006).

Most of the Baltic marine area is impacted at least by a level of noise that has been estimated to mask the communication of animals (**Fig. 3.5**). Noise levels causing an avoidance reaction in mobile organisms are likely to occur only in areas with construction works, such as the cable between Helsinki and Tallinn in the Gulf of Finland or in wind farm contruction sites, for example, in Kemi in the Bothnian Bay and Malmö in the Sound.

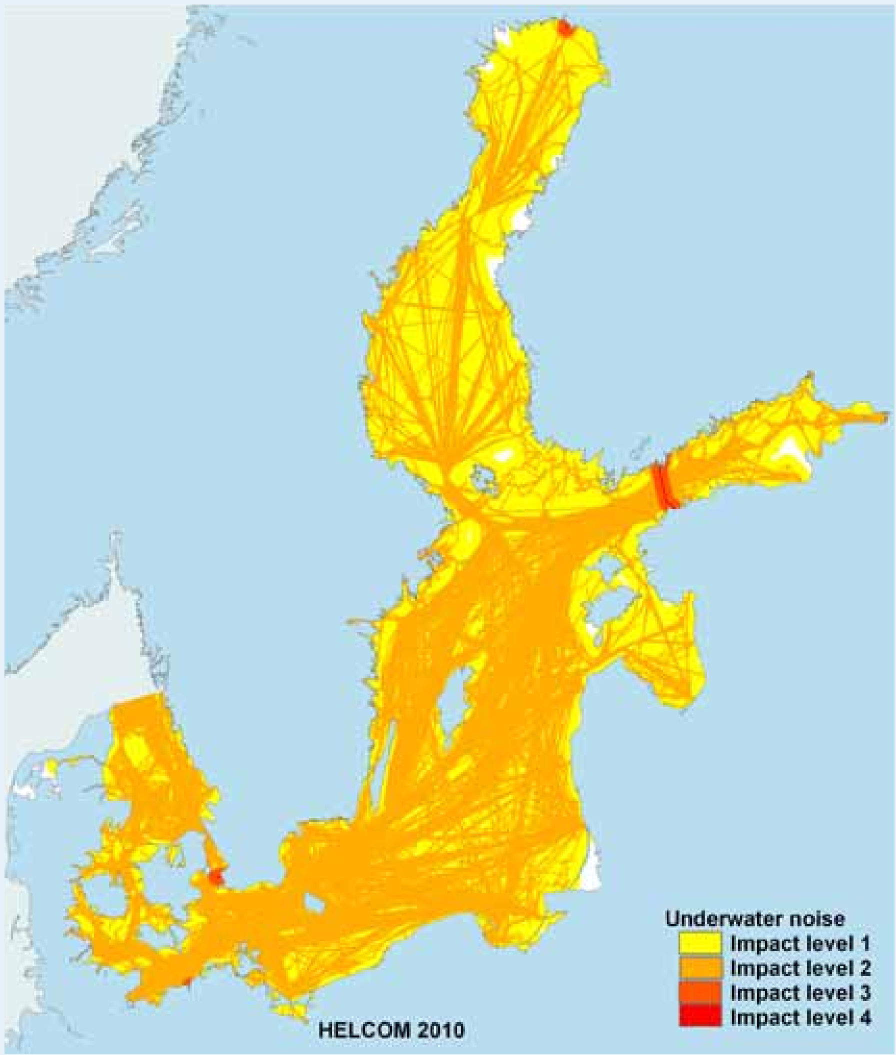


Figure 3.5 Distribution of underwater noise in the Baltic Sea during 2003–2007. Impact level 1 indicates that the noise is audible to biota; level 2 indicates that masking of communication occurs; level 3 indicates an avoidance reaction; level 4 indicates physiological impacts from construction work. Impact levels are based on studies on harbour porpoises, seals and cod (Thomsen et al. 2006). Data sources: shipping during six days in November 2008 (HELCOM), construction of wind farms and cables (see HELCOM 2010b) and operational wind farms (EWEA). Note that noise from construction work is temporary but from shipping it is almost continuous.

3.1.4 Marine litter

There are no comprehensive field studies on the extent of the marine litter problem in the Baltic Sea. Individual field surveys from coastal strips (HELCOM 2007d) or Swedish studies on microscopic plastic fibres and particles indicate that marine litter may pose a threat to marine life.

The macroscopic marine litter in the Baltic Sea originates from fishing, shipping, leisure boating, tourism, coastal urban areas and rivers. The coastal surveys have concentrated on medium-sized or large particles, which usually amount to fewer than 20 particles, but sometimes up to 700–1200 particles, per 100 metres of coastal strip (HELCOM 2007d).

Not all marine litter is visible to the human eye. Microscopic particles from various sources, e.g., degradation of plastic waste, disturb food webs by mimicking food particles, attaching to organisms' feeding appendices and causing famine to passive filter-feeders. Some hazardous substances adsorb onto the litter particles and may cause enhanced accumulation of hazardous substances in the food web. Studies in Swedish waters have shown that the amounts range from several hundred to a hundred thousand microscopic pieces in a cubic metre of seawater (Noren 2007, Noren et al. 2009). For unknown reasons, the largest micro-litter problem was found in the Gulf of Bothnia, whereas other basins had lower concentrations.

3.1.5 Interference with hydrological processes

Man has changed the water characteristics and flow in the Baltic by, among others, coastal defense structures, coastal power plants, dams and wastewater treatment plants. In addition, bridges and wind farms potentially also cause interference with the hydrological processes of the sea.

Coastal power plants and wastewater treatment plants are major local sources of inputs of warm and/or fresh water to the sea. The warm water outflow from a coastal nuclear power plant can be observed over an area reaching several kilometres from the coast and warm water in such an area is known to change local productivity and species composition significantly.

Coastal defense structures have been built onto or close to sandy coasts near urban settlements to protect the coastline from natural erosion and the settlements from flooding. The resultant changes in local hydrography have sometimes altered the coastal water currents and the transport of sand and fine-grained soil as well as possibly affected the drifting of larvae, spores and other reproductive propagules of marine organisms (Martin et al. 2005). Such human interventions occur mainly in the southern parts of the Baltic Sea, where sandy shores are prevalent and coastlines have no sheltering islands (**Fig. 3.2**).

3.1.6 Contamination by hazardous substances

Hazardous substances exhibit disturbing characteristics including persistence, the ability to accumulate in organisms such as predator species (bioaccumulation), and toxic effects. Compounds featuring all three traits are labelled PBT-compounds (Persistent, Bioaccumulating and Toxic). Hazardous substances can be man-made, such as most of the chemical compounds termed 'Persistent Organic Pollutants' ('POPs') or occur naturally, such as heavy metals. In addition to POPs and heavy metals, radioactive substances have been included in hazardous substances in this assessment.

Most POPs are produced by man either deliberately or are created as by-products of other processes. A few of these hazardous compounds, including dioxins and polycyclic aromatic hydrocarbons, also originate from natural combustion processes.

Input estimates of POPs from atmospheric deposition are available for only a few substances, such as dioxins and furans (**Fig. 3.6**). Their deposition is greater in the southern parts of the Baltic Sea and on the eastern coastal areas. Substances deposited from the atmosphere originate from land-based emission sources both in the Baltic Sea catchment area and further away outside the catchment. Distant sources outside the Baltic catchment have been estimated to account for about 60% of the dioxins deposited onto the Baltic Sea (Bartnicki et al. 2008). There are no known estimates of waterborne inputs from land-based sources.

The sediments of river estuaries and deep accumulation areas that have accumulated particulate-borne contaminants over many decades are secondary sources of PCBs, DDT/DDE, alkylphenols, phthalates, dioxins and furans and other PBT-compounds. Harbours, shipyards, marinas and shipping lanes show very high concentrations of tributyltin (TBT), which was the main compound of anti-fouling paints until the ban on its use in 2008. Dredging operations, bottom trawling and the disposal of dredged material can reintroduce sediment-bound TBT and other POPs to the marine environment. The Helsinki Convention prohibits the disposal of contaminated dredged material in the sea without a specific permit and only when is carried out following common guidelines.

Leaking hydraulic oils and illegal and accidental oil spills from ships can contribute significantly to the input of hazardous substances to the Baltic Sea. No major shipping accident has occurred in the Baltic Sea since the "Fu Shan Hai" incident in 2003 which resulted in the release of 318 tonnes of fuel oil after 616 tonnes had been recovered from the sea. However, the shipping intensity in the Baltic Sea has increased enormously during recent years, and is predicted to increase even further. From 2000–2008, 61 accidents were reported to have occurred resulting in some pollution, ranging from 0.015 m^3 to 150 m^3 of oil (HELCOM 2009c). The number of deliberate, illegal oil discharges has been successfully reduced over the past twenty years, from 763 spills in

1989 to 210 spills in 2008 (HELCOM 2009d). The size of the spills has also been decreasing. The total estimated volume of oil spills in 2008 was 64.3 m^3.

There are around 2000 sizable ships at sea at any time in the Baltic. In 2008, vessels entered or left the Baltic Sea via the Kattegat 60 843 times, 18% more than in 2006 (HELCOM 2007e, 2009c). Of these, 20% were tankers, carrying as much as 170 million tonnes of oil (HELCOM 2009e). The export of Russian oil through Baltic ports is expected to reach 180 million tonnes in 2020; this will be facilitated by the construction and expansion of Russian oil terminals.

Metals and radionuclides are elements occurring naturally in the Baltic marine environment. The high current concentrations of heavy metals, however, are a result of human activities. This assessment illustrates the riverine waterborne input sources of lead, cadmium, mercury, nickel and zinc to the Baltic Sea (**Fig. 3.7**). Atmospheric deposition is another major source of heavy metal inputs to the Baltic Sea (**Fig. 3.8**) and almost half of the lead inputs and one quarter of mercury inputs to the Baltic Sea originated from atmospheric deposition (Knuuttila 2009, Gusev 2009). The total annual deposition of heavy metals has declined in the Baltic Sea catchment area from 1990 to 2006: by 45% for cadmium, 24% for mercury, and 66% for lead (Gusev 2009).

While the highest waterborne inputs of lead and cadmium flow into the Gulf of Finland and the Baltic Proper (**Fig. 3.9**), the waterborne input of mercury is ten times higher to the Baltic Proper than to any other basin in the Baltic Sea.

There are two radioactive isotopes, cesium-137 and strontium-90, in the Baltic Sea, which have clearly higher concentrations than the other isotopes. Cesium-137 was the main isotope released from the Chernobyl accident in 1986, whereas strontium-90 originates mainly from past nuclear weapon tests. Other minor sources of radionuclides are nuclear reactors in the Baltic Sea area and Western Europe, as well as research laboratories in the Baltic Sea catchment area. The radioactivity levels of both isotopes are low enough not to cause biological effects in the Baltic marine environment (HELCOM 2009f).

3.1.7 Nutrient and organic matter enrichment

Nutrients and organic matter entering the sea have a great impact on the Baltic Sea ecosystem. Excessive nutrients foster the growth of photosynthetic plants and algae leading to an unbalanced energy flow in the ecosystem. Over the years, excessive nutrient concentrations in the Baltic ecosystem have altered the

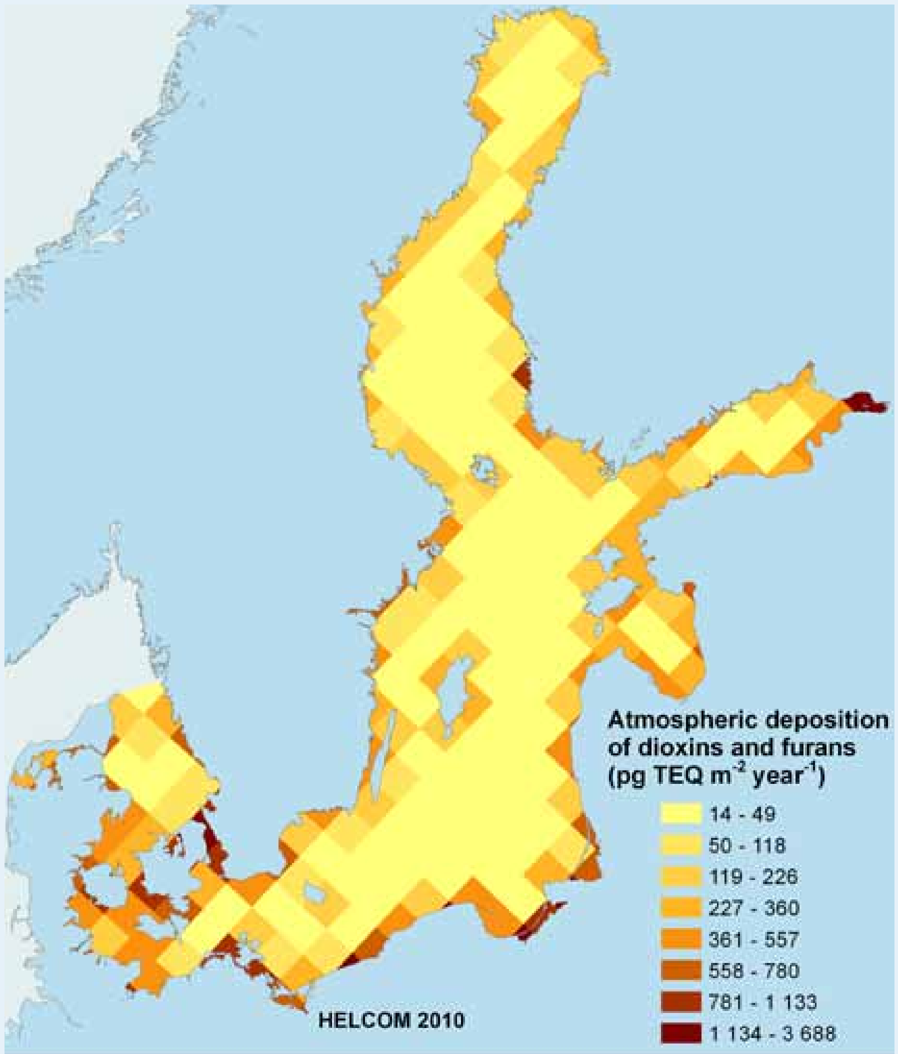


Figure 3.6 Inputs of dioxins and furans (pg Toxic Equivalent m^{-2} year^{-1}) from atmospheric deposition in 2006. Data source: EMEP (2009).

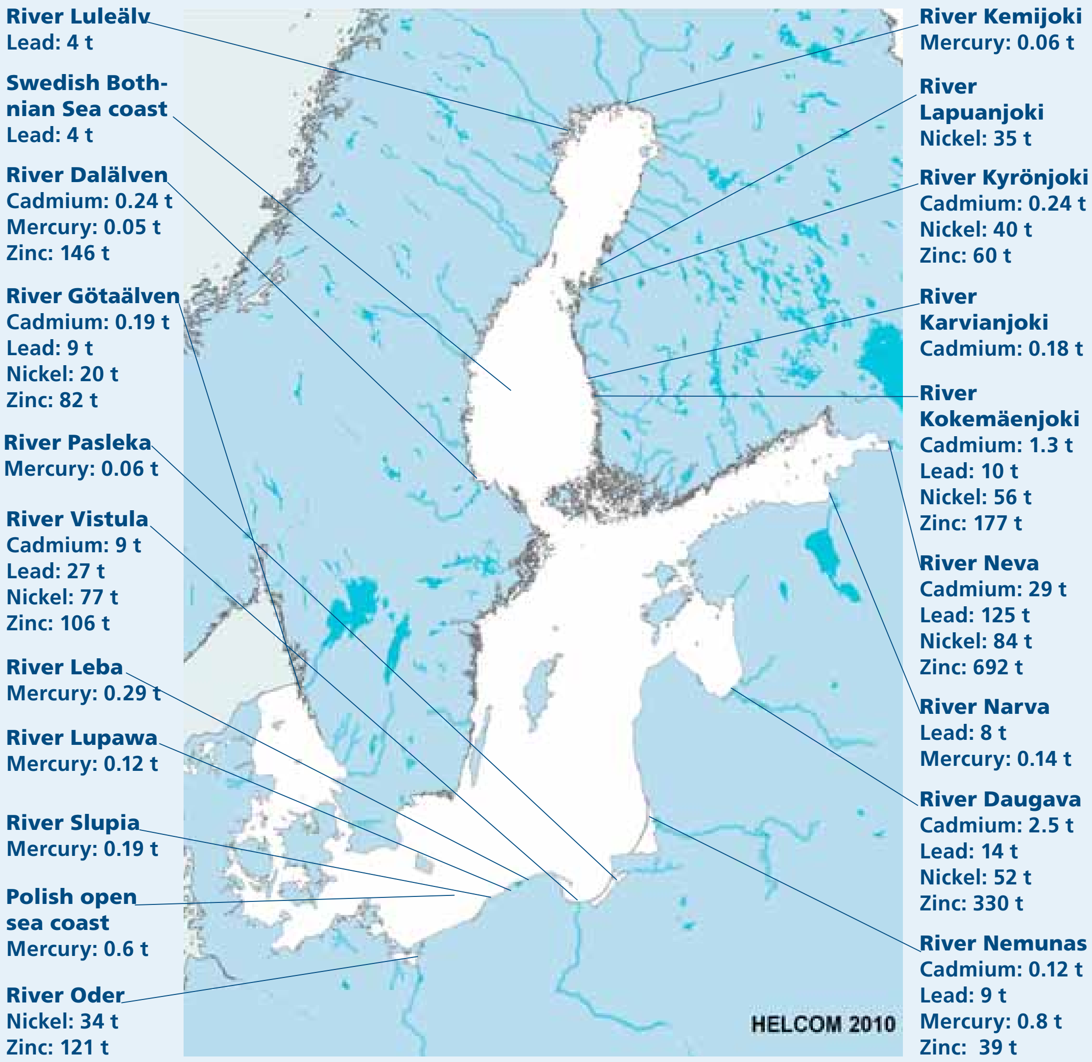


Figure 3.7 The most important riverine waterborne input sources of heavy metals to the Baltic Sea (2005–2007 average annual inputs). Data source: HELCOM PLC-5.

natural food-web structure, changed the species composition and disturbed the population dynamics.

Excess biomass sinks down to the seabed, introducing organic matter to the benthos and stimulating bacterial activities that lead to hypoxia and ultimately to anoxia, and suffocation of benthic organisms in the worst case.

Organic matter from land or from the sea may add to the eutrophication stress of the Baltic Sea. Although nutrients bound to particulate organic matter (e.g., humic substances) are often not readily available for photosynthetic growth, different processes such as photodegradation of humic substances driven by UV light liberate the nutrients over time. Moreover, organic matter is an important food source for bottom-dwelling organisms, but large quantities that lead to increased oxygen consumption and hypoxia reduce the number of sensitive bottom dwelling animals.

Inputs of nutrients to the sea

The main pathways of nutrient inputs to the Baltic Sea are presented in **Figure 3.10**.

Over the period 2001–2006, the average annual total waterborne nitrogen (N) inputs amounted to 641 000 t (635 700 t N in 2006, Knuuttila 2009). The largest amount of the total nitrogen input to the Baltic Sea originates in waterborne sources (about 75% of total N inputs, **Fig. 3.11, Panel A**, HELCOM 2009a). Atmospheric deposition of nitrogen to the sea accounts for about one quarter of the total inputs (**Fig. 3.11, Panel A,** HELCOM 2009a). About 40% of the total inputs originates from waterborne diffuse sources, primarily introduced by agriculture (approximately 80% of diffuse sources, HELCOM 2004) and about one tenth is discharged from point sources such as municipal wastewater treatment plants or industry (**Fig. 3.11, Panel A**). In addition, about one fifth of the total nitrogen input is from natural background losses and slightly less than one tenth is from transboundary sources, mainly in Belarus and Ukraine.

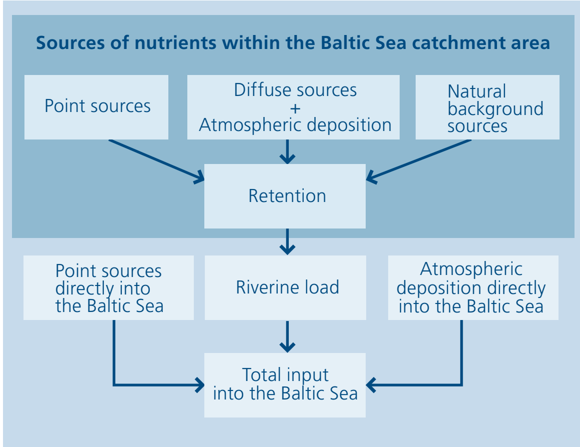


Figure 3.10 Conceptual model of nutrient input sources to the Baltic Sea.

