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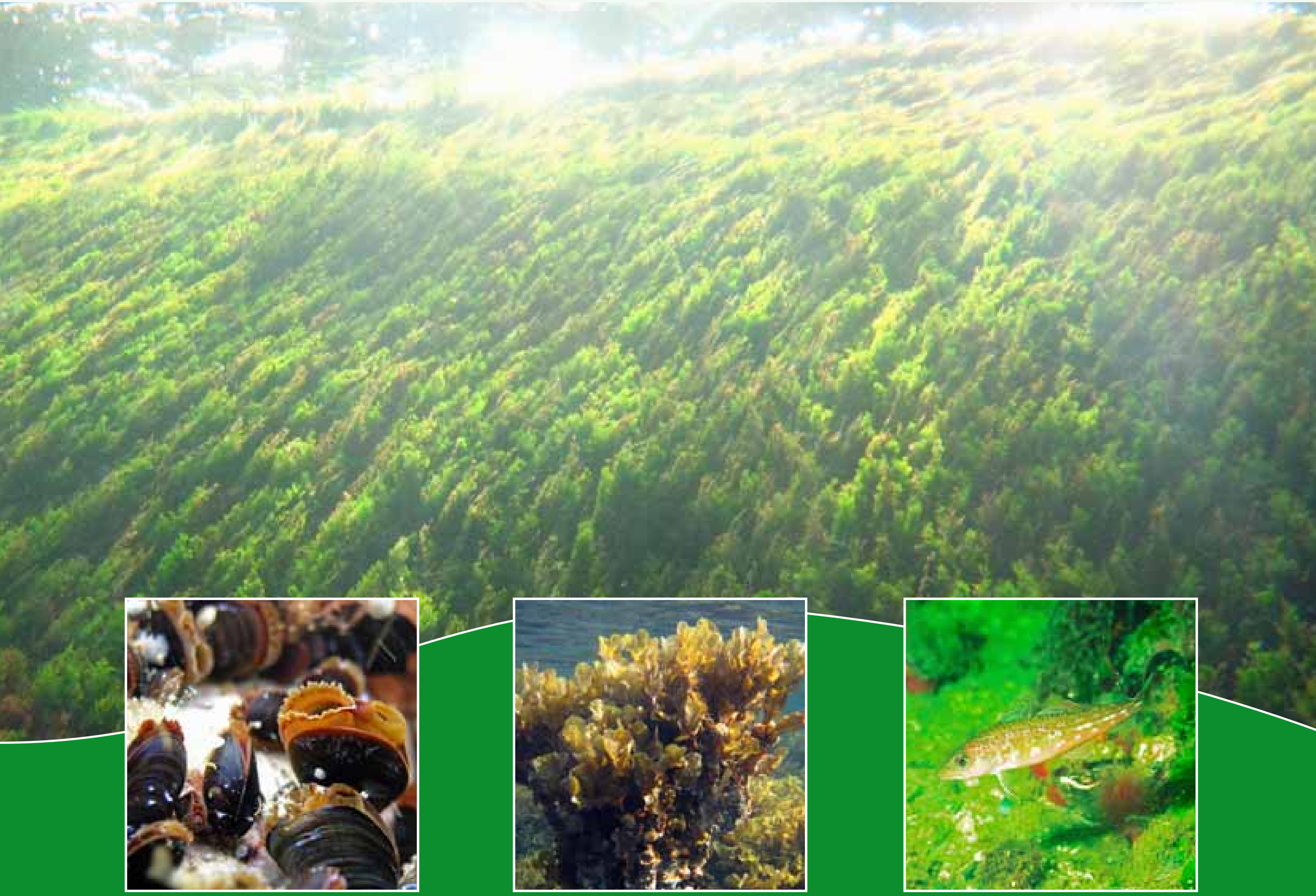
Biodiversity in the Baltic Sea

An integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea



Helsinki Commission

Baltic Marine Environment Protection Commission

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PREFACE

Sixty different benthic landscapes, 150 biotopes, and a richness of about 100 species of fish, 450 macroalgae species, 1000 zoobenthos species, 3000 plankton species, and many thousands of unknown species of bacteria and viruses—that is a rough estimate of the biodiversity hidden under the Baltic Sea surface. These organisms and their ambient environment form the building blocks of the ecosystem and the interactions among all components determine the characteristic features of the Baltic Sea.

During the past few centuries, human activities have gradually changed the Baltic Sea environment in many ways: loads of nutrients and hazardous substances have increased, resource extraction has intensified, and the physical environment has been modified by construction and dredging activities. Since the Second World War, the pressures have increased. The more we learn about the effects of these activities, the clearer it becomes that they have a profound and even irrevocable effect on the diversity of life in the sea. Today, changes to the Baltic Sea ecosystem, such as reduced water transparency and shifts in coastal bottom vegetation, are obvious not only for ecologists but also for the layperson. Increasing human pressures have changed the Baltic Sea ecosystem and thus undermined its structure and functions. This affects not only the characteristic appearance of the sea, but also the supply of goods and services that are recognized as valuable to society, such as revenues from fisheries and bathing waters free from algal blooms.

In order to improve the condition of the Baltic Sea, the Contracting Parties of the Helsinki Commission (HELCOM) adopted a plan in 2007 to restore the sea to good ecological status: the Baltic Sea Action Plan (BSAP). One of the four main goals of the Action Plan is to achieve a favourable conservation status of Baltic Sea biodiversity. This biodiversity component of the Action Plan can also be seen as a contribution to the wider goal of protecting biodiversity at a global level. Member States of the European Union (EU) as well as the parties to the UN Convention on Biological Diversity (CBD) have agreed to halt the loss of biodiversity by 2010, including that of the marine environment.