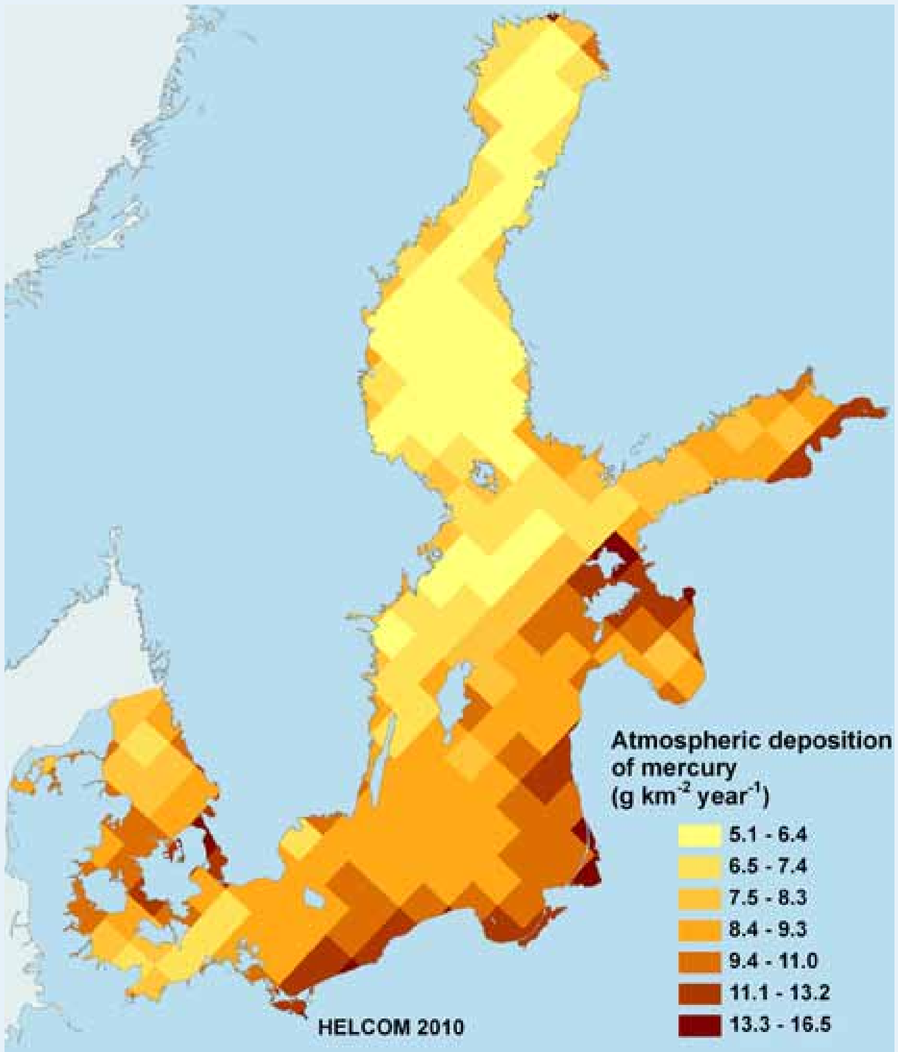


Figure 3.8 Atmospheric deposition of mercury (g km^{-2} year^{-1}) in 2006. Source: EMEP (2009).

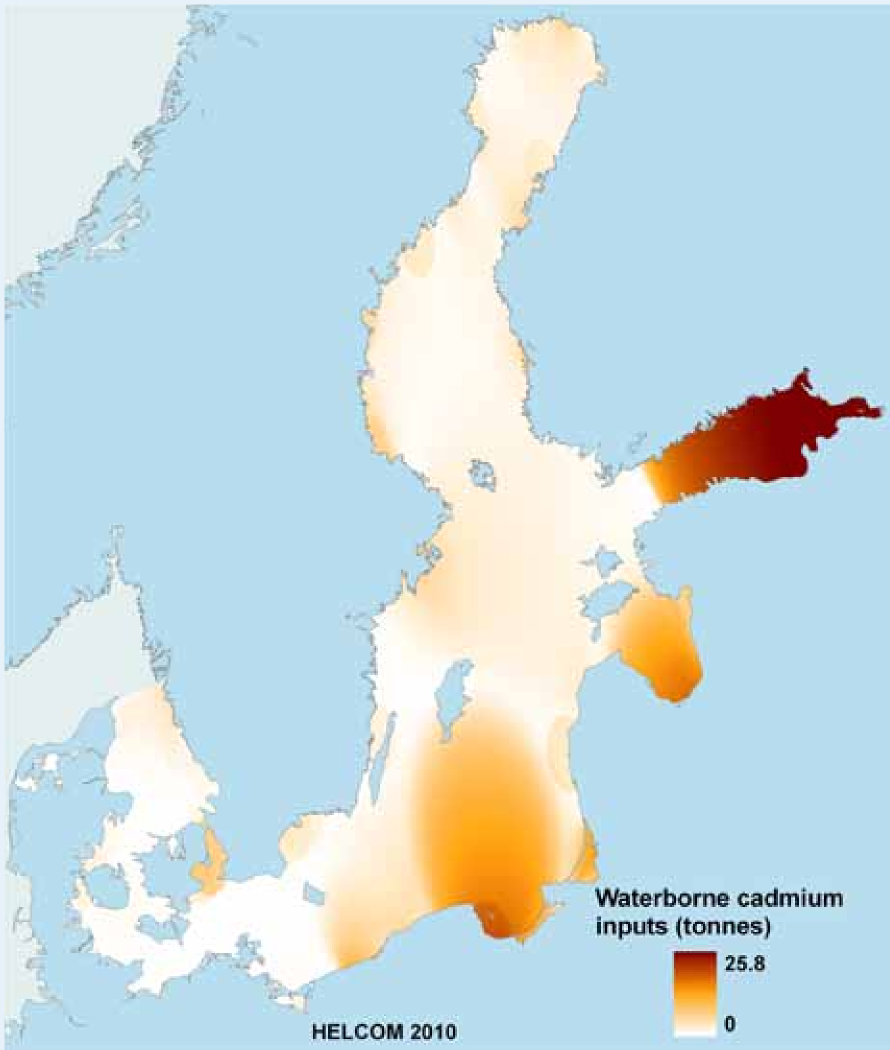


Figure 3.9 Waterborne inputs of cadmium (annual average for 2003–2006). The visualization of the distribution of the inputs to the sea area is based on a simple linear extrapolation of the inputs from point sources and river mouths towards the open sea. The input quantities refer to these sources. Data source: HELCOM PLC-5.

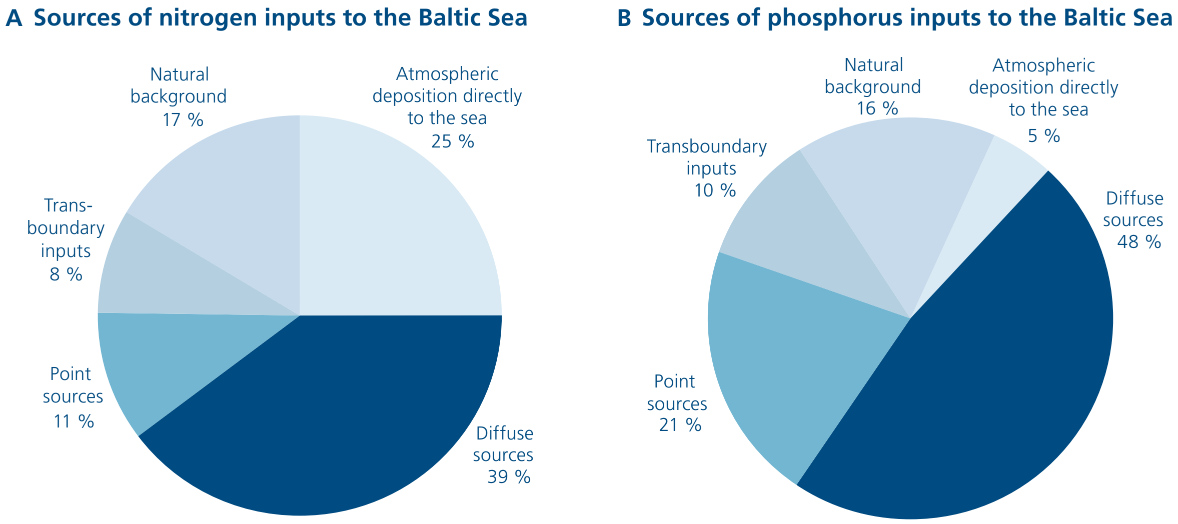
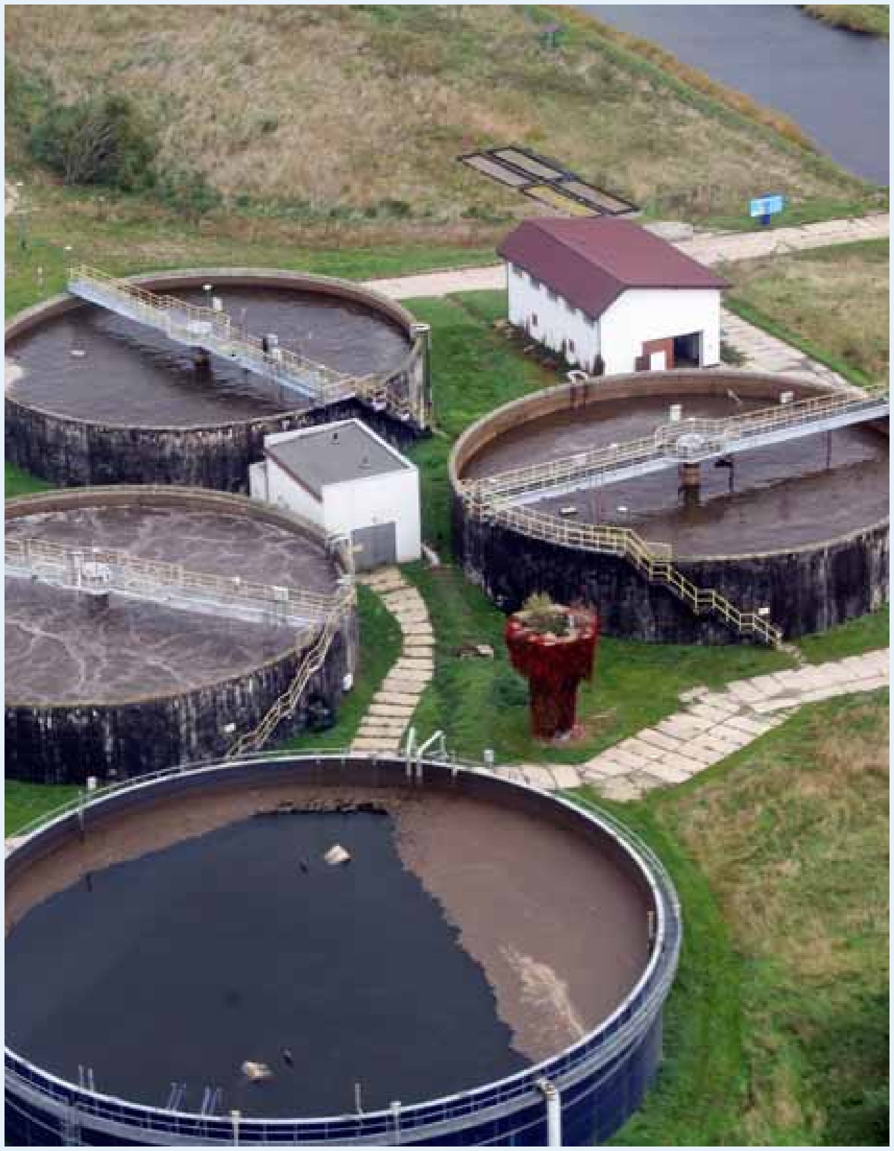


Figure 3.11 Proportions of different input sources of nitrogen (Panel A) and phosphorus (Panel B) to the Baltic Sea. Point sources include both coastal and inland point sources. Note that transboundary inputs have not been divided into point or diffuse sources. Data source: HELCOM PLC-5.

During 2001–2006, the average annual total waterborne phosphorus (P) inputs amounted to 30 200 t (HELCOM 2009a). In 2006, the P input amounted to 28 200 t (Knuuttila 2009). Most of the phosphorus input arrives as waterborne phosphorus because atmospheric deposition accounts for a maximum of 5% of the inputs. Total phosphorus inputs from point sources account for approximately one fifth of the total inputs and municipal wastewater treatment plants contribute about 90% of the point-source phosphorus inputs (**Fig. 3.11, Panel B**, HELCOM 2004 and 2009a). Diffuse waterborne sources are responsible for about one half of the total phosphorus inputs to the Baltic Sea, while agriculture is responsible for almost 80% of the waterborne diffuse input (**Fig. 3.11, Panel B**, HELCOM 2004). In addition, about 16% of the total phosphorus input is from natural background losses and about one tenth is from transboundary sources, mainly in Belarus and Ukraine.



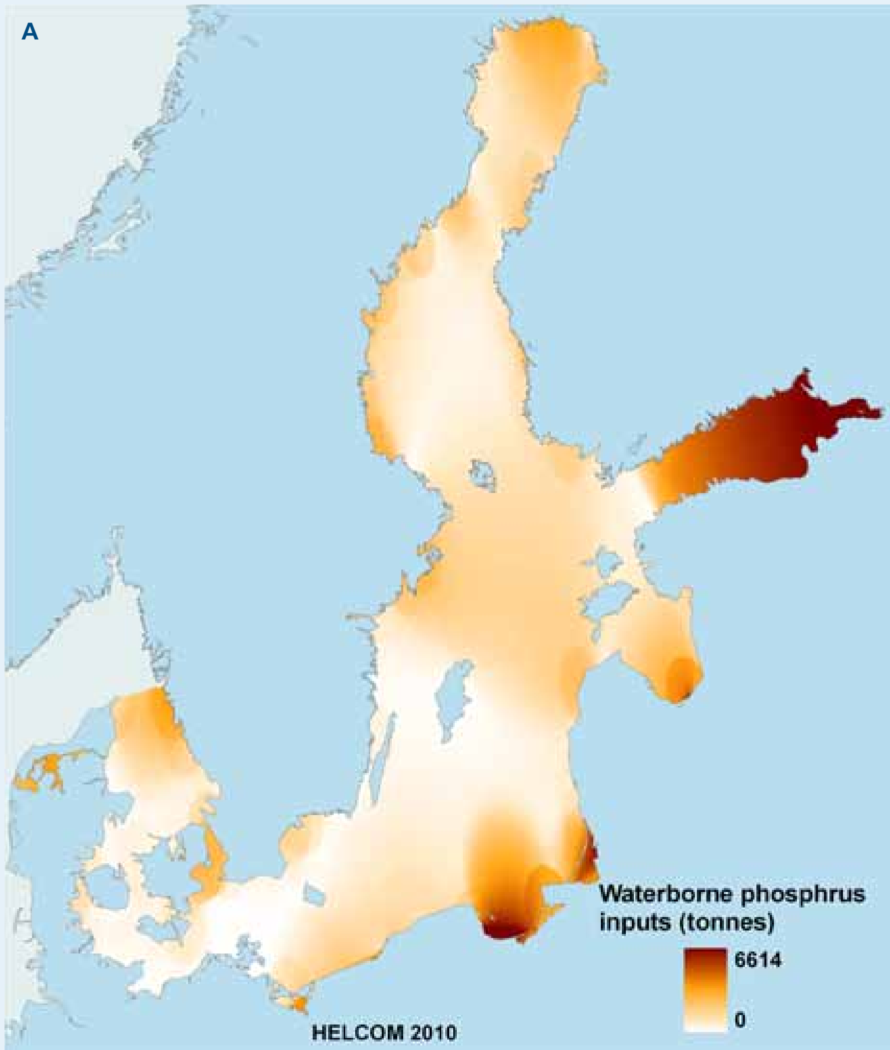


Figure 3.12 Average annual waterborne inputs of phosphorus (Panel A) and nitrogen (Panel B) from rivers and coastal point sources in 2006. The visualization of the distribution of the inputs to the sea area is based on a simple linear extrapolation of the

The five largest sources of phosphorus and nitrogen are the rivers Vistula, Neva, Oder, Daugava and Nemunas (**Fig. 3.12, Panel C**). Thus, the highest nutrient enrichment pressure is on the Baltic Proper, the Gulf of Finland and the Gulf of Riga. Natural background loading of nitrogen and phosphorus is high in the Bothnian Bay and Bothnian Sea (N: 40–70%, P: 40–90%), whereas in the Baltic Proper and in the southwestern sea areas its share is smaller (N: 15–25%, P: 15–25%) (HELCOM 2004).

Nutrient inputs to the Baltic Sea originating from sewage discharges from ships have been shown to be small, less than 1% of the total inputs of either nutrient (Hänninen and Sassi 2009). These nutrients may nevertheless have considerable effects on the growth of pelagic phytoplankton because the nutrients are discharged directly to the open-sea ecosystem.

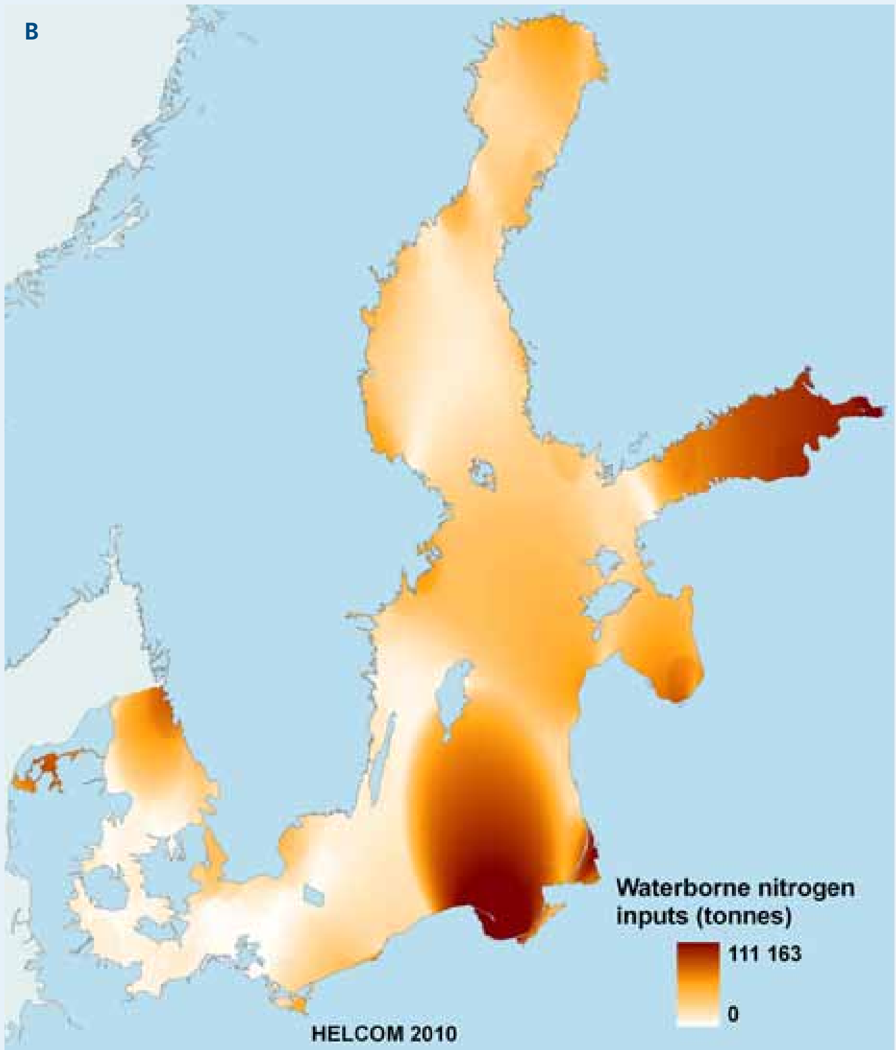
The atmospheric nitrogen deposited onto the Baltic Sea originates mainly from emissions in the catchment area (Germany 20%, Poland 13%, Denmark 8%, Sweden 6%), but the proportions from long-range transport and shipping in the Baltic Sea are also high (38% and 6% of total annual deposition, respectively) (**Fig. 3.13**, Bartnicki and Valiyaveetil 2009).

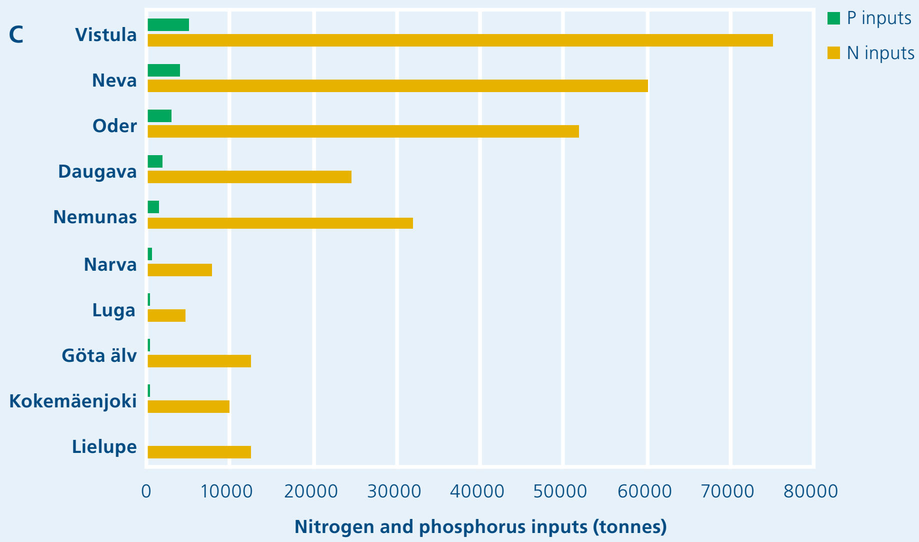
The waterborne inputs of nitrogen and phosphorus as well as the atmospheric deposition of nitrogen have declined since 1990 (**Fig. 3.14, Panels A to C**). During 1990–2000, the phosphorus inputs from direct point sources decreased by 68% and the nitrogen inputs by 60% (HELCOM 2009a). Overall, the total waterborne phosphorus input decreased by 45% between 1990 and 2006, while the waterborne nitrogen input decreased only by 30% during this period (**Fig. 3.14, Panels A, B**). This observed decrease is partly explained by the lower runoff in 2006. The atmospheric deposition of nitrogen has declined by about one third since 1980 and by 8% since 1995, but it increased during the assessment period 2003–2007 (Bartnicki 2009) (**Fig. 3.14, Panel C**).