With the BSAP, the HELCOM Contracting Parties also agreed to develop a common approach and tools for assessing the conservation status of Baltic Sea biodiversity. This thematic assessment report can be seen as a contribution to fulfilling this task. The report is also the second integrated thematic assessment report to be published following the HELCOM Monitoring and Assessment Strategy adopted in 2005.

The HELCOM integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea is the first comprehensive report on biodiversity and nature conservation in the region. The report provides a baseline for monitoring progress towards the goals and targets of the Baltic Sea Action Plan that relate to biodiversity. The ambition is to provide an overview of the state of Baltic biodiversity and nature protection at the beginning of the 21st century, to illustrate the links between the different pressures and activities in the Baltic area and the resulting environmental state, and to suggest specific recommendations to safeguard, and when necessary to restore, Baltic Sea biodiversity. The report also introduces a new tool for assessing the status in relation to set targets concerning biodiversity and nature conservation of the Baltic Sea, allowing a preliminary classification of conservation status.

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1 INTRODUCTION

1.1 An integrated thematic assessment of biodiversity and nature conservation in the Baltic Sea

The HELCOM Baltic Sea Action Plan as a background

The HELCOM Baltic Sea Action Plan (BSAP) was adopted in late 2007 by the environment ministers and high-level representatives of the Baltic Sea coastal countries and the European Community (HELCOM 2007a). By implementing the Action Plan, the HELCOM Contracting Parties are applying the ecosystem approach to the management of human activities in the Baltic Sea region. The ultimate goal of the BSAP is the achievement of a Baltic Sea in good environmental status by 2021.

The Action Plan devotes a specific chapter to nature conservation and biodiversity. The strategic goal for biodiversity is 'Favourable conservation status of Baltic Sea biodiversity'. In addition, ecological objectives further define the status that HELCOM Contracting Parties want to achieve:

- Natural marine and coastal landscapes,
- Thriving and balanced communities of plants and animals, as well as
- Viable populations of species.

For each of the ecological objectives, the Action Plan contains a number of more detailed targets to be employed for monitoring the progress towards achieving the strategic goal and ecological objectives. The targets contain deadlines for their achievement.

A set of measures addressing biodiversity was adopted in the Action Plan, *inter alia*, measures concerning the development of a marine spatial planning approach, finalization of a coherent network of well-managed Baltic Sea protected areas, elaboration of a habitat classification and updated Red Lists of threatened and declining species and habitats as well as measures to protect species, including a large number of fisheries-related actions.

Biodiversity and nature conservation were included as Article 15 in the revised Helsinki Convention of 1992. Since then, a number of HELCOM recommendations in the field of protection of biodiversity and conservation of nature have been adopted. These include recommendations on HELCOM Baltic Sea Protected Areas (Recommendation 15/5) and recommendations on the protection of species, such as the protection of seals in the Baltic Sea (Recommendation 27–28/2).

The purpose of this integrated thematic assessment of biodiversity is to provide a baseline for measuring progress towards the goals, objectives, and targets identified in the Action Plan. This assessment will provide information on the status of and pressures on biodiversity and nature conservation that prevailed before the implementation of the Action Plan. Improvements in the status of the environment achieved as a result of implementing the Action Plan will be evaluated by a HELCOM ministerial meeting in 2013.

This biodiversity assessment contributes to the development of harmonized assessment methods and tools. In particular, the pilot application of the indicator-based Biodiversity Assessment Tool BEAT is part of the development of quantitative assessment methodologies.

Topics of the biodiversity assessment

This assessment focuses on the marine environment of the 'Baltic Sea area'. Following the 1992 Helsinki Convention, the 'Baltic Sea area' covers the Baltic Sea and the Kattegat, including the coastal waters up to the landward limit. In accordance with the hierarchy of the biodiversity-related ecological objectives of the BSAP, the assessment has been carried out at the levels of landscapes, communities, and species (Chapters 2, 3, 4 and 5, Box 1.1).

Human pressures and activities have been assessed in terms of their sources and magnitude and their impact on Baltic biodiversity. The pressures include physical loss and damage, pollution and contamination by hazardous substances, nutrient enrichment, and biological disturbance (Chapter 6); these pressures are similar to those in Annex III, Table 2 of the Marine Strategy Framework Directive (MSFD, 2008/56/EC).

Map of the Baltic Sea area and the sub-basins of the Baltic Sea.

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Box 1.1. Biodiversity

The term biodiversity is simply a short version of the two words 'biological diversity', coined by Edward O. Wilson in the 1980s. The concept embraces not only the variety of living organisms but also the genetic diversity within a species, as well as the diversity of habitats and landscapes. The formal definition given by the Convention on Biological Diversity is that "Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

It should be noted that the term biodiversity can be used in widely different contexts and with different meanings. In a management context, as in this report, the abstract term 'biodiversity' is used to reflect the 'health' of the ecosystem, rather than the absolute diversity. The aim is also to depict the concept in more concrete terms by using specific time series or indicators. In this context, links between biodiversity status indicators and human pressures or activities are also described to point out the anthropogenic activities whose regulation is the key to preserving biodiversity.

The report also includes a special assessment of the network of Baltic Sea Protected Areas (BSPAs) (Chapter 7). The BSPA network is a central tool for protecting Baltic Sea biodiversity and is essential from the point of view of nature conservation. In addition, one of the targets of the BSAP is to have, by 2010, an ecologically coherent and well-managed network of BSPAs.

The synthesis (Chapter 8) discusses challenges and opportunities for improving biodiversity protection in the future.

Process of producing the assessment

This assessment is based on existing knowledge and the chapters cover different types of components: qualitative descriptions, assessments based on time-series analyses, whenever applicable, and a pilot application of an indicator-based assessment tool, the HELCOM Biodiversity Assessment Tool (BEAT).