Inputs of organic matter

Most of the organic matter delivered to the Baltic Sea is transported by rivers, most prominently by the rivers, Vistula, Neva, Oder, Daugava and Nemunas. Diffuse runoff from farms and farmlands as well as managed forests comprises most of the man-made inputs of organic matter from the catchment area. However, in some regions, such as the Bothnian Bay, the natural background input is high (HELCOM 2004).

The extent of the inputs depends on the natural characteristics, e.g., density of wetlands or mires, land-use patterns in the catchment area and the strength of





inputs from point sources and river mouths towards the open sea. The input quantities refer to these sources. Panel C: The ten largest input sources of nitrogen and phosphorus from rivers based on average annual inputs (tonnes). Data source: HELCOM PLC-5.

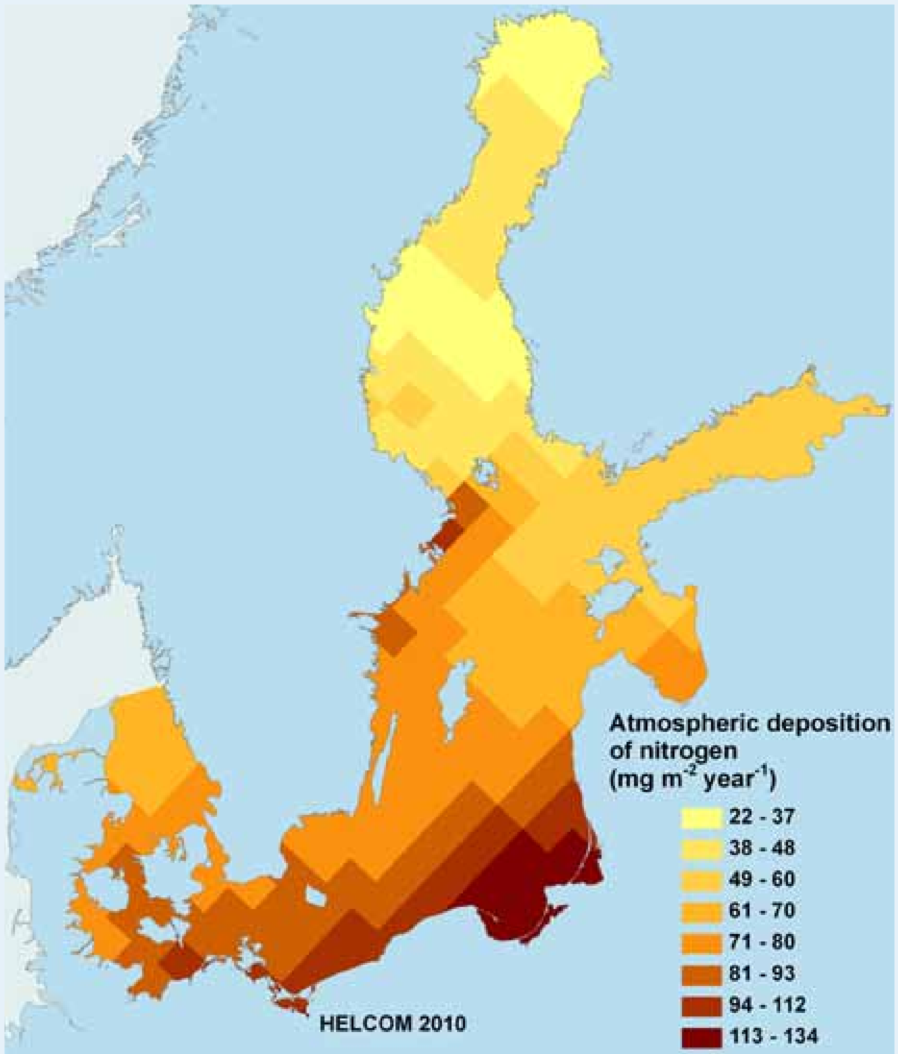


Figure 3.13 Deposition of nitrogen onto the Baltic Sea in 2006. The nitrogen deposition has not been included in the Baltic Sea Impact Index in the Bothnian Bay, because it is not considered a pressure in that area where primary production is strictly phosphorus limited. Data source: EMEP (2009).

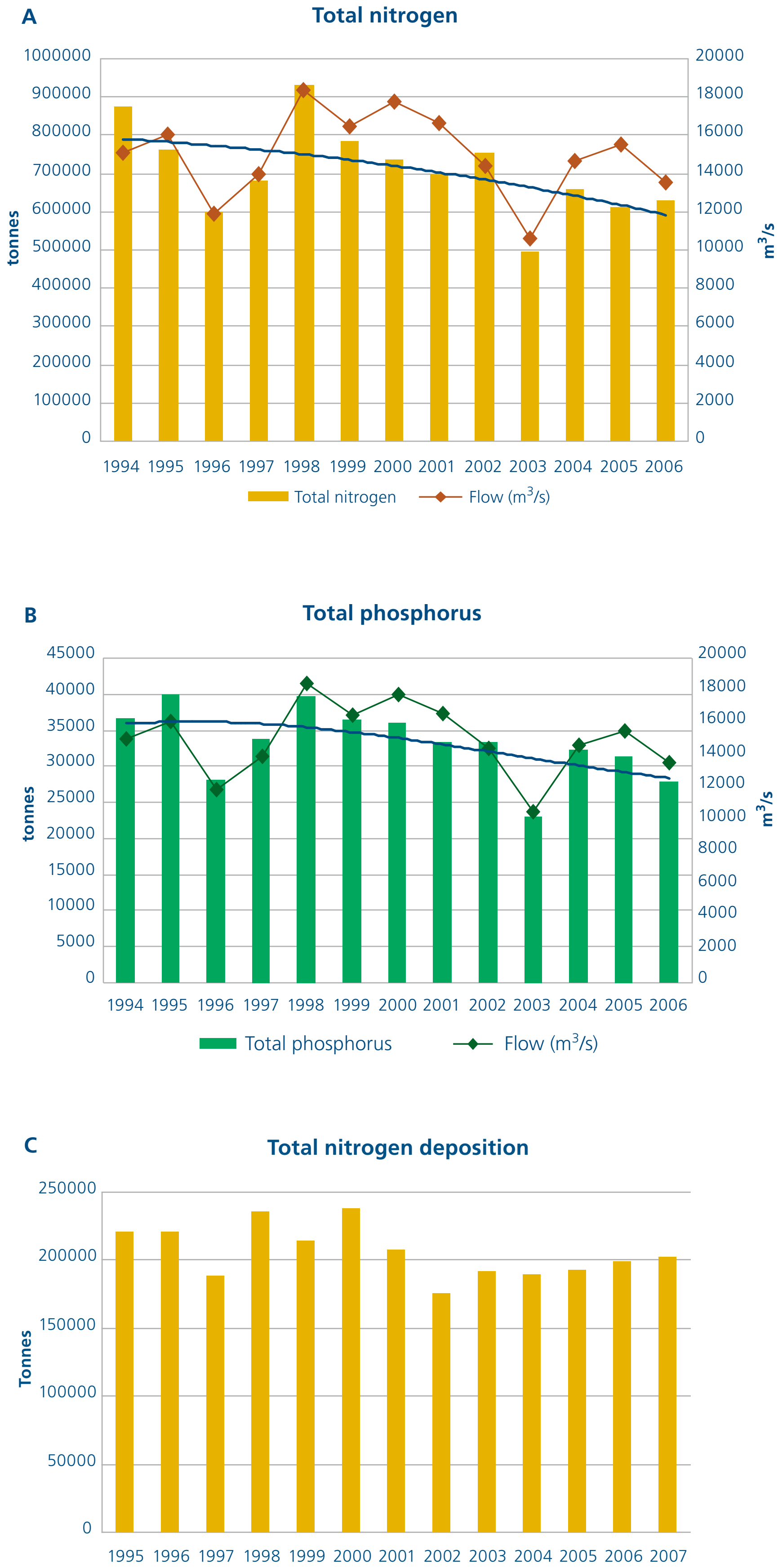


Figure 3.14 Changes over time in the annual average direct riverine and point-source inputs of nitrogen (A) and phosphorus (B) and atmospheric deposition of nitrogen (C) to the Baltic Sea. The bar marked with light green in Panels A and B indicates the maximum allowable input (tonnes) according to the Baltic Sea Action Plan (Bartnicki 2009, HELCOM 2009a).

the riverine flow. The input of humic substances to the Gulf of Bothnia has increased from its natural level because wetlands have been drained in large parts of the catchment area of the Gulf of Bothnia.

Organic matter is also introduced to the Baltic from sea-based sources, including discarded organic waste and sewage discharged from ships and mariculture operations. Mariculture, the aquatic farming of fish and crustaceans in the marine environment, is a direct source of organic matter in the Baltic Sea. Finland and Sweden host most of the fish farms in the sea areas, whereas, for example, Poland has only inland freshwater fish farms. Sea-based farms are usually located in sheltered bays where water currents are slow. Because organic matter enhances biological oxygen consumption and benthic nutrient reserves, it usually leads to increased eutrophication at the site, especially if the site is in an enclosed area with restricted water exchange (HELCOM 2009a).

3.1.8 Biological disturbance

Fishing and hunting in the Baltic Sea area

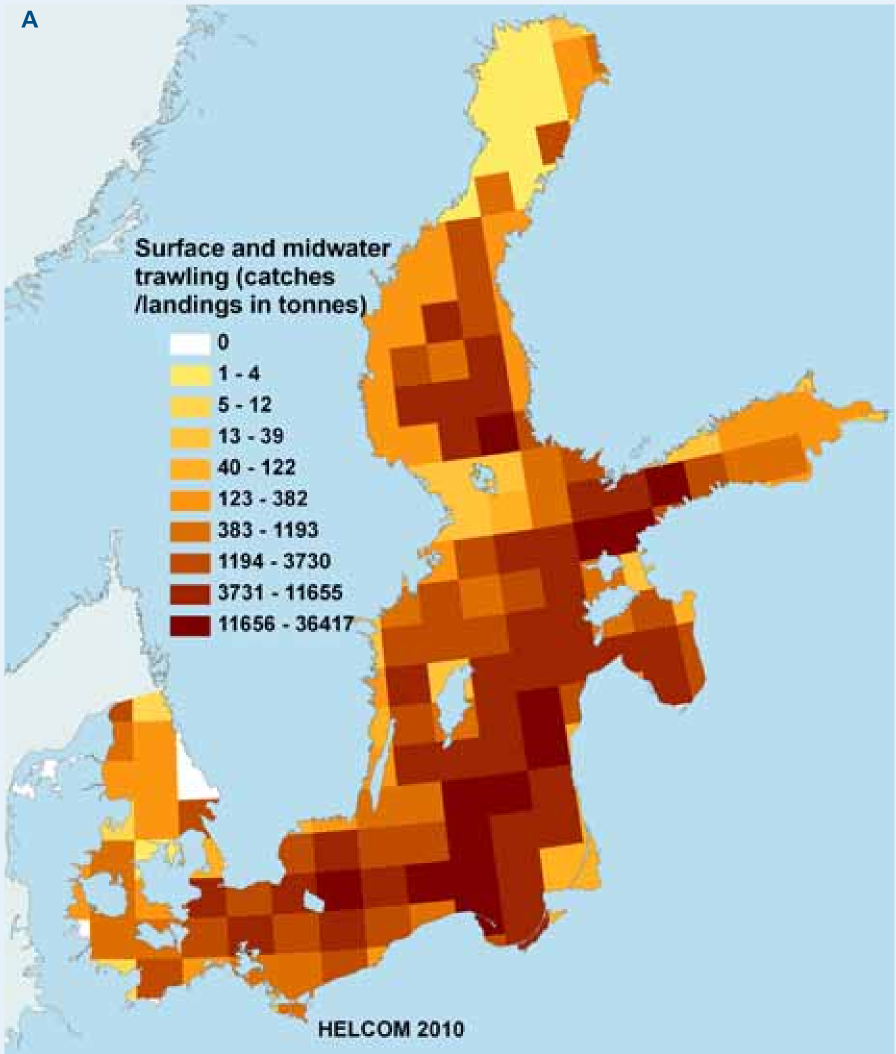
Fishing, and to a lesser extent hunting, affect the Baltic Sea food-web structure by removing mainly large predatory species such as cod, pikeperch, pike, salmon and grey seal which have an important role in the food web in regulating the lower trophic levels. Several recent analyses have shown that overexploitation of predatory species has contributed to ecosystem regime shifts, increases of nuisance species and even enhanced eutrophication (Heck and Valentine 2007, Möllmann et al. 2007, Österblom et al. 2007, Eriksson et al. 2009).

During the past 50 years, fishing has changed from a sustainable small-scale profession to an international industry, relying on high location technology, onboard treatment and storage, as well as global markets. Commercial fisheries in the open Baltic have concentrated on three to seven regulated species: cod, herring, sprat, salmon, flounder, plaice and eel, whereas coastal fisheries have targeted species such as sea trout, whitefish, pike and pikeperch, which do not fall under regulations stipulating total allowable catches. According to an ICES assessment in 2007, both the eastern as well as the western cod stocks were overexploited and the reproductive capacity of salmon in Baltic rivers was low, while the stocks of herring and sprat were harvested sustainably (ICES 2007). Information on flatfish species did not allow a specific stock assessment. Cod stocks of the Baltic Sea have been subject to a cod management plan since 2008 and the level of exploitation of the eastern stock has decreased to a sustainable level and the same is anticipated for the western stock (ICES 2009a). Despite this positive development, the status of both stocks is still at a low level.

Fish catches in 2007 were divided into four classes according to the fishing gear employed: bottom trawling, surface- and mid-water trawling, traps and pots, and gillnets. In 2007, reported landings or catches by bottom trawling amounted to 32 600 t cod, 32 500 t sprat, 18 500 t herring, 27 000 t of blue mussels (only in the Limfjord), and 11 000 t flounder. The largest catches or landings by surface- and mid-water trawling were reported for sprat (378 000 t), herring (214 000 t), cod (13 300 t) and flounder (400 t), while the largest catches or landings using gillnets and similar gears were reported for herring (22 700 t), cod (16 400 t), flounder (8 600 t) and perch (2 400 t). Stationary fishery catches or landings, i.e., from traps and pots, included 2 100 t of herring, 600 t of roach, 450 t of perch and 420 t of bream. It should be noted that these figures include only reported catches or landings and there are estimates that the unreported catches may be 35–40% of the reported catches or landings (e.g., Swedish Board of Fishery 2004). In 2008, measures to eliminate illegal, unreported and unregulated fisheries were adopted by the EU (Anon. 2008b).

The largest total catches were made in the Bornholm Basin and southwestern sea areas, where the fishery is also more diverse than elsewhere in the Baltic Sea. On the other hand, the herring fishery in the Bothnian Sea was also notably high, but on a sustainable level (ICES 2009a). Bottom trawling is a practice mainly employed in the southern sea areas (**Fig. 3.4**), targeting many fish species, prawns, lobsters and blue mussel. It is also practiced to a smaller extent in the Bothnian Bay, targeting vendace and herring. The largest catches by surface- and mid-water trawling were landed from the Arkona and Bornholm Basins and from the Bothnian Sea (**Fig. 3.15, Panel A)**. Trap and pot fisheries were mainly concentrated in the coastal areas, whereas large catches by gillnets occurred in the Bornholm Basin in addition to coastal areas (**Fig. 3.15, Panels B and C)**. Crustacean and mussel fishery is performed only in the Kattegat, Limfjord and Belt Sea.

Fishing causes unintentional by-catches of non-target species such as benthic invertebrates, other fish species, under-sized target species, seabirds, and marine mammals. Bottom trawling is the fishing method with the largest by-catch of non-target fish species, some of which are threatened and/or declining (Ottosson 2008). In the Kattegat, the by-catch in the *Nephrops* trawl fishery can be up to 50% of the *Nephrops* biomass and comprise up to 24 different species (Ottosson 2008). The impacts of bottom trawling on the benthic habitats can also be great (**Sections 3.1.1 and 3.1.2**). The gillnet fishery is a



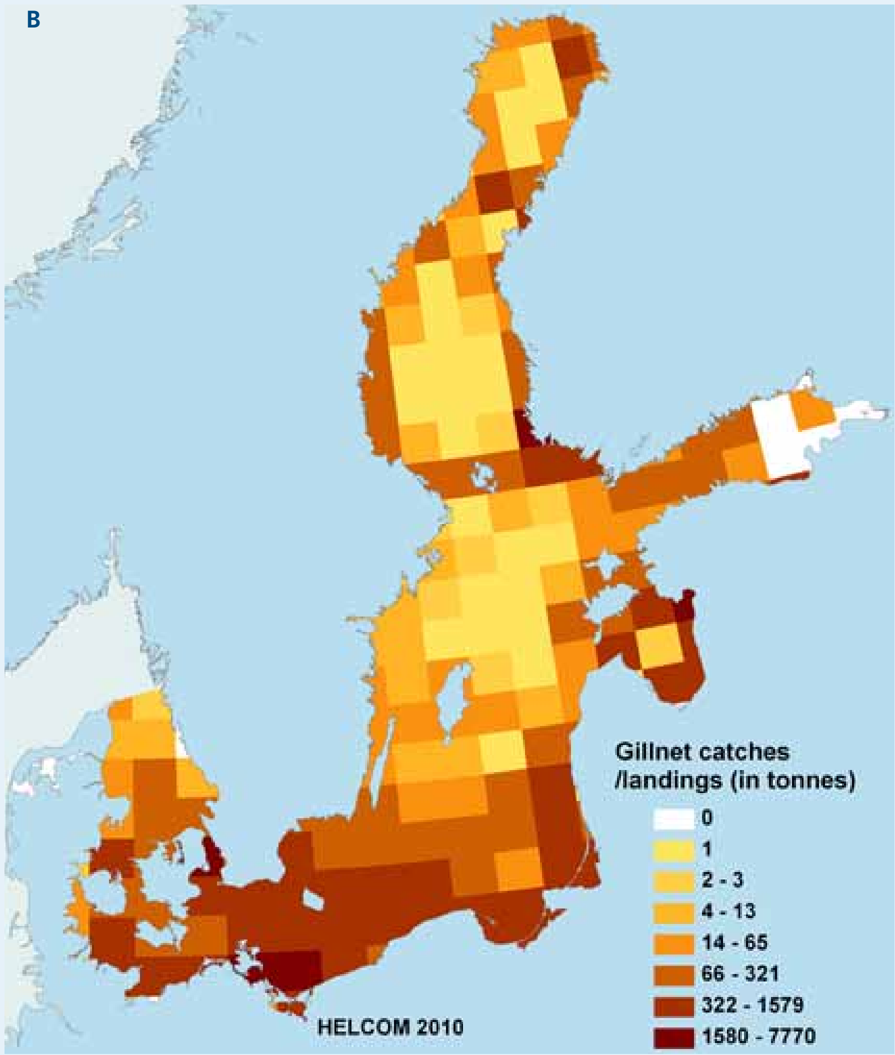


Figure 3.15 Reported catches/landings of commercial fisheries using different gear types in the Baltic Sea in tons. Panel A presents catches/landings from mid- and surface-water trawling, Panel B presents catches/landings by gillnets and Panel C presents catches/landings from traps and pots. Catches/landings in bottom trawling are presented in Fig. 3.4. Data are from the national fishery authorities of HELCOM Contracting Parties.

major threat to diving seabirds and marine mammals, especially harbour porpoises (ICES 2009b).

Hunting has not been a commercial profession in the Baltic Sea for decades. However, the hunting of birds is a very popular—though government regulated—free-time practice in coastal and archipelago areas. The hunting pressure on the marine environment is often difficult to assess because many ducks and geese also breed in freshwater areas and game bags of birds are rarely counted separately for marine areas. In this assessment, game bags of eider (*Somateria mollissima*), long-tailed duck (*Clangula hyemalis*) and cormorant (*Phalacrocorax carbo*) were compared across regions. Finland, Sweden, Denmark, and Germany have many free-time hunters delivering high quality data. Other countries have less interest in hunting and lack specific data on game bags. The eider bag in the Baltic Sea was about 75 000 birds in 2006 (HELCOM 2009b). Cormorant population reductions are currently conducted in Estonia, Germany, Finland and Sweden by hunting or oiling eggs. In 2006, it was estimated that 10 000–15 000 cormorants were shot annually (HELCOM 2009b). The pressure to reduce the population size is increasing with the continuous growth of the cormorant population in the Baltic.

There were about 22 000 grey seals in the Baltic Sea in 2007 (Finnish Game and Fisheries Research Institute 2010). The hunting of seals is practiced only in Finland and Sweden. Quotas of 685 seals in Finland and 210 in Sweden in 2007 were set only for grey seal (*Halichoerus grypus*), but ringed seals (*Phoca hispida bothnica*)—the populations of which have not increased as successfully as those of grey seals—can currently be killed only by separate permission. The coastal areas of the Gulf of Bothnia, in particular in Finland, face the heaviest hunting pressure but hunting is also heavy in the Åland archipelago (**Fig. 3.16**). In total, about 200 grey seals were shot in Finland and 100 in Sweden in 2007.

Introduction of alien species

During the past century, the Baltic Sea ecosystem has experienced invasions by species that have been introduced to the Baltic Sea both unintentionally by marine and inland shipping (ballast water and ship hulls) and intentionally for improving fisheries and for use in mariculture or inland freshwater aquaculture (**Fig. 3.17**). Since the early 1800s, about 120 alien species have been recorded in the Baltic Sea including the Kattegat (**Fig. 3.17**). The invasion rate for the region was approximately 1.3 new alien species every year over the period 1961–2007 (derived from the Baltic Sea Alien Species Database 2008, HELCOM 2009b). Although most of the alien, i.e., non-indigenous, species have not been harmful, adverse impacts of these species have also been found in the Baltic Sea. HELCOM has compiled a list of the presence and distribution of non-indigenous species in the Baltic Sea.