The time-series analyses are based on data submitted by the national contact points of HELCOM countries in a HELCOM BIO project that was carried out to produce the assessment, as well as data submitted directly by associated experts. The BEAT case studies, presented in Chapter 5, are based on a compilation of records gathered through the HELCOM BIO project and the HELCOM project on the elaboration of an integrated thematic assessment of eutrophication in the Baltic Sea (HELCOM EUTRO-PRO). Together, the time-series and the BEAT analyses were used to evaluate the overall status of biodiversity and nature conservation in the Baltic Sea.

1.2 A brief look at the history of the Baltic Sea and its biodiversity

The Baltic Sea has a long history of changing salinity conditions, with both marine and freshwater phases. This is clearly visible in fossil records, which show an alternating dominance by typical freshwater and marine species since the last glaciation period (Berglund et al. 2005). The Baltic Sea with salinity levels and climate conditions close to the current conditions has existed for about 3000 years. In terms of ecological history, this is a short period and the Baltic Sea still offers ecological niches available for immigration (Bonsdorff 2006).

The Baltic Sea is still a highly dynamic system. During the past one hundred years, the system has undergone decadal variations in salinity, oxygen and temperature (Winsor et al. 2001). Changes in the abundance and distribution of pelagic and littoral species and communities in the Baltic Sea have been linked to these climate-driven variations in hydrography (Alheit et al. 2005).

In recent decades, increased anthropogenic pressures on the Baltic Sea marine environment have contributed to considerable changes in biodiversity, as will be seen throughout this report. There are also a few cases of extinction of species that have occurred in the Baltic Sea in recent history. The best-known example is that of Atlantic sturgeon (*Acipenser oxyrinchus*), which, after a period of over-exploitation by fisheries and obstruction of migratory pathways, has been recorded only occasionally since the 1960s (Paaver 1999). Owing to the open link to the North Sea, there are also a number of marine species that have occasionally migrated into the Baltic Sea but are absent or rarely observed at present. The bluefin tuna (*Thunnus thynnus*), for example, was abundant and the subject of commercial fishing in the Kattegat and Sound in the beginning of the 1900s, but disappeared from these areas in the 1960s (MacKenzie & Myers 2007). Currently, there is a total of 59 species and 16 biotopes that are considered as threatened and/or declining in such a way that their future sustainability depends on protective measures (HELCOM 2007b, Figure 1.1).

1.3 Current Baltic biogeography

The species diversity in the Baltic Sea is low compared to open oceans and most freshwater systems, primarily owing to the brackish water that constitutes a stressful environment for many aquatic organisms, but also to its character as a geologically young sea with a prehistory as a freshwater lake.

The seabed of the Baltic Sea is shaped into sub-basins separated by shallow sills. Each sub-basin is characterized by a different depth, volume and water exchange, resulting in sub-basin-specific chemical and physical properties. In addition, the Baltic Sea has highly varied coastlines and seabeds. Large archipelago areas add to this diversity. All of these factors have a profound influence on the proliferation and distribution of species on a sub-regional as well as a local scale.

Salinity sets boundaries for existence

Salinity in the Baltic Sea is primarily determined by the freshwater inflow from rivers and the influx

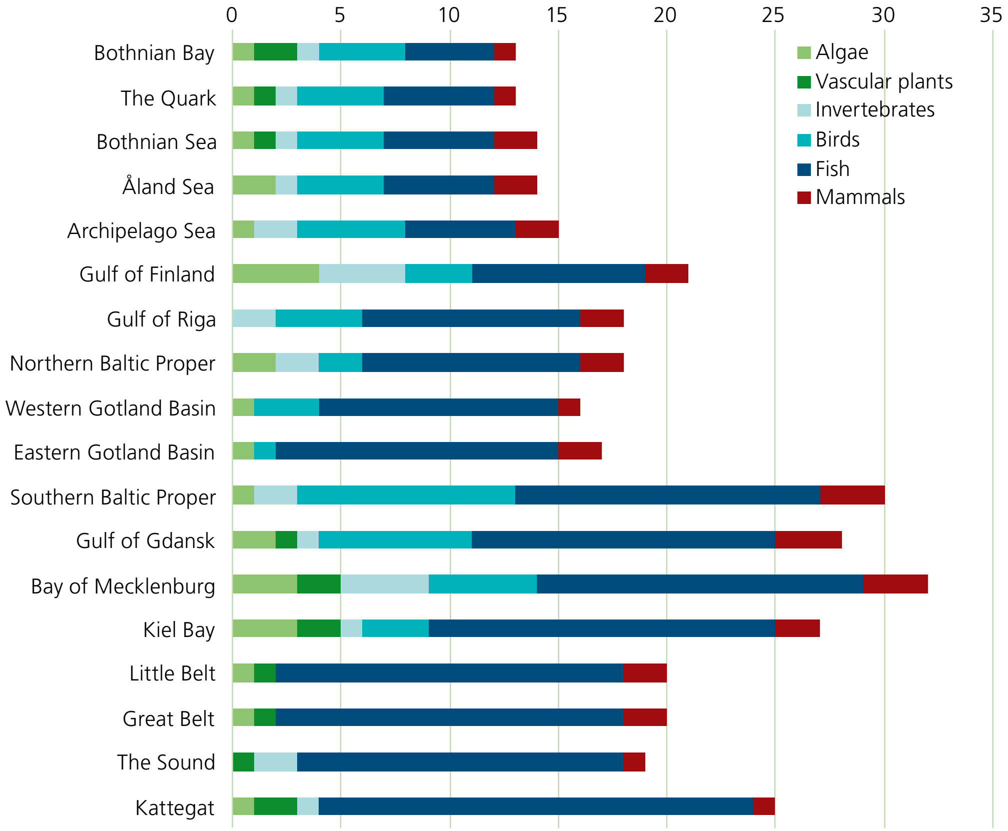

Figure 1.1. Number of threatened and declining species in the Baltic Sea (based on HELCOM 2007b).

of saline water from the North Sea through the Danish Straits (Lass & Matthäus 2008). There is a pronounced salinity gradient from south to north: surface water salinity averages 20 psu in the southern Kattegat, 8 psu in the Baltic Proper and 5 psu in the Bothnian Sea. In the innermost parts of the Bothnian Bay and the Gulf of Finland, the water is practically limnic with a salinity <1 psu.

The number of species also decreases dramatically along the south-to-north gradient. A particularly steep decrease takes place across the Danish Straits. In the open Skagerrak, there are about 1 600 marine zoobenthic species, decreasing to 500 in the southwestern Baltic Sea, while fewer than 20 inhabit the bottoms of the Bothnian Sea (Bonsdorff 2006). Closer to the coasts and in the inner reaches of the Gulf of Finland and the Gulf of Bothnia, the benthic diversity increases compared to open areas owing to the influence of freshwater species and insect larvae. The total number of macroalgal species drops from about 250 in the Sound area to about 40 in the Bothnian Bay (Nielsen et al. 1995).

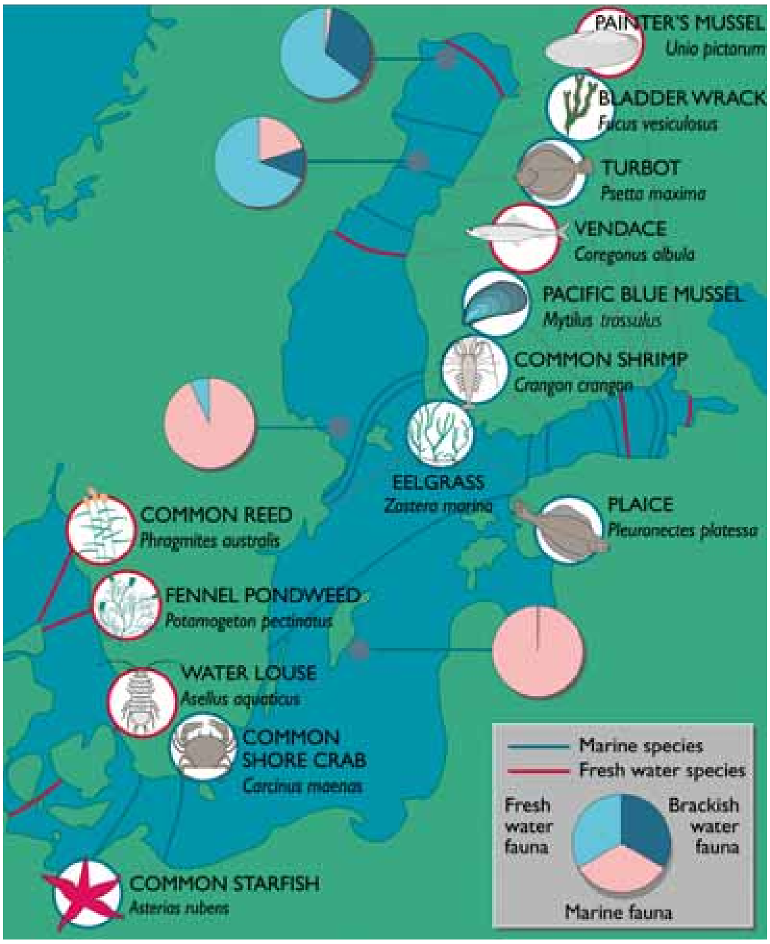

Figure 1.2. Map with distribution limits of Baltic Sea species either from the marine or freshwater point of view. Source: Furman et al. 1998.

The primary reason for the low diversity is that very few species are endemic to brackish conditions in general or to the Baltic Sea in particular. Instead, both marine and limnic species meet their physiological limits in the Baltic. The eelgrass *Zostera marina* has its geographic distribution limit at about 5 psu, coinciding with areas in the southern Bothnian Sea (Figure 1.2). Vendace (*Coregonus albula*), on the other hand, is an example of a freshwater fish that tolerates brackish waters and is found in coastal waters of the Bothnian Bay and the northernmost Bothnian Sea. Distribution of cod (*Gadus morhua*) is also limited by salinity. Successful spawning of cod requires a relatively high salinity (> 11 psu) that primarily occurs in the deep basins of the Baltic Proper and in the Belt Sea and Kattegat. Adult cod, however, migrate to all basins except the Bothnian Bay.

Physiological stress is manifested in the limited body size and slower growth rate of some marine species that inhabit the Baltic Sea. Bladder wrack (*Fucus vesiculosus*) is found down to a salinity of 4 psu. The Baltic bladder wrack is, however, smaller and displays a lower photosynthetic production potential than bladder wrack in the Atlantic (Nygård & Ekelund 2006). On the other hand, some freshwater species such as pike and pike perch grow faster and larger than in most rivers or lakes.

Oxygen conditions determine life in the deep

Vertical stratification of the water column is a predominant feature in all Baltic basins (e.g., Lass & Matthäus 2008). Stratification is caused by a seasonal temperature gradient and by a more permanent halocline. Salinity stratification is due to layering of the dense high-salinity waters of marine origin under the fresh water originating from runoff from land and rivers, and it is particularly pronounced in the open Baltic Proper and the western Gulf of Finland.

The halocline prevents vertical mixing of the water column and consequent ventilation of the deeper layers. Oxygen in the deeper layers is consumed by microbial and chemical processes mostly related to the degradation of organic matter. The prevention of ventilation by vertical mixing results in pronounced periods of oxygen deficiency or complete anoxia and the formation of hydrogen sulphide. Long-term anoxia is prevalent especially in the deeper layers of the Baltic Proper. In the Bothnian Bay and Bothnian Sea, the vertical salinity and temperature differences are much less pronounced and the water column generally mixes fully every year, resulting in good oxygen conditions in the bottoms of both basins. Oxygen deficiency can also be seasonal, often taking place in the autumn in coastal waters.