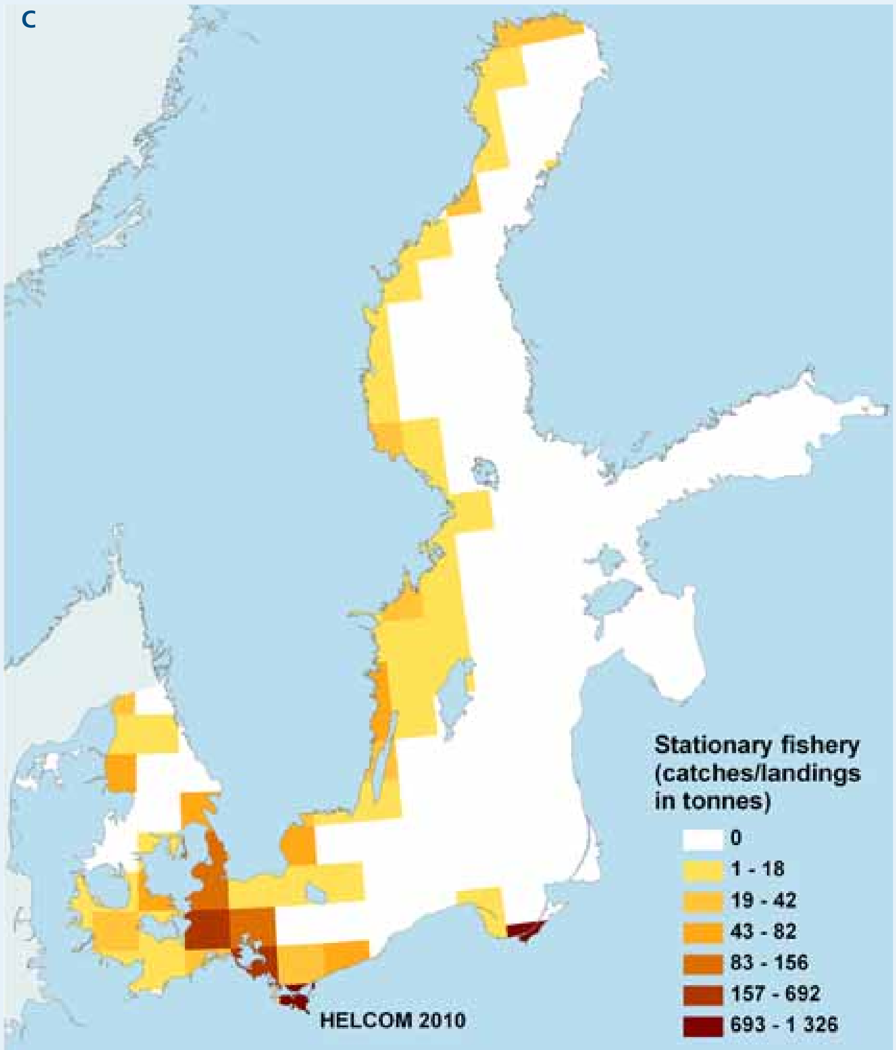


Figure 3.15 continued

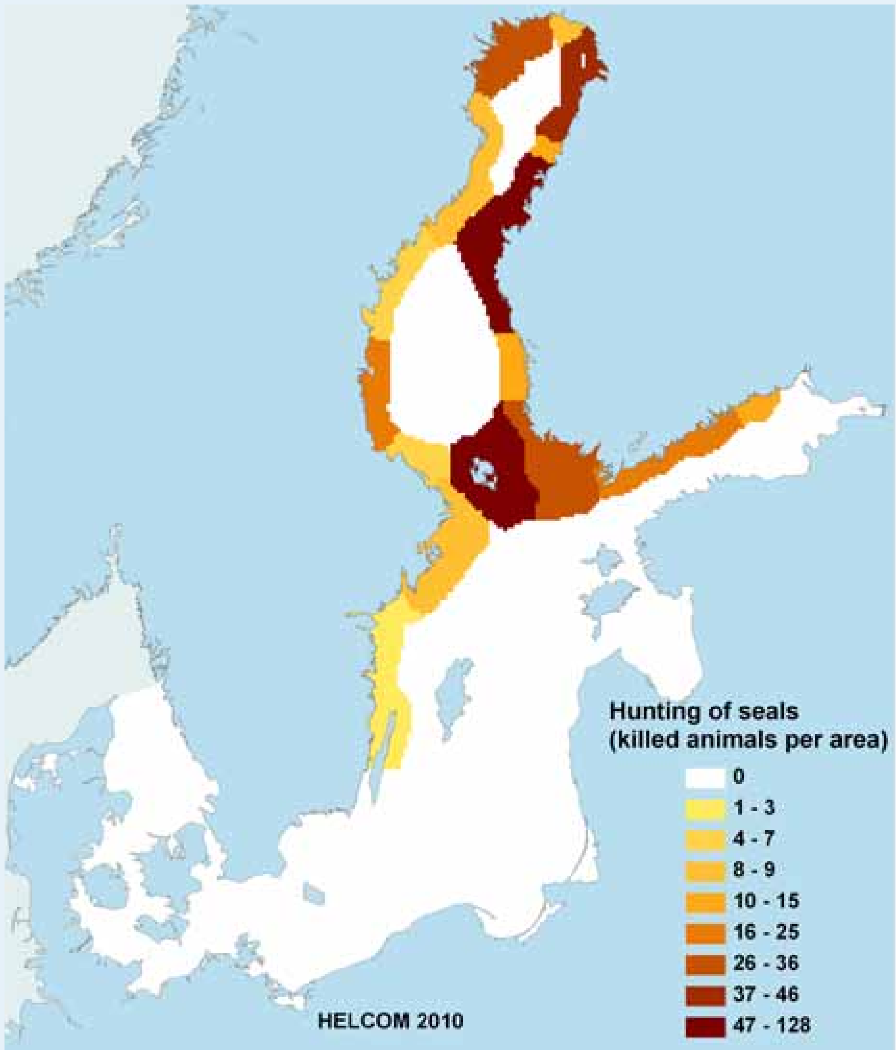


Figure 3.16 Number of grey seals killed by hunting in Finland and Sweden. The data are presented per hunting district within the territorial waters of Finland and Sweden, under the assumption that hunting occurs within territorial waters. Data sources: national hunting data.

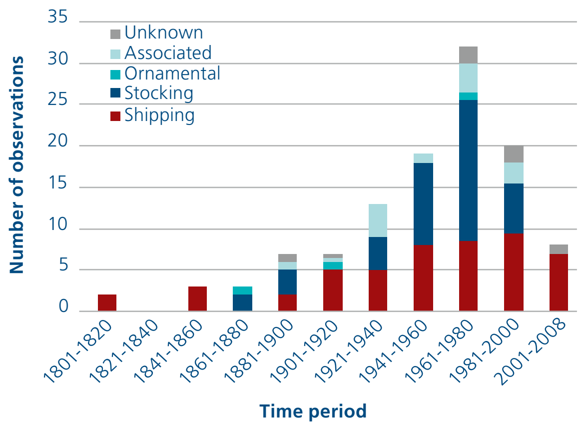


Figure 3.17 Number of new alien species observed since the early 1800s in the Baltic Sea (including the Kattegat) and likely vector of introduction (derived from the Baltic Sea Alien Species Database, update 10 April 2008, HELCOM 2009b). Note that the last bar only covers the past 8 years, while the other bars cover 20-year periods.

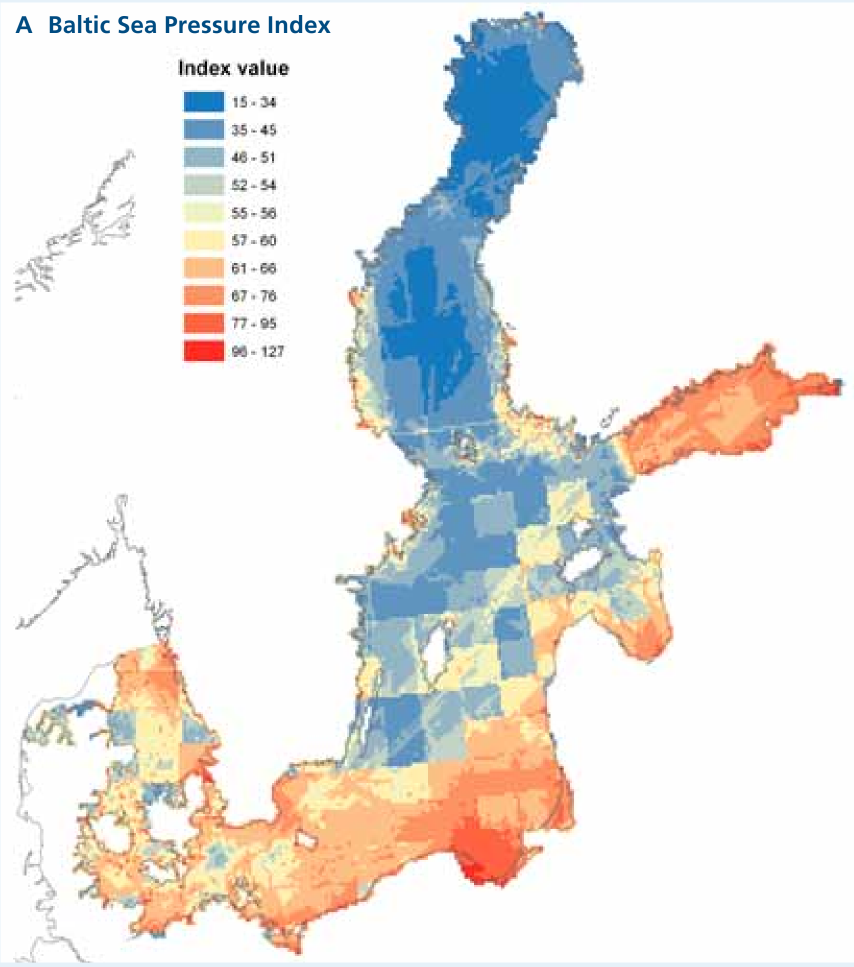
Microbial pathogens

Microbial pathogens from areas of high population density or animal husbandry may degrade the status of the marine environment. There is very little information on the extent and spatial distribution of this pressure in the open Baltic Sea, for example, from passenger ships, which are allowed to discharge wastewater outside territorial waters. In coastal areas, fish farms, wastewater treatment plants, and dense bathing sites are sources of microbes to the sea.

3.2 Cumulative pressures from multiple human activities

For the first time, this assessment brings together all available data layers relevant to human uses and pressures acting on the Baltic Sea ecosystem and rates their impacts on the marine environment. The sum of all the potential pressures throughout the Baltic is visualized by a figure termed the Baltic Sea Pressure Index (BSPI) (**Fig. 3.18, Panel A**). The Baltic Sea Impact Index (BSII) is a tool to estimate potential anthropogenic impacts on the marine ecosystem. The purpose of the BSII approach is to assess which areas of the Baltic Sea are sensitive to anthropogenic pressures. This tool is thus based on the spatial distribution of species, biotopes and biotope complexes in addition to the sum of anthropogenic pressures (**Fig. 3.18, Panel B**). The potential anthropogenic impacts are illustrated in **Figure 3.19.**

According to the BSPI, anthropogenic pressures are concentrated in the Gulf of Finland, southeastern Baltic Proper and the southern and southwestern sea areas (**Fig. 3.18, Panel A**). The pressures in the Gulf of Finland and the southeastern Baltic Proper are mainly caused by riverine inputs of nutrients, organic matter and heavy metals. In the southern and southwestern sea areas, the high cumulative pressures mainly arise from heavy fishing pressure and large inputs of nitrogen and heavy metals from atmospheric deposition. At the scale of the entire



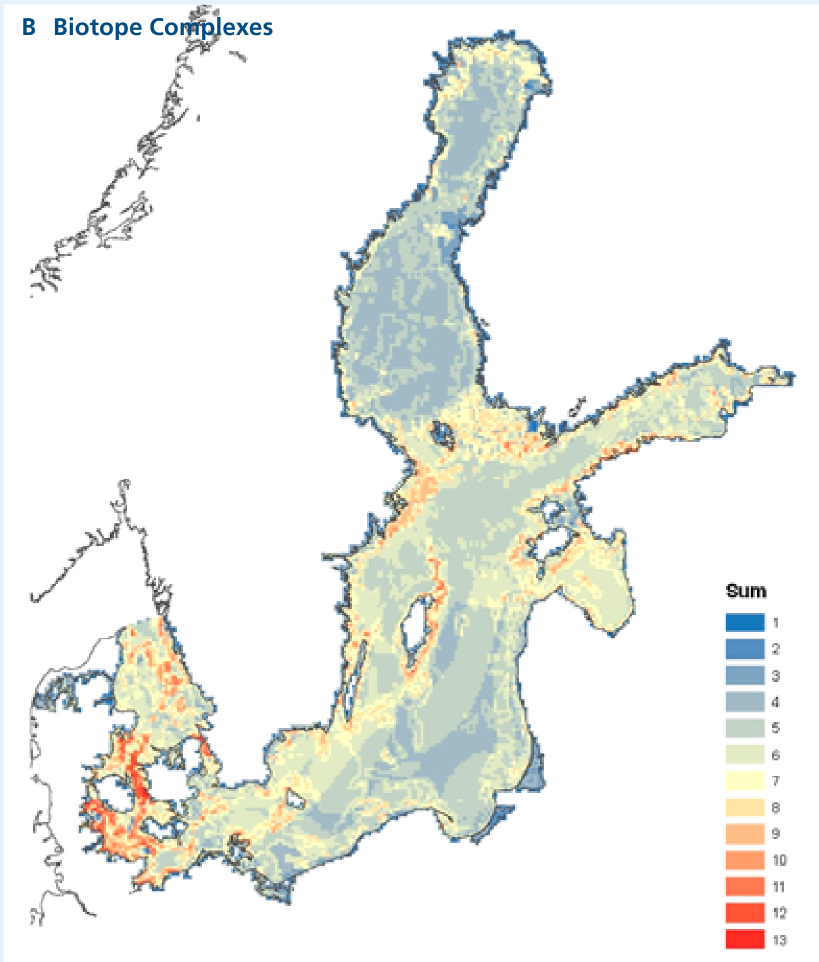


Figure 3.18 Panel A: Baltic Sea Pressure Index (BSPI) showing the sum of pressures present in areas of 5 km × 5 km (52 pressure data layers included). The index sums up all anthropogenic pressures in an area of 5 km × 5 km. Weighting of the pressures by expert opinion is required to balance among the different types of pressures. See HELCOM (2010b) for a detailed description of the BSPI methodology. Panel B: Number of biological ecosystem data layers with different sensitivity in 5 km ×5 km areas used for the production of the Baltic Sea Impact index (BSII), see also Table 1.4.

Baltic Sea, fishing and inputs of nutrients and organic matter cause the greatest pressures on the marine environment.

The HELCOM BSII shows that the largest potential anthropogenic impacts on the Baltic Sea ecosystem take place in the sea areas south of 60°N (**Fig. 3.19**). This is not surprising since the population density in southern areas is up to 500 inhabitants per km^2 compared to the scarcely inhabited northern parts of the catchment area. In addition, the Belt Sea and Kattegat areas are under pressures that are rare or non-existing in the northern parts, such as bottom trawling, large wind farms and large-scale extraction of seabed resources. Commercial fishing of cod, herring, sprat, lobster and blue mussels is also heavy in the southern basins. In the open-sea areas of the Baltic Proper, the influence of intensive shipping is clearly seen. In coastal areas all around the Baltic Sea, the multitude of coastal pressures, e.g., fish farms, municipal wastewater discharges, industries, cooling waters from power plants and coastal development works, may create a heavy burden on the marine environment. However, the BSII also shows large cumulative impacts in the vicinity of large cities, such as Stockholm, St. Petersburg and Gdansk, and near river mouths. The Gulf of Bothnia has received a low cumulative impact index value, arising from the lower level of pressures.

The sea areas that exhibit a high diversity of marine biotopes show higher BSII values. The Kattegat, Belt Sea, Kiel Bight and Archipelago Sea have the highest diversity of biological ecosystem components (**Fig. 3.18, Panel B**). Coastal areas have a larger number of biological ecosystem components than open-sea areas and, hence, they have generally received higher index values throughout the Baltic, while, for example, the open Northern Baltic Proper and open Western and Eastern Gotland Basins received relatively low index values. The Gulf of Gdansk and the Gulf of Finland support only a few biotopes or biotope complexes, but they received high index values due to several exceptionally high pressures reflecting pollution by heavy metals, nutrients and organic matter in the Gulf of Gdansk and the Gulf of Finland originating from the rivers Vistula and Neva, respectively.

The open-sea areas are affected by a few strong pressures such as waterborne and atmospheric inputs of nutrients and heavy metals and all forms of commercial fishing. Underwater noise from shipping was a high pressure in the Northern Baltic Proper, Arkona Basin, Kiel Bight and Mecklenburg Bight. Coastal areas face a wider array of pressures, the magnitudes of which are different among the sub-basins. In the Gulf of Bothnia and the Archipelago Sea, hunting of seals and birds poses significant pressures in the coastal areas, whereas various dredging and sand extraction-related pressures are significant in southwestern coastal areas.

The highest potential cumulative impacts were found in the Belt Sea, Kiel Bight, Mecklenburg Bight, Arkona Basin and the Eastern Gotland Basin. The impact index values for each sub-basin are presented and further discussed in **Chapter 6**.

It should be noted that BSPI and BSII were demonstrated for the first time in this assessment; there is a need for further development and validation of these tools and, hence, verification of corresponding results. The results presented here are therefore preliminary and represent the first step towards addressing the anthropogenic pressures in the Baltic Sea. More work is needed to estimate the impacts of various pressures on species and biotopes, and the spatial and quantitative data on pressures should be improved using real measurements instead of proxies to assess the true magnitude of human influence on the marine environment. For example, non-linear or synergistic effects are not currently specified in the index. In addition, knowledge on the distribution of various types of biotopes should be improved to arrive at a more reliable impact assessment.

The current limited understanding of the synergistic effects of anthropogenic pressures hinders our possibilities to determine the true impacts of human activities in the marine environment. From relatively few examples, we know that the key components of the Baltic Sea ecosystem are threatened by complex and potentially synergistic interactions of multiple pressures. It is also known that the accumulation of several relatively low stress factors causes unanticipated harmful effects on organisms (Crain et al. 2008). Thus, the human impact on the Baltic Sea ecosystem—measured here by the prototype Baltic Sea Pressure Index and Baltic Sea Impact Index—is likely an underestimation of the true pressure.

Baltic Sea Impact Index

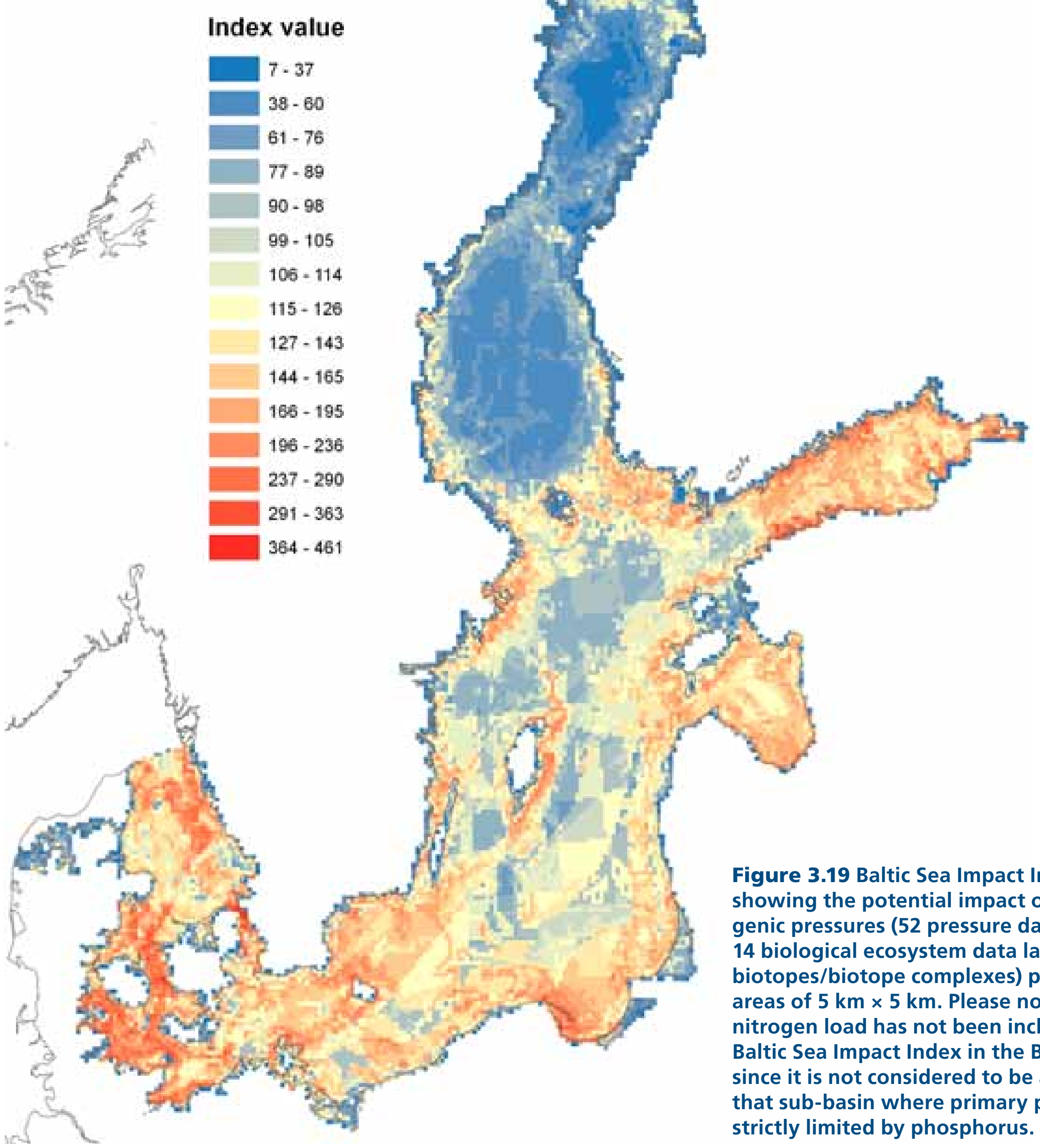


Figure 3.19 Baltic Sea Impact Index (BSII) showing the potential impact of anthropogenic pressures (52 pressure data layers) on 14 biological ecosystem data layers (species/biotopes/biotope complexes) present in areas of 5 km × 5 km. Please note that nitrogen load has not been included in the Baltic Sea Impact Index in the Bothnian Bay since it is not considered to be a pressure in that sub-basin where primary production is strictly limited by phosphorus.