Stagnation periods are directly related to major inflows of saline water to the Baltic Sea that largely depend on climatic factors, especially travelling depressions that result in sea level differences between the Kattegat and Arkona Sea (Lass & Matthäus 2008). These inflows are, in principle, the only source of oxygenated water to the deepest parts of the Baltic Proper. For the benthic fauna that depend on oxygenated conditions, these inflows determine the conditions for their existence. When the oxygen concentration drops below 2 ml per litre (hypoxia) during extended periods, higher life-forms are obliterated and the bentho-pelagic processes become dominated by anaerobic bacteria.

Since the mid-1970s, major inflows of saline water have become rare with no intrusions taking place between 1983 and 1993 (Lass & Matthäus 2008). The latest major inflows of saltwater to the Baltic Sea occurred in 1993–1994 and 2002–2003. Since then, hypoxic and anoxic areas have increased in the Baltic Proper and Gulf of Finland and in autumn 2006 and spring 2007 they corresponded to half of the surface area of the basins (Axe 2007). Anoxia drives the release of nutrients, particularly phosphorus, from the sediments, and thereby exacerbates eutrophication and the production of organic matter, further enhancing anoxia.

Coastline, substrate and light penetration shape sub-regional and local diversity

The coastline of the Baltic Sea is highly varied with exposed bedrock and extensive rocky archipelagos in the central and northern Baltic, sandy beaches and eroding cliffs along the shores of the southern Baltic Proper, large shallow lagoons along the southern coasts, and fjords and fjord-like bays in the Belt Sea and Kattegat (HELCOM 1998). The shape and exposure of the coastline affect the substrate of the seafloor and the rate of water exchange in the coastal zone. The latter, in turn, influences the salinity and nutrient levels in the costal area. Open and exposed areas of the Baltic Sea, therefore, harbour different communities than enclosed and sheltered coastal areas (Olenin & Daunys 2004).

For animals and plants associated with the sea bottom, the substrate is an important selective factor. For aquatic vegetation, light penetration, wave exposure, and also ice conditions are factors that further structure the distribution of species in the coastal zone. When the ice breaks up in spring, shallow bottoms in exposed areas can be scoured down to 1–2 metres resulting in a dominance of annual species. The Bothnian Bay, Bothnian Sea, Gulf of Finland and Gulf of Riga are covered by ice during an average winter, with decreasing length of the ice season towards the south. In the coastal zone, ice is common all along the coasts of the Baltic Proper. There is, however, a general tendency towards a shortened ice season and decreasing annual extent of sea ice in the Baltic Sea (HELCOM 2007d).

Within each sub-basin, salinity, nutrients and temperature are important factors affecting the temporal variation in diversity, particularly in the littoral and pelagic communities that undergo a pronounced seasonal succession.

1.4 Why does Baltic biodiversity need protection?

The biodiversity of the Baltic Sea is valuable as such, but it also provides a variety of goods and ecosystem services. Nutrient recycling, water and climate regulation, production of fish and other food items as well as high quality of life and recreational opportunities are among the ecosystem services provided by the Baltic Sea (Rönnbäck et al. 2007). The most obvious goods are fish, which also have a market value. The annual value of the fish catch in the western Baltic Sea (Denmark, Germany, Finland and Sweden) was estimated at 1 520 million Euros in 2001 (HELCOM & NEFCO 2007).

On a global scale, marine ecosystems have been estimated to produce 63% of all the world's ecosystem services, with a total annual value of 33 trillion (10^{12}) US dollars (Costanza et al. 1997). The Baltic Sea was estimated to be among the most productive ecosystems, with much of the area providing services with an annual worth in the range of 2 000 to 3 000 US dollars per hectare (Costanza et al. 1997).

Ecosystem goods and services also include a number of invisible benefits that are not directly valuable to humans. These include the features and processes that are important for the maintenance of the ecosystem, such as provision of habitats and resilience or capacity of the ecosystem to withstand changes (Beaumont et al. 2007). The significance of 'diversity' is highlighted by its role in supporting the capacity of the ecosystem to adapt to changing conditions. In this respect, certain components of biodiversity that are particularly important from the point of view of maintaining the integrity of the ecosystem need particular consideration and possibly also specific management actions.

Landscape diversity provides the basis for habitat diversity

Maintenance and protection of species diversity are inextricably linked to preservation of the environment that serves as a habitat for the species and populations in question. Important features of the environment include sediment type, light penetration, exposure and salinity, which also distinguish specific marine landscapes. In addition to the physical environment, certain organisms are of particular importance because they form a structure that is the habitat for many other species and communities during parts or the entire span of their life. Such key species in the Baltic Sea include, for example, eelgrass (*Zostera marina*), bladder wrack (*Fucus vesiculosus*), and blue mussels (*Mytilus trossulus* and in the Kattegat *Mytilus edulis*).

When key species have a large influence on the structure of the ecosystem, as in the Baltic Sea, the systems are characterized by low resilience. When designating protected areas, it is thus very important to include large marine landscapes that are known to support these key species.

Functional diversity is an insurance against species loss

Functional groups refer to organisms that can be characterized by common traits or roles in the ecosystem such as feeding behaviour, capacity to conduct certain biogeochemical processes, or the occupation of a specific niche. For the ecosystem to uphold a certain function, for example productivity, the number of functional groups as well as redundancy within a functional group are key properties (Walker 1995, Nyström 2006). If species diversity within a functional group is high, a species can even be lost, in the short-term, without affecting the ecosystem function.

In the Baltic Sea, functional diversity is well documented for invertebrate bottom-dwelling animals. Owing to the pronounced salinity gradient in the Baltic Sea, the number of functional groups decreases from the south to the north, from 20 in the Kattegat-Skagerrak transition area, to 8–10 in the southern Baltic Proper and down to 1–2 in the Bothnian Bay (Bonsdorff & Pearson 1999). In addition, the number of species within the functional groups drops from 4–5 in the Kattegat-Skagerrak to 1–2 in the Baltic Sea (Bonsdorff & Pearson 1999). Thus, the Baltic Sea is characterized by a small number of functional groups as well as a low diversity within the functional groups. The low diversity accentuates the unique role of each Baltic species not only within the functional groups but also in the ecosystem at large. The loss of just one species can have a much more severe impact in the Baltic Sea than in areas with high functional diversity and within-group redundancy.

Trophic diversity safeguards the structure of the ecosystem

Large predators have an important structuring role in the ecosystem and the trophic levels can be considered as a vertical diversity of the food web. Reduction of top predators through fishing or hunting has been shown to cause trophic cascades in many aquatic environments, e.g., by affecting the abundance of organisms in several levels of the food chain (Pace et al. 1999, Frank et al. 2005).

Evidence of change in the trophic structure can also be found in the Baltic Sea where the commercially most important fish stocks shifted from domination by cod (*Gadus morhua*) to domination by sprat (*Sprattus sprattus*) in the late 1980s (Österblom et al. 2007). This has been attributed to a combined effect of high fishing pressure on cod and climatic forcing which has given the sprat stock a competitive advantage (Köster et al. 2005). It has been suggested that the reduction of the cod population has caused a trophic cascade that has resulted in increased summer phytoplankton biomass (Casini et al. 2008). In addition, change in the trophic structure may render an ecosystem more sensitive to other pressures such as an invasion of alien speices (Daskalov et al. 2007).

Genetic diversity increases the ability to recover

Genetic variation within a species has great importance for the individual species' capacity to establish, recover and adapt to new conditions. The Baltic Sea has two features that make protection of the genetic diversity especially important: the genetic diversity is low and many genetic traits are unique.

Comparison between species from the Baltic Sea and those from the Skagerrak-Kattegat area has shown that the cod and eelgrass in the Baltic Sea have a lower genetic diversity than their counterparts in the more saline environment (Johannesson & André 2006). The same pattern is true for macroalgae. The low genetic diversity indicates that the species in the Baltic Sea may be particularly sensitive to disturbances.

Species from the Baltic Sea also display distinct genetic traits, indicating that they have adapted to the specific conditions of this sea area. For example, the cod eggs of the eastern Baltic Sea stock are larger and have a lower density than the North Sea cod eggs. This makes them 'float' better at a lesser depth which is also more often well oxygenated (Vallin & Nissling 2000). With low genetic variation, the possibilities for replacement by other variants are more limited in case of loss. Moreover, if genetic variants are lost, there is no depository from which they can be collected and reintroduced.

Diverse systems are more resilient

As an ecological concept, resilience describes the capacity of an ecosystem to absorb disturbances while maintaining structure and function (Holling 1973, Walker et al. 2004). In this sense, a 'resilient' ecosystem can appear virtually unaffected while exposed to considerable stress. The apparent lack of response can be explained by natural feedback mechanisms such as biogeochemical compensation, regulation through trophic and competitive interactions within the system, and, to a certain degree, also by the functional diversity and redundancy among species. However, at a certain point even a small increment in external pressure can cause a dramatic shift—a so-called regime shift—that results in the collapse of populations or other characteristics of the ecosystem (Scheffer et al. 2001). An idiom that reflects this type of event is 'the straw that broke the camel's back'.


***Ranunculus* sp.**

In the Baltic Sea, it has been suggested that several regime shifts driven by variability in climate, eutrophication, as well as seal hunting and fishing pressure have occurred during the past 80 years (ICES 2008a, Österblom et al. 2007, Box 1.2). Once anthropogenic pressures have caused a regime shift, extensive and costly management actions are generally needed to reverse the situation because new feedback systems come into play that contribute to stabilizing the new regime. From a management point of view, it is therefore essential to avoid reaching the break-point where regime shifts occur.

Box 1.2. Regime shifts in the Baltic Sea as detected by an Integrated Ecosystem Assessment

The ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB) has conducted Integrated Ecosystem Assessments (IEAs) on a number of offshore and one coastal sub-region of the Baltic Sea (see table) (ICES 2008a). IEAs are multivariate analyses of time series of the physical, chemical and biological environment as well as socio-economic factors. The analyses were targeted to assess the impact of climate, fisheries, and eutrophication on the different sub-regions.

All seven sub-regions investigated displayed pronounced structural changes, i.e., regime shifts, during the past two to three decades. The major period of restructuring in the Baltic sub-regions was at the end of the 1980s. The Sound, central Baltic Sea, Gulf of Riga, Gulf of Finland, and Bothnian Bay also underwent structural change during the mid-1990s, probably related to the major inflow in 1993.

For the central Baltic Sea, two relatively stable periods were detected in 1974–1987 and 1994–2006. The first period was characterized by comparatively high cod and herring spawner biomass and recruitment, and high abundances of the copepod *Pseudocalanus acuspes*, whereas in the later period the system was sprat-dominated with high abundances of *Acartia* spp. and *Temora longicornis*. Between the two shifts, there was a transition period of highly variable climatic and hydrographic conditions and no major inflow events, resulting in low salinity and high temperature values.

The main drivers of the observed ecosystem changes vary between sub-regions, but they all include the increasing temperature and decreasing salinity influenced by large-scale atmospheric processes. In addition to temperature and salinity, fishing pressure was identified as an important driver for the central Baltic Sea and Bothnian Sea as well as nutrients for the highly eutrophied Gulf of Finland.