Chapter 4: What are the solutions?

Solutions providing multiple positive effects should be used.

Reduction of nutrient inputs and of environmentally disruptive fishing should be given the highest priority.

Restoration of the highest levels of the food web, e.g., by recovery of top predators such as cod, harbour porpoise, seals, predatory birds, as well as pike and pikeperch in the coastal areas should be seen as a solution for improving the biodiversity.

Reduction of inputs of hazardous substances and oil pollution will yield direct benefits in terms of the hazardous substances and biodiversity status.

Reduction of physical disturbance to biotopes, habitats, and species enables their recovery.

Restoration of natural habitats, including riverine habitats and coastal wetlands, can provide large benefits at a local scale.

Establishment of sound management and stricter restrictions on human activities in marine protected areas is a necessity for improving the protection efficiency of the network of protected areas.

Maritime spatial planning, with the ecosystem approach to the management of human activities as the overarching first principle, should be seen as a potent tool for integrating the various needs for marine space and arriving at a good environmental status of the marine environment.

This chapter outlines solutions to the environmental problems of the Baltic Sea. It builds upon the knowledge basis provided in the assessment of the status of the marine environment (**Chapter 2**) and pressures on the marine environment (**Chapter 3**), as well as the thematic assessments on eutrophication, hazardous substances and biodiversity (HELCOM 2009 a, b, 2010a).

This chapter aims at providing a holistic and overarching view of the selected solutions following the ecosystem approach, and does not limit itself to the presentation of separate problem areas such as eutrophication, pollution effects by hazardous substances and the decline of biodiversity. The starting points for identifying the most urgent and efficient solutions are the actions and measures contained in the HELCOM Baltic Sea Action Plan. Additional solutions are presented on the basis of this assessment.

4.1 How are the pressures and their effects connected?

Many of the pressures on the Baltic Sea tend to have multiple effects. Almost all of them have the potential to cause unfavourable effects on the biodiversity status (**Table 4.1**).

In the long run, each of the pressures resulting in increased eutrophication can also have an unfavourable impact on biodiversity. Negative effects of eutrophication on biodiversity include the simplification of plant and animal communities and an increase in opportunistic species such as filamentous or blooming algae at the expense of perennial species or species with slower growth rates and, in the worst case, total disappearance of communities due to anoxia. It is worth noting that the initial stages of eutrophication may also be associated with a positive development of biodiversity and an increase in species.

Table 4.1 **Effects of pressures and related human activities in regard to eutrophication (E), contamination and pollution effects by hazardous substances (HS) and biodiversity (BD). Pressures are aggregated according to Annex III, Table 2 of the EU MSFD. The pressures have been further divided into various human activities, proxies or direct measures. The potential for direct 'x' or indirect '(x)' increases in eutrophication, increased contamination and pollution effects by hazardous substances, or decline of biodiversity are shown for each pressure.**

Pressure	Human activity, proxy or a direct measure of the pressure	E	HS	BD
Smothering	Wind farms, bridges, oil platforms (construction phase)		(x)	x
Smothering	Cables and pipelines (construction phase)		(x)	x
Smothering	Disposal of dredged material		x	x
Sealing	Coastal defense structures			x
Sealing	Harbours			x
Sealing	Bridges			x
Changes in siltation	Shipping (coastal)		(x)	x
Changes in siltation	Riverine input of organic matter			x
Changes in siltation	Bathing sites, beaches and beach replenishment			x
Changes in siltation	Dredging, sand, gravel or boulder extraction		(x)	x
Abrasion	Dredging, sand, gravel or boulder extraction		(x)	x
Abrasion	Bottom trawling	(x)	(x)	x
Selective extraction	Dredging, sand, gravel or boulder extraction resulting in, e.g., habitat loss			x
Underwater noise	Shipping (coastal and offshore)			x
Underwater noise	Recreational boating and sports			x
Underwater noise	Cables and pipelines (construction phase)			x
Underwater noise	Wind farms, bridges, oil platforms (construction phase)			x
Underwater noise	Wind farms (operational)			x
Underwater noise	Oil platforms			x
Changes in thermal regime	Power plants with warm-water outflow			x
Changes in salinity regime	Bridges and coastal dams			x
Changes in salinity regime	Coastal wastewater treatment plants with freshwater outlets to the sea			x
Introduction of synthetic compounds	Polluting ship accidents		x	x
Introduction of synthetic compounds	Coastal industry, oil terminals, refineries, oil platforms		x	x
Introduction of synthetic compounds	Harbours		x	x
Introduction of synthetic compounds	Atmospheric deposition of dioxins		x	(x)
Introduction of synthetic compounds	Population density (e.g., hormones and pharmaceuticals)		x	(x)
Introduction of non-synthetic compounds	Illegal oil spills		x	x
Introduction of non-synthetic substances and compounds	Waterborne input of Cd, Hg and Pb		x	x
Introduction of non-synthetic substances and compounds	Atmospheric deposition of Cd, Hg and Pb		x	(x)
Introduction of radionuclides	Discharges of radioactive substances		x	
Inputs of nutrients	Waterborne input of nitrogen	x		x
Inputs of nutrients	Waterborne input of phosphorus	x		x
Inputs of nutrients	Aquaculture	x		x
Inputs of nutrients	Atmospheric deposition of nitrogen	x		x
Inputs of organic matter	Aquaculture	x		x
Inputs of organic matter	Riverine input of organic matter	x		x
Introduction of microbial pathogens	Coastal wastewater treatment plants with outlets to the sea			x
Introduction of microbial pathogens	Aquaculture			x
Selective extraction of species	Bottom trawling (landings or catches)	(x)		x
Selective extraction of species	Surface- and mid-water trawling	(x)		x
Selective extraction of species	Gillnet fishery	(x)		x
Selective extraction of species	Coastal stationary gear fishery			x
Selective extraction of species	Hunting of seals			x
Selective extraction of species	Hunting of birds			x

Most of the pressures causing contamination and pollution effects by hazardous substances can also result in an unfavourable development of biodiversity. The connections and mechanisms, however, are not as clear and well known as the effects of eutrophication. Most of the well-known effects of hazardous substances on species or communities have been related to top predators, such as the declining populations of seals and white-tailed eagles in the 1970s due to PCBs and DDT.

None of the individual pressures is considered to have direct effects on all three problem areas that HELCOM is concerned with: eutrophication, pollution by hazardous substances and unfavourable development of biodiversity. But as far as the secondary effects are concerned, bottom trawling can be regarded as a pressure which in some areas may affect all three problem areas.

4.2 What are the pressures of most concern for the Baltic Sea?

Nutrient inputs and different methods of fishing—pressures causing eutrophication and a decline of biodiversity—were rated the top pressures in the Baltic Sea (**Fig. 4.1**, see also **Sections 3.1.7 and 3.1.8**). Most of the pressures leading to inputs of hazardous substances, whether synthetic or non-synthetic, ranked within the top 25. Numerous pressures causing physical disturbance of the sea bottom or causing noise, mainly impacting biodiversity, were distributed among the pressures with the least overall magnitude. This is associated with the relatively low spatial coverage of these pressures but they can still be highly destructive at the local scale. The sub-basin specification of major pressures is presented in **Chapter 6**.

4.3 Solutions with multiple positive effects

Any good solution should have several positive effects and environmental managers are advised to prioritize solutions that help to resolve as many problems as possible at the same time. This is in line with the holistic view and the ecosystem approach.

As a first step, the results of the Initial Holistic Assessment of the ecosystem health of the Baltic Sea suggest prioritizing solutions that address eutrophication and the decline of biodiversity. **Chapter 3** and the HELCOM thematic assessments (HELCOM 2009a, b, 2010a) demonstrate that eutrophication and the impairment of biodiversity are of great concern, since much of the Baltic Sea area is classified as being in a 'bad' status. In addition, solutions addressing eutrophication and the loss of biodiversity are the most promising, because

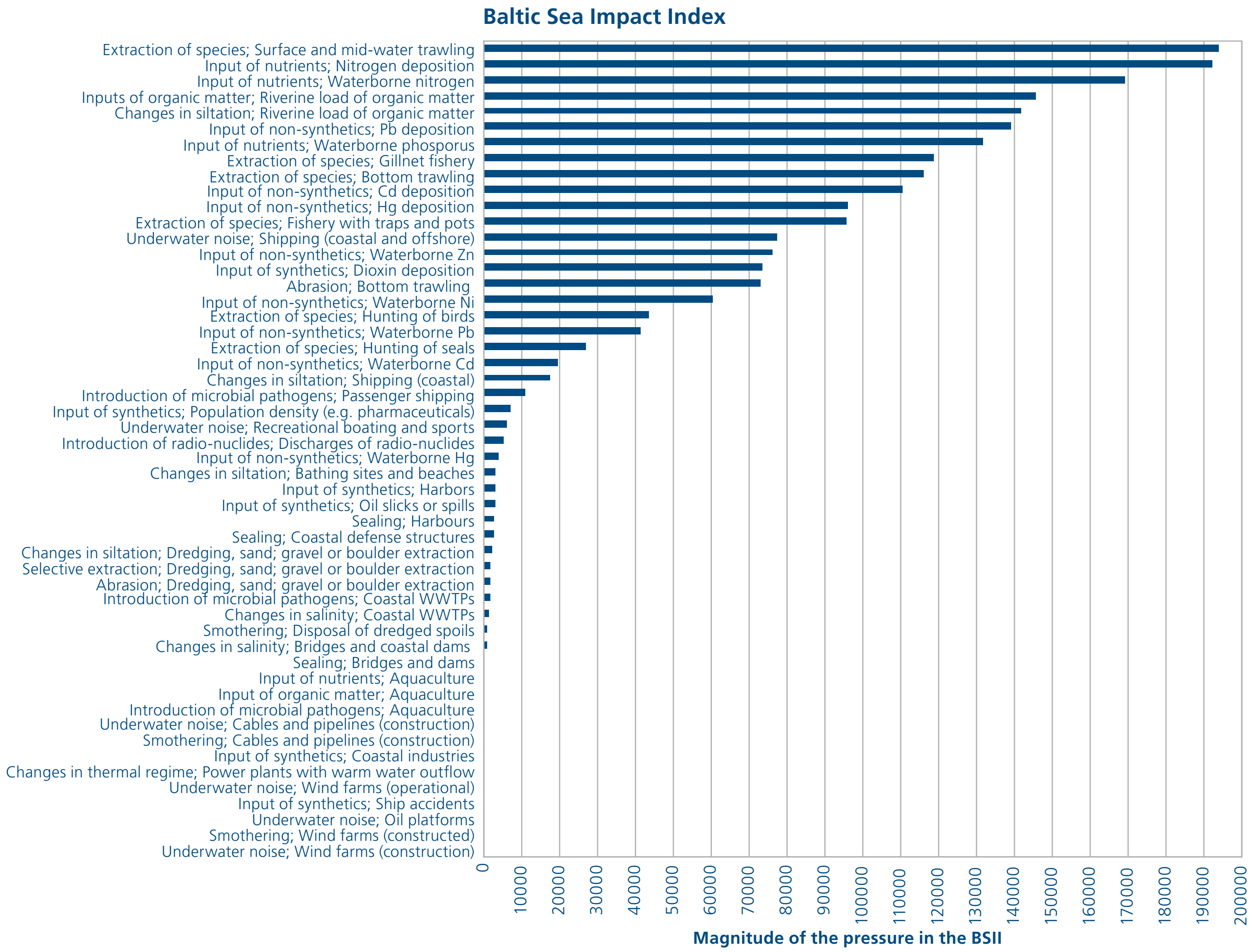


Figure 4.1 Ranking of the magnitude of all potential pressures on the Baltic Sea based on the Impact Index values. The sum value of each pressure depends on the spatial coverage of the potential impact, the intensity of the potential impact and the constants used for evaluating the severity of the impacts of pressures on the local ecosystem components. The figure does not present the relative harmfulness of pressures in local scales, but gives an overall picture of the sources of potential anthropogenic impacts on the Baltic Sea. WWTPs = wastewater treatment plants. See Sections 1.6 and 3.2 and HELCOM (2010b) for details.

they are to a large extent current problems resulting from pressures caused by ongoing human activities.

Solutions to increase the number of sea areas that are not impaired by hazardous substances are not as easily found. Although the map illustrating the pollution status by hazardous substances (**Fig. 2.5**) shows fewer areas of 'bad' status than, for example, for eutrophication, the pollution effects of hazardous substances are widespread and areas in 'high' or 'good' status are few and isolated. The identification of efficient solutions is also challenged by the fact that some of the hazardous substances pollution effects arise from pressures and human activities that took place a long time ago, such as pollution from DDT and PCBs which were banned by the 1980s in the Baltic Sea region.

Certain solutions provide multiple positive effects by simultaneously releasing pressures causing two or three types of impairment of environmental quality (**Table 4.2**). A reduction of nutrient inputs will yield simultaneous positive effects of eutrophication reduction and often also biodiversity improvement, while reduction of the inputs of hazardous substances has the potential to yield simultaneous benefits of reduced contamination and pollution by hazardous substances and positive effects on biodiversity and seafood quality. Similarly, reduction of oil pollution will result in simultaneous benefits of decreased pollution effects and reduced pressure on biodiversity.

Another solution well-suited to address several environmental problems of the Baltic Sea at the same time is reducing the physical disturbance of the seabed. Many different activities cause physical disturbance and they mainly take place in the coastal zone which harbours the greatest biodiversity and is in that sense the most sensitive to disturbance. However, bottom trawling causes physical disturbance to large areas in the open sea, and thus also impacts the benthic communities. Physical disturbance not only seriously impairs biodiversity, but also increases eutrophication and contamination by hazardous substances. This occurs when activities disturbing the seabed also stir up bottom sediments into the water column and resuspend nutrients and hazardous substances that had sedimented long ago.

The restoration of the structure of the food webs by allowing an increase in the abundance of top predators and the restoration of natural habitats are also among the solutions that have the potential to provide multiple positive effects, both in the increase of biodiversity and the remediation of eutrophication. Solutions resulting in such effects include, for example, improved areas for fish spawning both in the sea and in rivers flowing into the Baltic and an increase in feeding and breeding

Table 4.2 **Solutions that have potential to provide multiple positive effects have been indicated by 'X' and solutions with potential indirect or weaker benefits are indicated by '(X)'.**

Solution	Eutrophication	Contamination and pollution by hazardous substances	Biodiversity decline
Reduction of nutrient inputs	X		X
Reduction of environmentally disruptive fishing activities, including overfishing	(X)	(X)	X
Restoration of food webs with the aim to increase numbers of top predators	(X)		X
Reduction of the inputs of hazardous substances		X	X
Reduction of oil pollution		X	X
Reduction of physical disturbance to natural habitats	(X)	(X)	X
Restoration of natural habitats (e.g., coastal wetlands and reefs)	X	(X)	X

areas for birds and seals. The large-scale restoration of natural habitats such as wetlands, meadows of algae and seagrass will increase both the buffering as well as the filtering capacity of coastal waters. The restoration of coastal wetlands has the additional potential to provide filtering capacity for urban and agricultural runoff, thereby reducing the inputs of nutrients and possibly even hazardous substances. Wetlands have also been identified as being valuable spawning habitats for coastal fish such as pike and valuable for climate change mitigation through carbon sequestration (TEEB 2008).

The solutions presented above can be implemented by numerous types of technological actions and environmental measures. In addition, there are two overarching solutions requiring the adoption and implementation of administrative and legal measures that would have great benefits if implemented properly: several fundamental problems of the Baltic marine ecosystem could be improved by establishing an ecologically coherent network of well-managed marine protected areas and by applying integrative cross-sectoral maritime spatial planning with the ecosystem approach as the overarching principle.

4.4 What are the actions to implement the solutions?

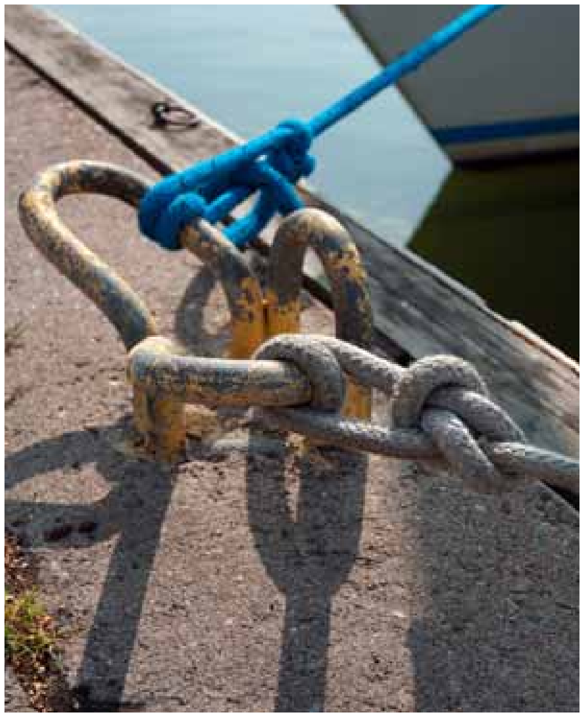
None of the six solutions described above (**Table 4.2**) is totally new, although more emphasis is placed on nature restoration than previously. The measures and actions needed to implement them are already covered by the Baltic Sea Action Plan, HELCOM Recommendations, as well as EU legislation and global agreements. This Initial Holistic Assessment has shown that fisheries together with eutrophication are the main pressures in the Baltic Sea area. Therefore, adequate measures to reduce the negative ecological effects of fisheries and nutrient inputs are needed urgently. Further suggestions for actions are contained in the HELCOM thematic assessments (HELCOM 2009 a, b, 2010 a, c). In addition, new actions are proposed here on the basis of this assessment.

The following section offers brief descriptions of each of the actions needed to implement the multiple-positive effect solutions.

Reduction of nutrient inputs

In general, the target can be reached by actively decreasing nutrient inputs from agriculture, urban and rural wastewaters and aquaculture, reducing the use of artificial fertilizers, preventing diffuse nutrient losses from fields and animal husbandry, and minimizing nitrogen emissions to air from shipping, animal husbandry and land-based traffic. Reversing the eutrophication process is slow and therefore long-lasting measures should be favoured.

The Baltic Sea Action Plan includes a set of nutrient reduction requirements for each HELCOM Contracting State based on a maximum allowable nutrient load approach and specific measures to reach this target. The treatment of wastewater can be improved in municipalities, rural settlements and passenger ships and this can be enhanced by the immediate ban on phosphorus in detergents, including for dishwashers, and by upgrading port reception facilities for ship sewage. In animal husbandry, manure handling and storage capacity can be improved and enforced, and the insertion of manure as a fertilizer directly to the soil should be implemented and



with this also the replacement of artificial fertilizers by manure should be supported. The runoff of nutrients can be prevented by winter crop cover, buffer zones, riparian zones, restored wetlands and sedimentation pools. Nutrient discharges from aquaculture can be reduced by transferring the fish farms to closed systems inland. The nitrogen emissions to air can be further reduced both from ships and land-based traffic by supporting a shift to new technologies.

In addition to the measures suggested in the Baltic Sea Action Plan, phosphorus trapping from animal husbandry and crop fields by precipitating chemicals can prove to be an efficient method. Such chemicals have been tested, for example, in wetlands and manure pools.

Restoration of food webs with the aim to increase the number of top predators

The Baltic Sea Action Plan introduces some measures to restore the food webs in the Baltic Sea. One of the main actions is to eliminate illegal, unregulated and unreported fishery in the Baltic Sea by efficient enforcement. One such measure could be an enhanced source identification system for marine products. Cod is the main predatory fish species in the Baltic Sea and its stocks have long been outside safe biological limits (ICES 2009a). The EU long-term management plan for cod from 2008 onward has decreased the fishing pressure, though recovery to safe biological limits has not yet been observed. If measures are successful, the recovery is expected to occur within a few years' time depending on reproductive success.

In addition to sustainable fishing quotas, the establishment of spatial or temporal and permanent closures of fisheries of sufficient size or duration in the Baltic Sea area would enhance both the size and age distribution of cod stocks and would provide safe havens for harbour porpoises and/or seals, which are often killed as a by-catch of fisheries. Currently, there are three areas in the Bornholm Basin closed to the cod fishery (Anon. 2007b). In 2008, a ban on the use of drift nets and a requirement for the obligatory use of deterrent devices came into force in the EU member states to decrease the by-catch pressure on harbour porpoises (Anon. 2004). In addition, there are specific demands in the BSAP to reduce fisheries by-catch and restore harbour porpoise populations. Apart from fishery, the long-term viability of the populations of the three seal species should be safeguarded. Consideration of the exclusion or strict regulation of certain fisheries in marine protected areas could be a first step in the right direction. Currently, EU member states are in the process of establishing Natura 2000 areas for the protection of marine species and habitats, and management plans are being devised that also require the responsible fisheries authorities to fulfill the targets of the protected areas.