Regime shifts (RS 1 to RS 4) in the different sub-basins of the Baltic Sea in several time periods.

System	Period covered	RS 1	RS 2	RS 3	RS 4
The Sound	1979–2005		1987/88	1995/96	
Central Baltic Sea	1974–2006		1987/88	1994/95	
Gulf of Riga	1974–2006		1988/89	1997/98	
Gulf of Finland	1979–2007		1988/89	1995/96	2002/03
Bothnian Sea	1979–2006	1982/83	1988/89		
Bothnian Bay	1979–2006		1987/88	1993/94	
Kvädöfjärden, Northern Baltic Proper	1971–2006	1976/77	1987/88		2004/05

There is ample evidence for a positive relationship between the number of species and ecosystem productivity and stability over time as well as for the capacity of an ecosystem to recover after disturbances (Naeem & Li 1997, Worm et al. 2006). Changes in the environment that result in decreased biodiversity are therefore considered to make systems less resilient and more prone to undergo regime shifts. In an ecosystem such as the Baltic Sea that is characterized by low species, genetic, and functional diversity, protection of biodiversity is thus central to ensuring ecosystem resilience.

1.5 Protection of biodiversity—Global and European targets

Protection of biodiversity is an integral part of the ecosystem approach to the management of human activities. The 1992 United Nations Convention on Biological Diversity has provided the basis and concepts for much of the work on biodiversity protection. At the UN World Summit on Sustainable Development in 2002, the governments committed themselves to significantly reducing the rate of biodiversity loss by 2010. Halting the loss of biodiversity by 2010 is also a target for EU Member States. This assessment will contribute to monitoring the progress towards the targets and to promoting measures enabling achievement of the biodiversity targets for 2010.

HELCOM's work on protecting biodiversity and conserving nature has a strong region-specific focus and it contributes to activities taking place under the Bern Convention on the Conservation of European Wildlife and Natural Habitats and the Bonn Convention on the Conservation of Migratory Species of Wild Animals. The EU has adopted two important pieces of legislation which provide the basis for implementing the above conventions, namely, the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC). These directives also specify requirements for the development of the European network of protected areas, the Natura 2000 network (which consists of Special Protection Areas (SPAs) classified under the Birds Directive and Special Areas of Conservation (SACs) designated under the Habitats Directive), and they include important provisions on the protection of species and habitats in EU Member States. While the establishment of the Natura 2000 network for terrestrial areas is largely accomplished, efforts are currently focused on the completion of the network in the marine environment, especially offshore, which is also a key objective of the EU Biodiversity Action Plan.

The EU Water Framework Directive (WFD) focuses on internal, transitional, and coastal waters and includes the objective of achieving good ecological status by 2015 in the waters of EU Member States.

In order to protect the marine environments in Europe, in 2008 the EU adopted the Marine Strategy Framework Directive (MSFD, 2008/56/EC). This directive aims at the achievement of good environmental status of the European marine environment by 2020. The national marine strategies to be elaborated by EU Member States will include the preparation of initial assessments of the status of the marine environment, as well as of predominant pressures impacting the environment, by 2012. This biodiversity assessment provides an important contribution to the elaboration of such national assessments. This assessment report as well as the process undertaken to produce it represent an example of the type of region-level coordination and cooperation that is also stipulated to be necessary according to the directive. The MSFD also includes spatial protection measures as a part of programmes of measures to be devised. In this respect, this report provides an overview of how HELCOM, in coordination with the OSPAR Commission and the EU, is working towards a coherent and representative network of marine protected areas by 2010, as agreed in a Joint HELCOM/OSPAR Work Programme on Marine Protected Areas in 2003 (HELCOM & OSPAR 2003).


A nest of Herring gull *(Larus argentatus)*

2 MARINE LANDSCAPES AND HABITATS

Habitats describe the abiotic characteristics of an environment and the associated biological assemblages at high-level resolution. Marine landscapes provide a simple broad-scale overview of the often complex interactions of the various oceanographic and physical factors constituting the marine environment. In general, areas with high landscape and habitat diversity can be expected to harbour a higher diversity of species. Coherent knowledge of the marine landscapes and habitats is therefore crucial for informed nature conservation, the designation of marine protected areas and, thus, the overall goal of achieving long-term sustainable development.

This chapter presents the current status in the development of marine landscape maps in the Baltic Sea and the conservation and threat status of Baltic habitats and biotopes.

2.1 Marine landscapes

The shores of the Baltic Sea reveal highly diverse landscape scenery with coastal lagoons, shallow bays, extensive sandy beaches and many islands. Similarly, though hidden from sight beneath the surface, there is a unique and largely undiscovered world of flooded canyons, deep-sea mud basins, as well as rippled sandy plains with isolated rocky patches rising from the seafloor—these are the marine landscapes of the Baltic Sea. The diversity of landscapes represents the range of living conditions available for the species and communities in the Baltic Sea. As such, a coherent marine landscape map is a fundamental tool for managing the biodiversity of the Baltic Sea marine ecosystem.

One of the overarching ecological objectives of the biodiversity segment of the Baltic Sea Action Plan (BSAP) is to achieve a good ecological status of 'natural marine and coastal landscapes'. A specific target of the BSAP is also to *"By 2021, ensure that 'natural' and near-natural marine landscapes are adequately protected and the degraded areas will be restored"*. This target, of course, requires that the marine landscapes are identified, mapped, and their biological and ecological relevance described. The next step will be to incorporate the use of the marine landscape map into maritime management through identification of indicators for ecosystem health and environmental thresholds, e.g., which percentage of a marine landscape should be preserved from human pressure in order to maintain a healthy ecosystem. Another relevant target of the BSAP is to *"By 2012, have common broad-scale spatial planning principles for protecting the marine environment and reconciling various interests concerning sustainable use of coastal and offshore areas, including the Coastal Strip as defined in HELCOM Rec. 15/1"*. In this regard, the broad-scale marine landscape maps are crucial tools for identifiying the total area and distribution of natural values and heritage in a Baltic Sea spatial context.