Baltic Sea Action Plan has a number of actions to improve the status of salmon stocks and their spawning areas in rivers. As a special case in the Baltic Sea river systems, a reintroduction programme of Baltic sturgeon may enhance the recovery of the Baltic Sea estuarine food webs.

Reduction of the inputs of hazardous substances

The hazardous substances segment of the Baltic Sea Action Plan and the thematic assessment of hazardous substances contain several actions that are seen as solutions for the contamination problem in the Baltic Sea:

- Ban the use, production and marketing of the most harmful substances, especially where less harmful substitute substances or techniques exist (e.g., pentaBDE and octaBDE, two forms of brominated diphenylethers).
- Restrict the use and releases of harmful substances when there is evidence of their harmfulness (e.g., mercury, perfluorooctane sulphonate (PFOS), perfluorooctanoic acid (PFOA), nonylphenol (NP)/nonylphenolethoxylates (NPEs), short-chained chlorinated paraffins (SCCPs), medium-chained chlorinated paraffins (MCCPs), hexabromocyclododecane (HBCDD), decaBDE, octylphenol (OP) and octylphenol ethoxylate (OPE); see HELCOM 2010a for information on these substances).
- Control the import of consumer products or articles containing harmful substances to the Baltic Sea region to reduce the flow of such substances to the Baltic Sea area.
- Strictly control the disposal of contaminated sediments at sea.
- Reduce the cadmium content of fertilizers used in the Baltic Sea catchment area.
- Apply treatment to leachates from landfills and storm waters from urban areas as well as waste sorting sites.
- Request industries with high emissions to introduce enhanced wastewater treatment measures.
- Implement the zero-discharge principle for offshore platforms.
- Eliminate backyard burning of wastes and establish limit values for small-scale combustion and emissions of dioxins from industrial combustion.
- Reduce the use of environmentally harmful antifouling agents, e.g., by promoting the development of environmentally friendly anti-fouling techniques and by providing boat-hull washing sites.

Reduction of oil pollution, including management of the risk of oil spills

According to the Baltic Sea Action Plan, the following four actions are needed to decrease the continuous pressure from illegal oil spills or discharges from oil platforms or to avoid large-scale accidents: (1) ensure that ships follow anti-discharge regulations, (2) implement the zero-discharge principle for offshore platforms, and (3) improve the safety of navigation, especially in winter. The risk of a major oil-spill accident can never be eliminated and therefore the HELCOM Contracting Parties have also agreed to (4) develop and maintain adequate emergency and response capabilities.

Reduction of physical disturbance to natural habitats

Physical disturbance of habitats is caused by several human activities in the marine environment. According to the Baltic Sea Action Plan, such activities should be banned in areas that contain threatened or declining marine biotopes. The mitigation of negative impacts on habitats should be conducted using a common approach.

In this assessment, it was determined that bottom trawling is among the main pressures on the marine seabed in all areas where it is practiced. As a first step, it is suggested that bottom trawling should be excluded within marine protected areas (MPAs).

Restoration of natural habitats, especially coastal wetlands

Projects to restore shallow-water rocky reefs, coastal or estuarine wetlands and rivers are actions which increase habitat diversity and have positive effects on fish and bird populations. Wetlands have been shown to be efficient in trapping inputs of nutrients, organic matter and potentially also hazardous substances. As habitat-forming species are seen as key components in the Baltic Sea ecosystem, their spatial distribution, abundance and habitat quality should be given first priority in the restoration projects. In addition, the protection of natural and near-natural marine landscapes ensures that habitat diversity and quality are maintained in the Baltic Sea.

Prevention of the introduction and spread of invasive alien species

The ballast water and sediment of ships should be managed so that invasive alien species and other harmful species are not introduced into or spread within the Baltic. The security of mariculture and aquaculture facilities should be improved so as to prevent escapes of the farmed fish. Caution should be exercised in introducing new species in mariculture. A risk assessment should be conducted for new species that are proposed to be used in mariculture and risk management plans should be implemented.

Solutions to bridge gaps of knowledge

Insufficient information is available concerning several human activities or pressures. In particular, there is an urgent need for developing the basis for a Baltic Sea-wide mapping of underwater noise. There is also a limited understanding of the extent of pollution by marine litter, despite the HELCOM Recommendation to monitor marine litter in the Baltic Sea. There is also insufficient information on the extent and impacts of alien species in the Baltic Sea. All three are descriptors in the EU MSFD and need to be addressed immediately to define good environmental status. Results should be made available as soon as possible on the national and HELCOM level, so that this work can be undertaken on the most appropriate basis.

Establishment of an ecologically coherent network of well-managed marine protected areas

The current network of marine protected areas (MPAs) covers over 12% of the Baltic Sea marine area (**Fig. 4.2**, HELCOM 2010d). It consists of both HELCOM Baltic Sea Protected Areas (BSPAs) targeted to protect Baltic Sea-specific features in marine and coastal areas and EU Natura 2000 sites providing protection to species and habitats under the EU Habitats and Birds Directives. The areal coverage of BSPAs has increased from only 3.9% of the marine area in 2004 to 5.5% in 2008 and 10.3% in 2010, and the network is now larger than the target of 10% areal coverage set for regional seas by the UN Convention on Biological Diversity COP7. However, the

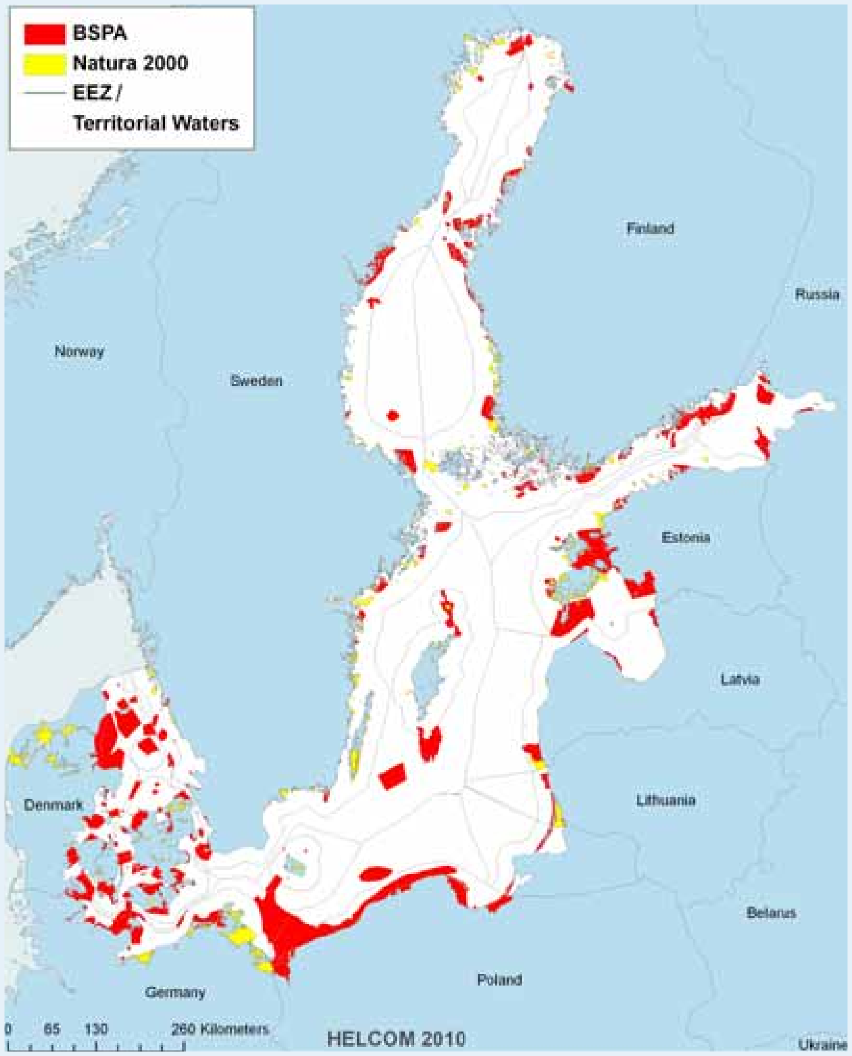


Figure 4.2 Overview of marine BSPAs and Natura 2000 areas in the Baltic Sea. EEZ = Exclusive Economic Zone.

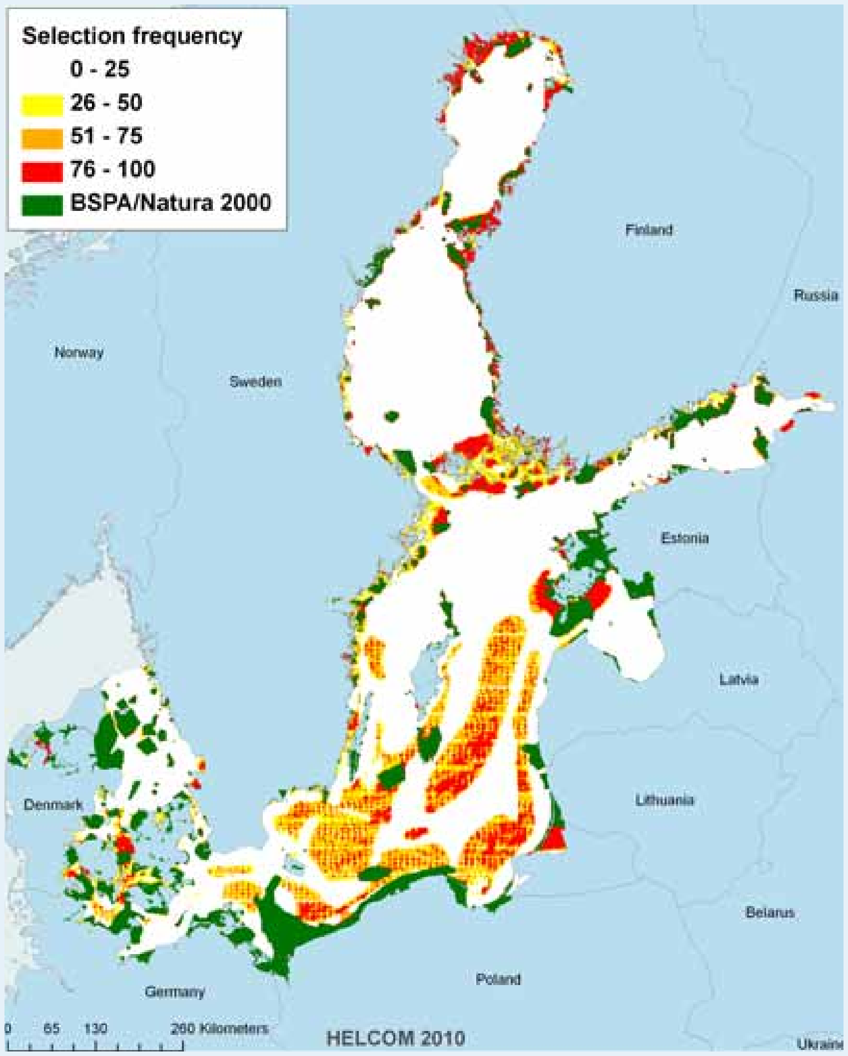


Figure 4.3 Frequency of MPA site selection; blue indicates the lowest and red the highest frequency of proposed MPAs using the MARXAN site-selection tool. Existing MPAs have been included in the analysis (areas in green). The MARXAN run used the aim of a minimum of 12% areal coverage for each of the sub-basins of the Baltic Sea. See HELCOM (2010d) for details.

10% areal coverage has not been reached for all sub-basins of the Baltic Sea; in particular the Gulf of Bothnia is lagging behind.

Despite the fairly good areal coverage, the network of BSPAs is neither ecologically coherent nor well-managed (HELCOM 2010d). The lack of ecological coherency, as well as the unbalanced area coverage between the sub-basins, warrants the need for the designation of new protected areas. According to an analysis carried out using the MARXAN site-selection tool, new areas would be ecologically and economically most relevant to designate especially in the Gulf of Bothnia and the Baltic Proper open waters (**Fig. 4.3**, HELCOM 2010d). The MARXAN selection frequency of sites in the southern Baltic Sea was lower, indicating better sufficiency of existing sites in that area. However, the anthropogenic pressures are also higher in the southern sea areas, suggesting that increased protection would enhance the ecosystem health in those sub-basins.

MARXAN is software that delivers decision support for MPA selection and network design (Possingham et al. 2000, 2008) by identifying efficient and comprehensive 'portfolios' of suitable planning areas that accomplish a number of ecological, social and economic goals. MARXAN aims to achieve the user-defined biodiversity targets in the most cost-efficient manner with minimum cost. Cost does not need to be a monetary value; it can reflect the relative suitability of an area. Human activities can be set as a cost in MARXAN and hence the proposed MPA networks tend to avoid areas of high human activity, unless the overlapping ecological values are even higher.

A major gap in the protection of marine biodiversity is the lack of a sufficient level of management of the BSPA network. Management measures are needed to accomplish the objectives agreed in the Helsinki Convention. In total, only 36 BSPAs (= 40%) have been provided with management measures (HELCOM 2010d). Efficient management and the design of the BSPA network should be coordinated with the management of human activities affecting these areas, such as maritime transport, fisheries, dredging as well as the disposal of dredged material, construction and inputs of pollutants, in order to meet the long-term conservation goals of the protected areas network, as well as to secure the protection of single sites. Currently, based on data contained in the HELCOM BSPA database, the only activities that are **not forbidden** in any BSPAs are 'Fishing' and 'Research', while various construction and extraction activities were the activities most often reported as being restricted (**Fig. 4.4**). A project by Germany and ICES identified two major conflicts between fishing and nature protection: bottom trawling in reef and sandbank areas and by-catch of marine mammals and seabirds in bottom-set gillnets. ICES has published scientific advice containing management options to solve conflicts between fishing and nature protection, including spatial and temporal regulation of fishing activities and gears and the mandatory use of ecologically sound fishing gear (ICES 2009b), which could be used by HELCOM Contracting Parties when setting up management plans.

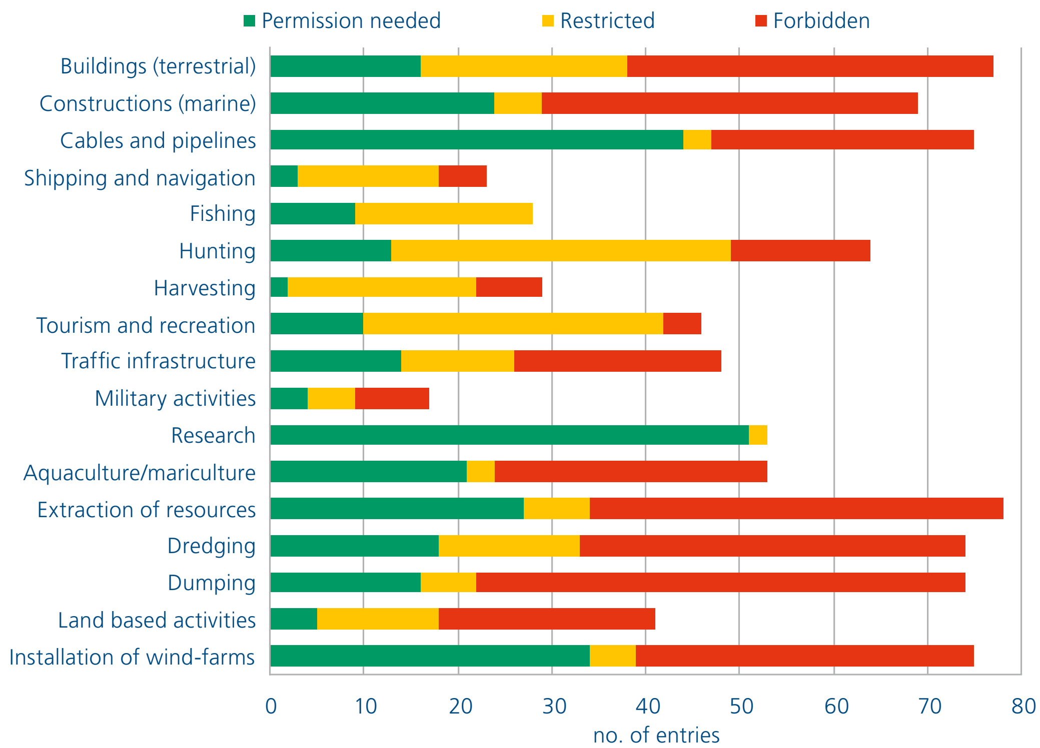


Figure 4.4 Restrictions of human pressures within Baltic Sea Protected Areas according to the HELCOM BSPA database as of July 2009 (see HELCOM 2010d for details).

The figures show that the management measures, particularly the regulation of human pressures with negative impacts in the marine protected areas, whether they are BSPAs, Natura 2000 sites or nationally protected, need to be significantly improved to achieve a network of protected areas that provides efficient protection to the valuable features of the Baltic Sea nature. This seems to apply to fishing in marine protected areas, which is not forbidden, but is reported to pose a real threat in a large number of sites.

Application of maritime spatial planning

Most human activities and pressures are already regulated by management through existing national laws and international agreements, and significant efforts are being made to handle specific pressures or uses. Given this, why do ecosystem degradation and the decline of biodiversity continue despite current management efforts?

The obvious answer is that—in addition to the inadequate implementation and enforcement of existing rules—our current approach to governance in the Baltic Sea is insufficient and does not match the dynamics of the complex marine ecosystem. The problem arises partly from the current fragmented approach to management, which is based on handling individual sectoral uses of marine resources, together with mismatches between political visions, actual political actions, management tools, and overall ecosystem capacity. What could be a solution that would contribute to the overall goal of 'Good Environmental Status' according MSFD and the HELCOM visions?

Adaptive management, or more simply 'learning by doing', which is an inherent part of the ecosystem-based approach to the management of human activities and also one of the principles of the HELCOM Baltic Sea Action Plan, could provide some of the solutions needed. Adaptive management is useful because it allows us to further develop and refine management measures as our understanding of the Baltic ecosystem and the impacts of human pressures on it improves. Recognition of this has resulted in advocating the use of a more holistic, ecosystem-based approach to the management of human activities.

Our challenge is to determine how to turn this concept into viable practical management tools, which ease the pressures on marine biodiversity—tools that are based on science and are capable of meeting political priori-

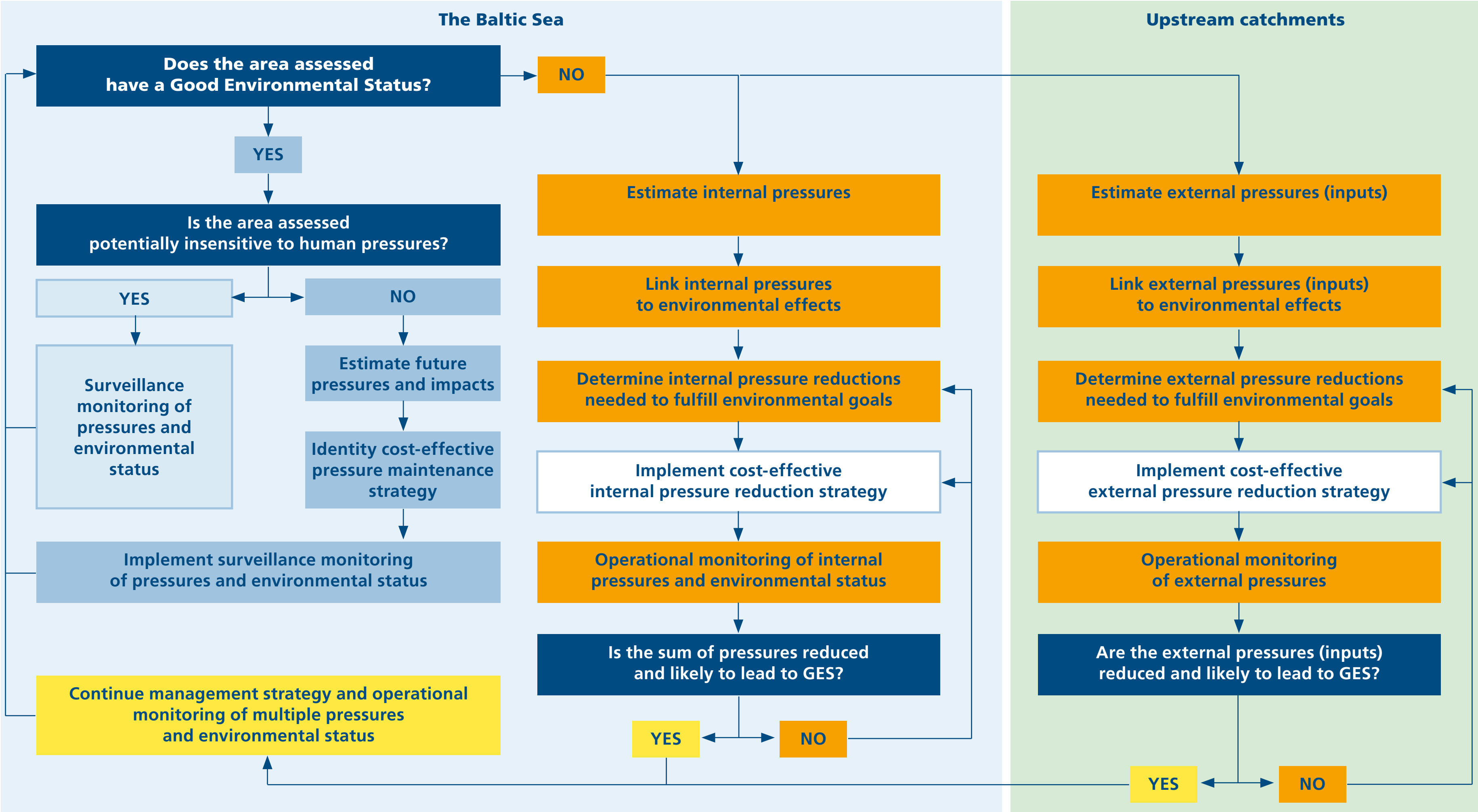


Figure 4.5 Conceptual model for arriving at a 'Good Environmental Status' of the Baltic Sea.
GES= 'Good Environmental Status'. Figure by courtesy of BALANCE, a Baltic Sea Region Interreg IIIB Programme project (www.balance-eu.org).

ties and sectoral interests, while ensuring that our sustainable use of the sea matches long-term ecosystem capacity. This includes integrated overarching management solutions to specific problems covering specific activities or sectors.

A key to meeting this challenge is to realize that maritime activities occur over the entire ecosystem, using or influencing marine space at the surface, in the water column, on the seafloor and/or under the seabed.

Maritime spatial planning is a worldwide emerging tool for analysing, coordinating and allocating the distribution of human activities in marine areas to achieve sustainable development by balancing economic, environmental and social objectives. HELCOM, together with the VASAB network (Vision and Strategies around the Baltic Sea 2010), is drafting a set of joint principles for broad-scale transboundary maritime spatial planning in the Baltic Sea that will be presented for adoption at the HELCOM 2010 Ministerial Meeting. These principles contain the ecosystem approach to the management of human activities as the overarching first principle. Further principles are the precautionary principle and the integration of interests, which set a basic framework for sustainable management of human activities in the marine environment.

In order to compare human uses and the needs of the ecosystem, basic maps of both are necessary. This will enable a direct comparison between activities and biodiversity distribution. The BSAP has set an ambition to map specific key habitats in the Baltic Sea and maps of a number of biological ecosystem components have been used in this report (**Sections 1.6 and 3.2**). Over time, this should be extended to include all habitats, as the ecosystem covers everything and no part can be set aside.

The next step will be to decide upon guiding principles for the planning efforts based on science as well as the consideration of the needs and concerns of various stakeholders. Such an approach could deliver a general level for the protection of biodiversity by concentrating pressures in specific areas. Hopefully, it would also contribute to reducing the overall level of impacts of human activities. Concrete spatial planning could be based on a type of zoning whereby sectors or local interests could be addressed directly and according to the sectoral rules for operation. The primary goal of maritime spatial planning is to set the framework for sustainable development by balancing economic, ecological and social aspects, but it can also contribute to reaching the environmental goals.

The proposed actions in this chapter were highlighted as the most potential ones to reach the BSAP vision of the good environmental status. As a note of caution, the principles on which the ecosystem operates are not negotiable and there are no linear linkages between cause and effects. **Figure 4.5** describes the process to achieve good environmental status (BSAP or Marine Strategy Framework Directive).

Chapter 5: What are the costs and benefits?

Huge economic values are at stake in the Baltic Sea today.

We cannot afford to wait for more information before action is taken.

Actions are costly but there is a great risk that non-action will result in even higher costs.

Large-scale studies of costs and benefits are needed to improve future decision-making.

The environmental problems of the Baltic Sea have often been described economically as being the "tragedy of the commons" (Hardin 1968). That is, individuals, polluting parties, and nations have little incentive to take environmentally improving actions because they themselves bear the full cost of their action, but the cost of inaction due to environmental deterioration is shared by everyone. Thus, shared limited resources such as Baltic Sea ecosystem services are bound to be depleted and destroyed even when it is clear that it is in no one's long-term interest for this to happen. This dilemma constitutes a serious challenge to the leadership skills in the Baltic Sea nations. Developing and fulfilling international agreements is one way to solve this problem.

This chapter presents our current knowledge of the costs and benefits of taking environmentally improving actions in the Baltic Sea. Analyses of costs and benefits related to ecosystem goods and services (see **Fig. 5.1**) are useful to decision-makers in several ways: first of all, a description of the degradation of ecosystem functioning in economic terms facilitates the understanding and acceptance of expenses allocated to environmental remedial measures. Second, it supports rational decision-making. Since resources in society are scarce, trade-offs must usually be made between a) environmental management decisions and other policy actions, as well as b) different areas of environmental policy. Third, once the policy targets are set, economic analyses can provide information on how to reach the targets in the least expensive ways.

The main purpose of carrying out a cost-benefit analysis is to determine whether or not a project (or a policy/regulation/decision, etc.) is economically profitable to society. This is done by comparing the positive (benefits) and negative (costs) impacts of the project. If the total benefits are greater than the total costs, the project is economically profitable. Even if the aim is to monetize as many benefits and costs as possible, there will always be some impacts that are difficult or even impossible to express in monetary terms. Such aspects often arise from the difficulty of predicting the benefits of ecosystem services over the long term, in contrast to the short-term profits of direct exploitation of these resources, often in an unsustainable way. The short-term benefits of using resources are often easier to assess and often gain higher priority. The quite frequently neglected long-term benefits may, however, be of great importance and must not be forgotten when the costs and benefits are compared in the final step of the cost-benefit analysis, as illustrated in **Figure 5.1**. This basic procedure is referred to in this chapter when cost-benefit analysis is discussed. A complete cost-benefit analysis should also contain a sensitivity analysis (how results are affected by different assumptions) and a distributional analysis (how costs and benefits are distributed among groups and individuals).

Existing data and the framework of this study have not allowed a full-scale cost-benefit analysis. The purpose of this chapter is rather to identify as many costs and benefits as possible in order to obtain indications of economic profitability.

The Helsinki Commission aims to provide as comprehensive a picture as possible. However, most of the studies concerning costs and benefits are of Swedish and Finnish origin; hence, most of the examples in this chapter are from these countries. The chapter is organized as

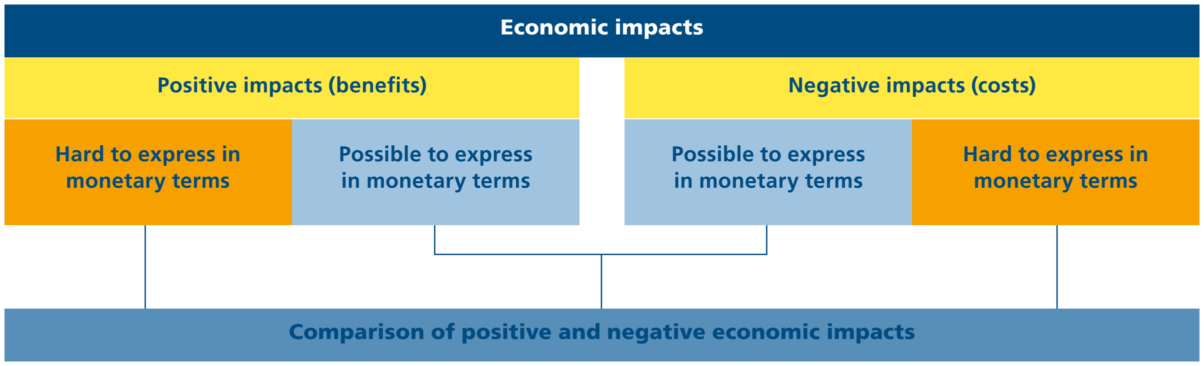


Figure 5.1 Main principles of a cost-benefit analysis.

follows: in **Section 5.1**, the ecosystem services of a healthy Baltic Sea are listed. **Section 5.2** describes which groups in society derive benefits from these ecosystem services. In **Section 5.3**, the costs of an unhealthy ecosystem are discussed. **Section 5.4** describes costs and benefits of actions to implement the BSAP.

5.1 Services provided by a healthy Baltic Sea

Nature provides humans with many valuable services. Obvious examples are services such as the provision of food and recreational opportunities, but there are also less obvious examples, such as the deposition and burial of hazardous substances in sea bottom sediments. Marine ecosystem services can be divided into provisioning, supporting, regulating and cultural services, following the classification used in the UN Millennium Ecosystem Assessment (MEA 2005).

The project Economic Marine Information conducted by the Swedish government (Swedish EPA 2009a) identified a total of 24 marine ecosystem services in the Baltic Sea (see **Table 1.1**). They are related to each other in various ways, and thus cannot be viewed separately. For example, in order for the sea to produce edible fish, suitable habitats and sediments with a 'good' or at least 'moderate' status or a good pollutant retention capacity are required. Most importantly, each service is likely to be irreplaceable (Swedish EPA 2009a).

5.2 Who uses/benefits from the services?

How does the general public use the ecosystem services listed in **Table 1.1**? In which ways do industries depend on ecosystem services for their activities?

The general public uses the ecosystem services in many different ways. For example, the sea provides food (provisioning ecosystem services) as well as recreational opportunities (swimming, walking along the beach, sailing, diving, etc.). But even if people do not use the ecosystem services directly, they may value the pure existence of certain ecosystem services, i.e., the sea holds or presents existence values that may be economically assessed.

Recreational opportunities are examples of cultural ecosystem services. Other examples of cultural ecosystem services provided by the sea are: the opportunity to enjoy beautiful scenery, education and scientific information, and cultural heritage. Also, there are many examples of motifs taken from the sea, e.g., in books, films, paintings, music, architecture and advertising. Furthermore, it is likely that the sea stimulates people to learn more about the environment in general so that school trips, museums, nature centres, aquariums, etc., are generated and related jobs are created in the Baltic Sea region (Swedish EPA 2009a). Humans also benefit considerably from the regulating ecosystem services listed in **Table 1.1**, for example, the impact on climate and air quality. In fact, all of the ecosystem services together are important for the well-being of humans.

Commercial fisheries and sport fisheries are, of course, highly dependent on well-functioning marine ecosystems to produce fish. The most important commercial fisheries in the Baltic Sea in terms of volume are sprat (*Sprattus sprattus*) and herring (*Clupea harengus*). The most important fish in economic terms, however, is cod (*Gadus morhua*). In order for the sea to produce fish, especially the species breeding close to shores, protection is needed for nursery areas such as seagrass meadows, which are in great need of preservation. Currently, many nursery areas are being destroyed due to human activities that cause eutrophication and physical damage. Furthermore, the current management of the fisheries in the Baltic Sea has led to large overexploitation within a number of fisheries, i.e., the fishing pressure exceeds sustainable levels. This imposes substantial costs on society (Swedish EPA 2009a). Another dependence on ecosystem services that exists in fisheries is that of clean water and sediments. High concentrations of hazardous substances in the water and sediments and in fish have resulted in sales bans in the EU on at least some fish species, directly decreasing the market value of these fisheries.

Tourism in the coastal areas of the Baltic Sea (and other sea areas) is, to varying degrees, dependent on the state of the sea. Swimming, diving, sailing and other water-related activities are more attractive to tourists when the water and the beaches are visually attractive (clear water and clean beaches) and safe for use. The value of clean beaches and good seawater to the tourism industry has been investigated by Swedish EPA (2009a). One conclusion from the study is that the state of the marine environment has so far generally not been a major issue in the tourism sector. One explanation for this relative lack of concern is that the situation is perceived as 'good enough' and the demand still matches the supply. However, there is an awareness

of the serious problems that the increasing frequency and scale of widespread algal blooms may cause, particularly for beach tourism in Sweden, Denmark and Finland. Apparently, tourism in these countries is more dependent on the state of the environment than tourism in Estonia, Latvia, Lithuania and Poland. Another concern of the tourism industry is the risk of large oil spills owing to their enormous impacts on tourism in affected areas.

5.3 Costs of an unhealthy Baltic Sea

It has been concluded that eutrophication and overfishing are the two main causes of ecosystem destruction in the Baltic Sea. At present, only ten of the 24 ecosystem services listed in **Table 1.1** are operating properly (Swedish EPA 2009a).

Exploitation of the most commercially attractive fish species in an unsustainable way represents a threat to the entire marine ecosystem and, obviously, to the fishing industry itself. Around 50 000 people are employed in the fisheries sector of the Baltic Sea (European Commission 2006) and their livelihoods are at least partly dependent on this industry. The annual total turnover in commercial fisheries and aquaculture in the Baltic Sea has been estimated at € 4.5 billion (HELCOM and NEFCO 2007).

Apart from the purely economic value from commercial fisheries, there are also cultural values of retaining a commercial fishery. In Sweden, these cultural values have been estimated at almost € 200 million per year. The estimate was based on the willingness of Swedish households to pay to enable 1500 of commercial fishermen to keep their jobs instead of 900 as forecasted (Kataria and Lampi 2008). From an economic point of view, however, sport fisheries is even more important with at least one million sport fishermen in Sweden alone, to be compared with the approximately 50 000 people employed in commercial fishery in the entire Baltic Sea area. The total willingness to pay for sport fisheries in Sweden, based on fishing in 2006, has been estimated at around € 265 million per year. In Finland, Denmark and Sweden, the willingness to pay to preserve the current level of recreational fisheries is estimated at € 700 million per year (Toivonen et al. 2000).

The annual turnover in the tourism industry in the Baltic Sea countries has been estimated at € 90 billion, but this includes all forms of tourism, not only those linked to the Baltic Sea itself. The number of people employed in the coastal tourism sector in the Baltic Sea countries excluding Russia amounts to 156 200 people (European Commission 2008). One example of tourism directly linked to the Baltic Sea is cruise tourism. In one study carried out in 2007 (COWI 2007), it was concluded that the Baltic Sea region is the fastest growing cruise market in the world. Cruise tourism in the countries around the Baltic Sea gives an annual turnover of around € 443 million and approximately 5 500–11 500 jobs are created. Another example is the leisure boat industry, with sales of approximately € 265 million in Sweden in 2006. A third local example is from the Swedish island Öland, where algal blooms in 2005 caused losses in the tourism industry estimated at around € 27 million (Swedish EPA 2009a). Thus, even if the total turnover associated with tourism on the coast and in the sea in the Baltic Sea countries is unknown, there are examples indicating that the size is considerable. Some of these economic values will be at risk if the environmental state deteriorates.

5.4 Costs and benefits of actions to implement the BSAP

The HELCOM Baltic Sea Action Plan is a strategy that has been adopted by the governments of all Baltic Sea coastal countries, aiming to restore the good ecological status of the Baltic marine environment by 2021. For each of the BSAP key issues below, i.e., eutrophication, hazardous substances, biodiversity and maritime activities, the costs and benefits of actions have been investigated to some extent.

Together with overfishing, eutrophication has the largest negative impact on the environmental state of the Baltic Sea. Ecosystem services, habitats, food, and tourism are all threatened by eutrophication. The cost of applying the BSAP eutrophication target by implementing the provisional nutrient reduction targets and decreasing the annual inputs of nutrients to the Baltic Sea (15 000 tonnes of phosphorus and 130 000 tonnes of nitrogen, as defined in the BSAP) has been estimated using available data and models (Swedish EPA 2009a, HELCOM and NEFCO 2007). The results from these two analyses are summarized in **Table 5.1**. Evidently, the two studies give results in the same order of magnitude, i.e., total annual minimum cost varies between € 2.6 and € 3 billion for the region as a whole.

Table 5.1 Total costs and benefits of achieving the BSAP target regarding eutrophication in the entire Baltic Sea region (millions of Euros per year).

Costs of proactive actions:	Million €
Total minimum cost of achieving the BSAP targets for emission reductions (Swedish EPA 2009a).	2 560
Total cost of achieving the BSAP targets for emission reductions (HELCOM and NEFCO 2007).	3 000
Benefit gained from reaching targets:	**Million €**
Total benefits of avoiding the effects of eutrophication estimated on the basis of the willingness of people to pay (Swedish EPA 2009a).	4 830
Total benefits of improved water quality based on meta-analysis (Huhtala et al. 2009).	2 564

The benefits of avoiding the effects of eutrophication have been estimated on the basis of the willingness of people to pay, using data from the mid-1990s (Swedish EPA 2009a). The benefits of improved water quality in general have been estimated in a meta-analysis by Huhtala et al. (2009). The results from these studies are presented in **Table 5.1**. The benefits estimated cover a wide range, i.e., an annual value of € 2.6–4.8 billion. The disparity in results can be at least partly explained by the fact that different methods were used to estimate the benefits. Among other factors, benefit estimates are very sensitive to the choice of method. A new, large-scale economic valuation study, covering the entire Baltic Sea area, would provide a more comprehensive picture of the total benefits from an improved environmental status in the Baltic Sea.

Hazardous substances also impact several ecosystem services. Most economic research in this area relates to the food service. Several species of oily fish caught in the Baltic Sea cannot be sold in the EU because they contain high levels of environmental toxins such as PCBs and dioxins. There are currently no systematic studies on the cost of reducing the levels of hazardous substances in the Baltic Sea (Swedish EPA 2009a).

However, Huhtala et al. (2009) presented a Finnish example with cost estimates regarding the implementation of the monitoring required by the EU Water Framework Directive (WFD) and the EU REACH Regulation. The total annual Finnish costs of monitoring, work expenses, analysis, investment and equipment have been estimated at around € 217 000–650 000.

The benefits of actions to reduce the problems of hazardous substances have not yet been estimated for the entire Baltic Sea area. One likely benefit, however, is the reduction of ecosystem risks related to the decoupling of ecosystem components resulting from the deterioration of basic habitats or species communities due to hazardous substances. Another benefit is the improvement in seafood quality.

Currently, no large-scale studies on the costs and benefits of preserving biodiversity in the Baltic Sea region exist. However, Swedish EPA (2009b) has estimated the cost for Sweden to fulfill its commitment in the BSAP regarding biodiversity at around € 15 million per year during the next five years. This cost is divided between actions for more sustainable commercial fisheries and mapping of key species and habitats.

Huhtala et al. (2009) argue that the valuation of ecosystem services related to biodiversity is particularly challenging due to the fact that biodiversity is connected to virtually all ecosystem processes and functions. A Swedish study (Konjunkturinstitutet 2007) discussed how biodiversity can be economically valued. It concluded that there are established literature and well-known methods regarding the valuation of different aspects, mainly species, in relation to biodiversity. However, much research is still required for the valuation of the productivity, stability and resilience of ecosystem services and how these are affected by biodiversity. One major conclusion from the study is that the economic value of biodiversity is determined by people's valuation of ecosystem services and these latter, in turn, are dependent on changes in biodiversity. People's valuations are also dependent on the social, cultural and political context.

Another project that examined the challenges of pricing ecosystem services was initiated by Germany and the EU Commission. In the report 'The Economics of Ecosystem Biodiversity' (TEEB 2008), the costs of lost biodiversity and the associated decline in ecosystem services worldwide were investigated and compared with the costs of effective conservation and sustainable use.

The Baltic Sea is one of the most heavily trafficked areas in the world. The number and size of ships, particularly oil tankers, have been steadily increasing. At present, there are constantly around 2 000 ships at sea in the Baltic Sea, accounting for up to 15% of the world's cargo transportation (HELCOM 2007e). In the Baltic Sea region, approximately 50% of all foreign trade is transported by sea and more than 50% of total maritime transport is related to the four Nordic countries (Norway, Denmark, Sweden and Finland). Between 2003 and 2020, maritime transport is expected to grow by 64%. However, the economic downturn in 2009 has led to a decrease in cargo volume turnover (Baltic Port Barometer 2009). The expectations for 2010 look brighter and port representatives from the nine Baltic Sea countries expect a growth in cargo volumes and passenger traffic. Furthermore, employment related to shipping in the Baltic Sea countries excluding Russia amounts to 108 000 people (European Commission 2008). Another fact is that 70% of all jobs related to shipping are onshore, e.g., naval, architecture, science, engineering, electronics, cargo handling and logistics (EU, Press Release 2009).

Trade in the region is certainly highly dependent on transport by sea, but the shipping industry creates obvious risks to the environment. Because transportation is heavily dominated by oil and oil products, there is a risk of major oil spills. In addition to operational emissions from shipping into air and discharges to water, another risk is the introduction of invasive alien species via ballast water and hull fouling. Ecosystem services help to assimilate some, but not all, side-effects from shipping (HELCOM and NEFCO 2007). The cost of preventing many of the alien species invasions in the Baltic Sea has not yet been estimated but preparing this estimate is an important task for the future. Huhtala et al. (2009) suggested that these costs are related to the benefits generated by maritime shipping. Gren et al. (2007) calculated the cost of reducing the impact of bay barnacles on boats to be € 18–45 million.

The low water temperatures, lack of water renewal and other factors make the Baltic Sea very sensitive to oil spills, but large-scale economic valuation studies on the economic costs of oil spill damage or their prevention have not yet been carried out in the Baltic Sea region. However, a pilot study has been conducted in 2009 in Germany, estimating the willingness of German households to pay to prevent pollution from oil spills in the North Sea (Liu et al. 2009). The total aggregated annual willingness to pay was estimated at € 1.1 billion. A scenario study of a major oil spill affecting parts of the Stockholm archipelago estimated the cost at over € 90 million in 2007 (Swedish EPA 2009a). In another study from the Gulf of Finland, the costs of investment in and renovation of oil combating equipment in 2008–2017 were estimated at € 210–240 million. Other related costs amounted to around € 52 million (Huhtala et al. 2009).

Litter also impacts recreation, food and habitat ecosystem services. Hall (2000) estimated the cost of beach cleaning on the west coast of Sweden at € 1.2 million in 1997. The corresponding estimate for Denmark in the same year was € 1.4 million. There do not appear to be more recent estimates of the benefits from beach cleaning.

Chapter 6: Conclusions and outlook

This first HELCOM Initial Holistic Assessment of the environmental status of the Baltic Sea delivers up-to-date, science-based information on the status and pressures based on data from the period 2003–2007. The assessment also offers solutions and associated actions including information on the economic benefits of restoring the ecosystem health on a Baltic Sea-wide scale as well as on a basin-wide scale. Perspectives for attaining a healthy Baltic Sea in 2021 are also described.

6.1 Conclusions

This chapter draws conclusions concerning the unacceptable health status of the Baltic Sea and its basins, as presented in **Figure 6.1**. Several vital functions of the marine ecosystem were found to be weakened during the years 2003–2007; overall, the ecosystem health of the Baltic Sea appears to be impaired. According to this assessment, none of the open basins of the Baltic Sea had an acceptable status. Only a very few coastal areas along the Gulf of Bothnia can be considered healthy.

The state of the ecosystem health is linked to the particular pressures and potential impacts acting upon each specific sea basin (**Fig. 6.2**).

Overall, the potential cumulative impact of human activities was estimated as being high in all areas except for the open-sea areas of the Gulf of Bothnia. In general, the basin-wise ranking of pressures implies that the two most dominant human pressures are related to eutrophication and selective extraction of species by fishing. Despite decreasing inputs during recent decades, inputs of heavy metals are still an issue of concern in all basins. The following concerns should also be highlighted: (1) hunting is an issue in the Bothnian Bay, the Åland and Archipelago Seas, and the Belt Sea, (2) underwater noise from shipping is an issue in the Northern Baltic Proper, the Arkona Basin, Kiel Bight and Mecklenburg Bight, and (3) bottom trawling, including its physical disturbance impact, is a significant issue in the Kattegat, Belt Sea, Kiel Bight, Mecklenburg Bight, Arkona Basin and Bornholm Basin.

The maximum allowable inputs of nutrient loads, as they were agreed in the Baltic Sea Action Plan, are currently being exceeded and the overexploitation of several fish stocks continues. Hence, a striking conclusion from the holistic assessment of ecosystem health is that the capacity of the Baltic marine ecosystem to deliver ecological goods and services has been widely overestimated. Our demands for marine resources far exceed the goods and services the sea can offer. Its resilience is weakened. This report reveals that our previous measures have been insufficient or too late to relieve the pressures acting on the marine ecosystem. Furthermore, they have been insufficient to halt fundamental shifts in the food-web structure.

The monitoring and data acquisition that formed the basis for the results presented in **Figures 6.1** and **6.2** were carried out in the years 2003–2007. It is an inconvenient truth that there are no quick fixes to reach our vision of a healthy Baltic Sea. Rapid achievements are hindered by the legacy of hazardous pollutants and the large pool of nutrients in the sea. In particular, nutrients and hazardous substances in the sediments are easily reintroduced into the ecosystem when impacted by hypoxia, dredging, bottom trawling or construction work. But despite all the challenges ahead of us, it is feasible to reverse the situation and bring the environmental management of the Baltic Sea area on track by 2021, at the latest.

We must acknowledge the fact that the Baltic ecosystem is sensitive and challenged by natural characteristics as well as by human activities. Environmental protection is even more important than in other sea regions. Clearly, the Baltic Sea is not in a position to meet the present demands of the 85 million people living in its catchment area.

The Baltic will never again be a wild and pristine sea area. Nonetheless, its health can be improved and its ecological goods and services restored for long-term use. The knowledge, technology and funds are in place. Now it is our turn to act.

6.2. Outlook

There are huge economic values at stake in the Baltic Sea today. Management actions are an insurance against the loss of these values. Waiting for more information before taking action seems a bit like waiting to put out a fire in a house because you do not know where to find the cheapest fire extinguisher or which of the house's rooms you would like to save the most.

The economic analysis in this assessment gives a clear picture regarding the economy of action versus inaction. We have a fairly clear idea of the costs and benefits associated with taking action. We know, if not always in quantitative, then at least in qualitative economic terms that eutrophication, oil spills, invasive alien species and hazardous substances cause several negative economic effects on, e.g., recreation, tourism, fisheries and ecosystems, and we know several measures and associated actions that could be taken or enforced to reduce these negative effects.

The obvious conclusion from this assessment is that, from an economic perspective, we cannot afford to wait. Actions will be costly and constitute a severe challenge to the leadership skills of the Baltic Sea countries, but there is an undeniable risk that it will be much more costly not to take immediate action, due to the potentially serious effects on highly valuable ecosystem services.

Given the findings of this Initial Holistic Assessment that almost the entire Baltic Sea is in an unhealthy condition, solutions should be implemented swiftly and in a cost-effective manner to fulfill the vision of a thriving and healthy Baltic Sea.

The two overarching issues identified by this Holistic Assessment are: 1) nutrient enrichment and eutrophication, and 2) the environmentally negative effects of fisheries. Substantial progress with regard to these issues is a prerequisite for improving the health status of the Baltic Sea. The Initial Holistic Assessment identified other pressures with environmentally negative effects, but their impacts are somewhat less important to manage at this stage because they are overshadowed by the effects of the immense nutrient loads and the selective extraction of certain commercial fish species. However, these other pressures can be very important on a smaller scale.

The further development and strengthening of nutrient management strategies by the countries in the Baltic Sea catchment area will be based on multiple policy drivers, inspired by the BSAP, and often also by national legislative plans implementing European directives and other national requirements. The specific management actions each country takes are not an issue—the key is that pressures are progressively reduced, especially with regard to diffuse nutrient sources. It should be clear that the ecosystem health status will only improve if inputs of both nitrogen and phosphorus are significantly further reduced. In this context, it should also be noted that there are strong links between eutrophication abatement and the protection of marine biodiver-

Bothnian Bay: The assessment of the ecosystem health of open and coastal parts of the Bothnian Bay indicates that the status is impaired. Eutrophication is generally not an issue in the Bothnian Bay, except in a few isolated coastal areas. In contrast, disturbance by hazardous substances is a major problem in the open and coastal waters, both in Finland and Sweden. Regarding the biodiversity, it seems that the status is good in Swedish coastal waters and only the open parts of the Bothnian Bay and Finnish coastal waters are likely to have an unfavourable status.

Bothnian Sea: The assessment and classification of the ecosystem health of open parts of the Bothnian Sea indicate that the status is impaired. However, one assessed area in the Swedish coastal waters is classified as good. Biodiversity of the Bothnian Sea in general is good, both for the open parts and the majority of coastal waters. The open parts of the Bothnian Sea, a few coastal areas in the southern Swedish parts, and Finnish coastal waters are affected by eutrophication, while the Swedish northern coastal waters are not affected by eutrophication. Regarding hazardous substances, all assessed areas are disturbed by hazardous substances.

Bornholm and Arkona Basins: The assessment and classification of ecosystem health of the Bornholm and Arkona Basins indicate that the status is impaired. Eutrophication and contamination by hazardous substances are significant issues and in combination with the pressures from fishing, biodiversity status has become significantly impaired. The Arkona Basin is in a slightly better condition than the Bornholm Basin.

Kattegat and Belt Sea: The assessment and classification of the ecosystem health of the open parts of the Kattegat and Belt Sea indicate that the status is impaired. Hazardous substances and biodiversity have an impaired status, while eutrophication is a problem mainly in the southern Kattegat and the Belt Sea.

Kiel Bight and Mecklenburg Bight: The assessment and classification of ecosystem health indicate an impaired status, more pronounced in the coastal waters. The status is more critical than that of the Arkona Basin. Eutrophication, biodiversity and contamination with hazardous substances are all significant issues.

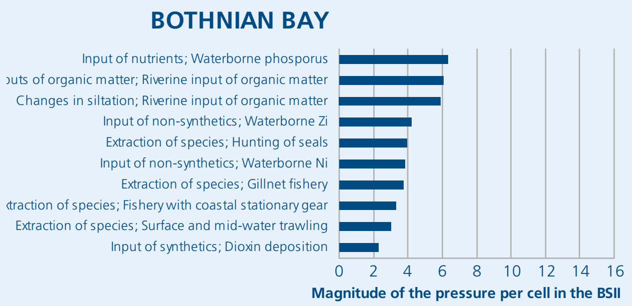
Gulf of Finland: The assessment and classification of the ecosystem health of open parts of the Gulf of Finland indicate that the status is impaired, especially in the eastern parts. Eutrophication and hazardous substances are the major and most widespread problems. Biodiversity generally has an unfavourable status in both open and coastal waters. However, results indicate that isolated coastal waters along the Estonian coast might have a favourable conservation status.

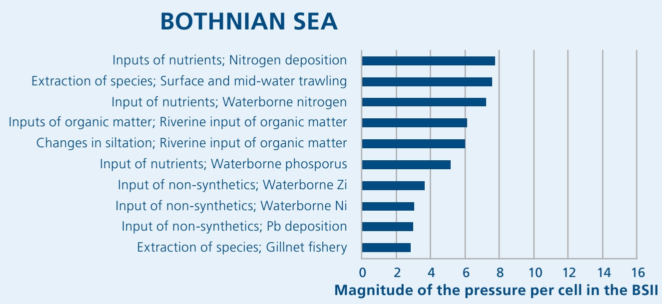
Gulf of Riga: The assessment and classification of the ecosystem health of both open parts and coastal waters of the Gulf of Riga indicate that the status is impaired. The Gulf is affected by eutrophication, especially in the northern and central parts. Regarding the status of hazardous substances, the Gulf is impaired and the same is true for the conservation status of biodiversity.

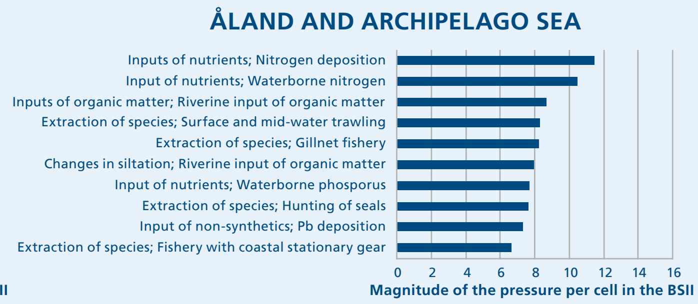
Baltic Proper: The assessment and classification of the ecosystem health of open parts of the Northern, Western and Eastern Baltic Proper indicate that these areas have the lowest status in the Baltic Sea. Eutrophication is a significant problem as are also hazardous substances and decline of biodiversity. No positive signals were encountered.

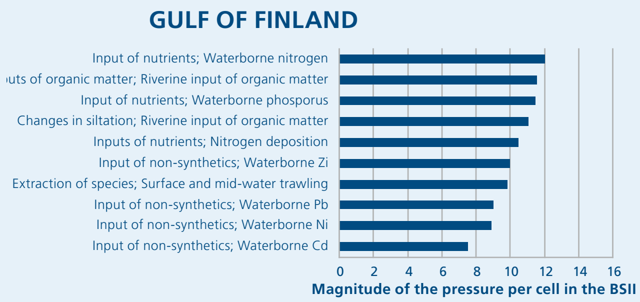
Gulf of Gdansk: The assessment and classification of the ecosystem health of the whole Gulf of Gdansk indicate that the status is impaired. Eutrophication is a major problem, biodiversity is under significant pressure and the hazardous substances status is disturbed; all of this is a consequence of discharges from the large, highly populated catchment area.

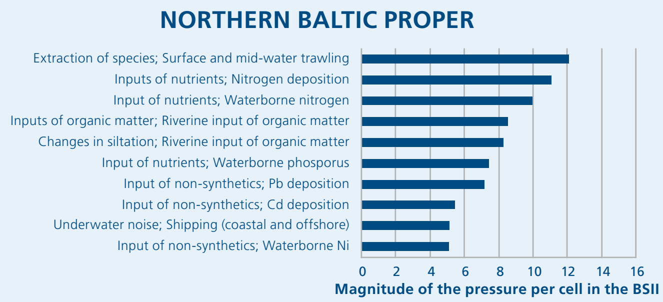
Figure 6.1 Summary of the status assessments for the Baltic Sea sub-basins.

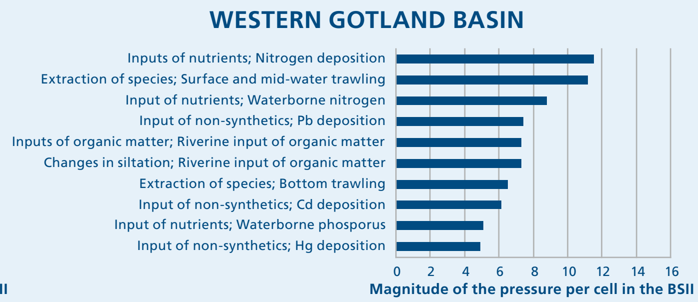


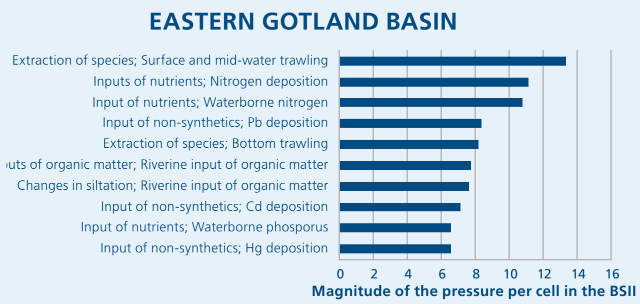


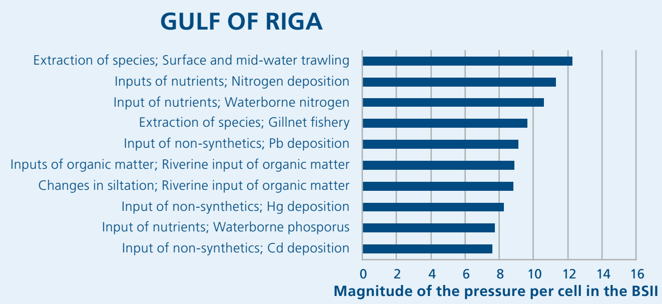


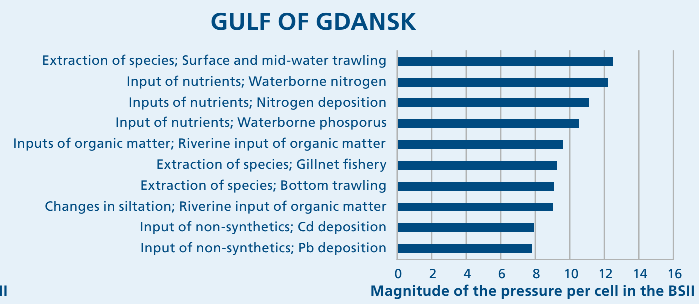


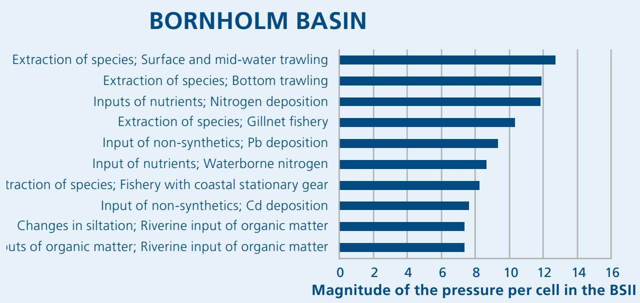


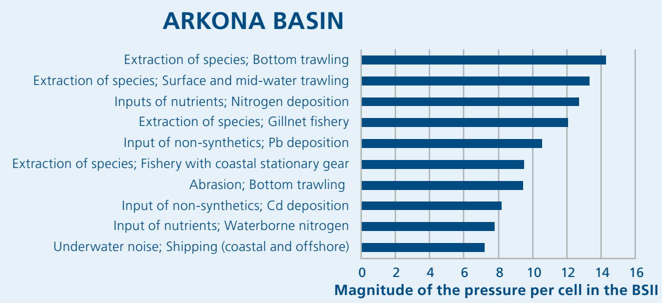


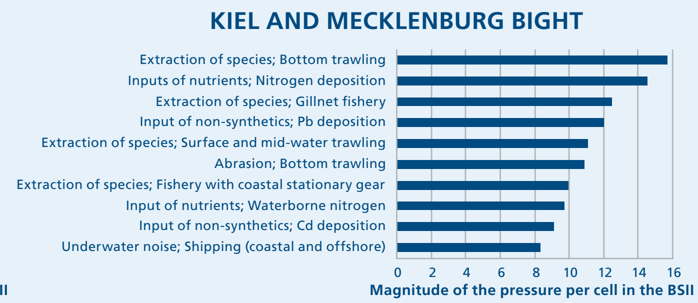


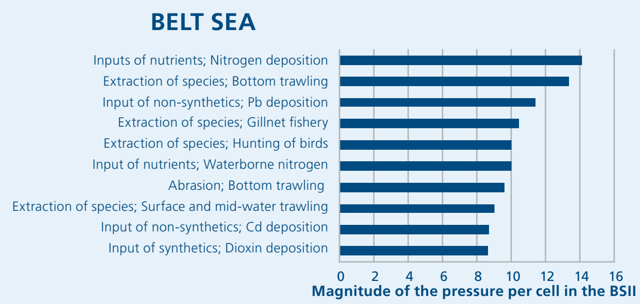












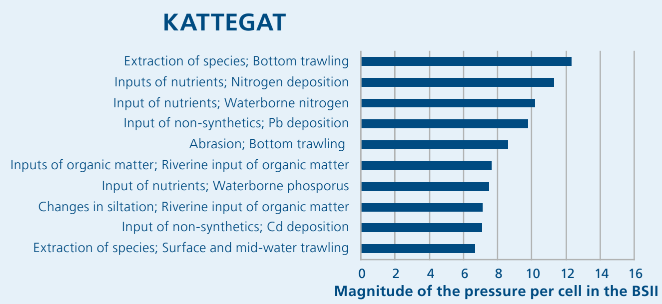


Figure 6.2 **Ranking of area-specific pressures and the potential impacts on the ecosystem for each sub-basin according to the Baltic Sea Impact Index. The magnitude of the potential impacts can be compared across basins. See Section 3.2 and HELCOM (2010b) for details.**

sity. Improving eutrophication status will, as an added value, result in significant improvements in habitat quality and conservation status in many parts of the Baltic Sea.

It is recommended that solutions with multiple positive effects be sought. Alleviating eutrophication will additionally improve conservation status, reducing the environmentally negative effects of fishing activities may improve both conservation status and eutrophication status, reducing inputs of hazardous substances will improve ecosystem structure and function and the quality of seafood for human consumption, the restoration of specific habitat types may result in improved eutrophication status, etc.

The links between pressures and ecosystem health are generally well understood. However, for the marine environmental policies in the Baltic Sea countries to be as balanced, well-targeted, and efficient as possible in the future, there are major knowledge gaps to be filled within the field of economics. In order to achieve this, it is recommended that large-scale studies be conducted on both costs and benefits to obtain a more holistic picture, as the literature today mainly rests on small-scale case studies. New studies should focus on, e.g., eutrophication, fisheries, oil spills, invasive species, and hazardous substances. Putting a price tag on ecosystem goods and services by the use of modern economic valuation techniques is also a means of clarifying that a healthy Baltic Sea really has a value to people in the Baltic Sea countries, that is, that people are willing to pay for actions. This work should be coordinated within HELCOM to facilitate a contribution to the implementation of the Marine Strategy Framework Directive where these assessments are required. It is also recommended that the results from such future cost-benefit analyses are not viewed as the sole decision-making criterion, but as one (although undisputable) part of the larger complex of topics to include in good, sustainable decision-making. In addition to economic issues, this complex should also include ecological and social or cultural aspects.

There is also a need to further improve the new methodologies (HOLAS, BSPI and BSII) for future operational applications as well as to adjust existing tools to new legal requirements and scientific knowledge or guidance. For HELCOM Contracting Parties that are also EU Member States, it is of utmost importance to harmonize the assessments based on HELCOM or EU regulations to the extent possible in order to ensure coherence within marine regions, as stipulated by the Marine Strategy Framework Directive. This harmonization is still pending. In addition to this urgent activity, there is also a need to improve our knowledge on human pressures on the Baltic Sea such as noise and marine litter. This would include adequate mapping (noise) and monitoring (litter) and the development of methods to assess their ecological impact. This would also contribute to other relevant requirements, especially of the EU Marine Strategy Framework Directive. Furthermore, in future it might enable the preparation of joint HELCOM contributions to responsible international organizations (e.g., International Maritime Organization) to request possible reduction measures if they are not under the remit of HELCOM.

In addition to the work to reduce human pressures, climate change creates an extra challenge. As precipitation is projected to increase especially in the northern part of the Baltic Sea catchment area, this may, in combination with increasing winter temperatures, lead to increased winter runoff and leaching of nutrients. Furthermore, an increase in water temperatures will make benthic communities and habitats more vulnerable to eutrophication and hypoxia. Ultimately, the effects of climate change might render the HELCOM vision of a healthy Baltic Sea difficult or impossible to attain using currently agreed actions and measures. Further reductions of pressures as well as specific adaptations will undoubtedly be required in order to improve the ecosystem health of the Baltic Sea and reduce eutrophication effects, especially under a changing climate.

Possible shifting baselines and regime shifts pose another challenge. Management should keep human pressures at a level that does not unbalance the ecosystem and avoids causing a regime shift. Hence, the system has the possibility to recover and develop to the status of the HELCOM 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 human economic and social activities".

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Ecosystem Health of the Baltic Sea 2003–2007
HELCOM Initial Holistic Assessment

This HELCOM Initial Holistic Assessment documents the ecosystem health status of the Baltic Sea by addressing eutrophication, hazardous substances and biodiversity during 2003-2007. It also documents the related pressures and possibilities for solutions, and establishes a baseline for following the effectiveness of the implementation of the HELCOM Baltic Sea Action Plan adopted in 2007.

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