2.1.1 Marine landscapes—the concept

The concept of marine landscapes provides a simple, yet ecologically meaningful way to describe the vast, and often unknown, expanses of the seafloor. It was originally presented for Canadian offshore waters with the aim of informing marine nature conservation. The idea was to develop a tool that could help environmental managers to enhance marine nature conservation schemes and, in general, inform marine spatial planning. The main criteria were that the marine landscape approach should be based on sound ecological principles and support an informed approach to the management of marine areas (Roff & Taylor 2000). The marine landscapes derived should also be individually distinct and reflect broad-scale species assemblages. Marine landscapes are, in principle, especially valuable in areas for which little biological information is available, such as in most offshore areas.

By recognizing this, marine landscapes have been tested since 2000 in Europe by, e.g., the UK Joint Nature Conservation Committee in the Irish Sea Pilot Project. This initiative was later expanded to include the entire UK territorial waters in the UKSeaMap (Vincent et al. 2004, Connor et al. 2007). Likewise, the UK has cooperated through MESH (Mapping European Seabed Habitats) with France, Ireland, the Netherlands, and Belgium to improve the classification and mapping of seabed habitats for north-western European waters. These mapping initiatives reflect the increased demands for the development of tools to support an ecosystem-based approach to management that has appeared on the European scene over the past two decades. Such demands are illustrated, for example, by the EC Habitats Directive,

Box 2.1.1. Development of marine landscape maps

2000 – Marine landscape concept presented for Canadian waters

2004 – Marine landscapes developed for the Irish Sea

2007 – Marine landscapes developed for UK waters

August 2007 – Marine landscapes developed for an entire Marine Region including the territorial waters of nine independent countries: the Baltic Sea Marine Region. See www.balance-eu.org for more information

October 2007 – First time marine landscapes are recognized in an international agreement: the HELCOM Baltic Sea Action Plan

November 2008 – Marine landscape maps available at www.helcom.fi

the EU Water Framework Directive, the EU Marine Strategy Framework Directive (MSFD), as well as the EU Maritime Policy initiative for developing 'A European Atlas of the Seas'. For the Baltic Sea region, the needs have been made even more concrete with the adoption of the HELCOM BSAP in 2007 (Box 2.1.1).

Through the BSAP, the countries surrounding the Baltic Sea have agreed on a wide range of topics to secure the general protection of the Baltic Sea. This requires the development of coherent, ecologically relevant maps spanning the entire Baltic Sea marine region, such as maps of marine landscapes.

The Baltic Sea region INTERREG IIIB part-financed BALANCE project has provided a first step towards identifying and mapping the marine landscapes of the Baltic Sea. This development process has included: i) facing the challenges related to data availability, ii) harmonization, and iii) access that is part of the daily life in the multinational, multiple stakeholder environment of the Baltic Sea region (Al-Hamdani & Reker 2007).

2.1.2 Development of marine landscape maps

In order to assess conservation status, a coherent broad-scale ecological habitat map spanning seamlessly across the HELCOM region is needed. At the same time, the map has to meet the legal requirements stated by HELCOM and EU policy initiatives such as the BSAP and the EU MSFD. The marine landscape maps provide such a tool.

Marine landscape maps for the Baltic Sea include three different classifications: i) benthic marine landscapes, which describe the seabed in an ecologically relevant way; ii) topographic features, which describe the seabed geomorphological complexity; and iii) physiographic features, representing the shape of the coast. A biological validation has only been carried out for the benthic marine landscape map. Furthermore, it was not possible to identify ecologically relevant criteria for delineating the topographic and physiographic features; therefore, these are not, at this time, suitable for broad-scale environmental assessments.

Methodology

When developing the Baltic marine landscape maps, the primary environmental parameters were chosen among those listed in Annex III of the EU MSFD. These were sediment, available light, and salinity at the seafloor (Figure 2.1.1a–c).

The composition of the sediment is a major determinant for the distribution of benthic species and detailed, high-resolution sediment composition maps are essential for marine landscape and marine habitat mapping efforts. The sediment map presented here was collated by harmonizing data from 19 different geological classification systems written in nine different languages. The sediment was divided into five categories ranging from bedrock to mud, each with a different ecological relevance.

From an ecological point of view, available light at the seabed is one of the primary physical parameters influencing and structuring the biological communities in the marine environment as it is the driving force behind primary production. Available light was included as it distinguishes between the photic zone where primary production occurs and the non-photic zone.

Salinity was divided into six categories reflecting species distribution boundaries or ecological requirements throughout the Baltic Sea. Unfortunately, no coherent data for benthic species covering the entire Baltic Sea region are available that can link species distribution and salinity. Focus was therefore placed on the known requirements of certain key species, e.g., the salinity at which bladder wrack (*Fucus vesiculosus*) becomes the dominating submerged brown alga. Table 2.1.1 summarizes the reasoning for the specific categories.

Other environmental parameters were considered, but they were either more relevant for detailed habitat mapping purposes, e.g., wave exposure; not relevant for the entire region, e.g., ice cover; not significantly influencing the species distribution in the Baltic Sea, e.g., temperature; or of only minor importance compared to other geographical areas, such as tidal currents. Lastly, the aim was to limit the number of marine landscapes to a manageable number (see Al-Hamdani & Reker 2007 for details). Using this approach, 60 marine landscapes were identified in the Baltic Sea (Figure 2.1.1d, Box 2.1.2).

How well can we trust the maps?

An essential factor in the durability of benthic marine landscape maps is that they provide a true reflection of the broad-scale species assemblages in the Baltic Sea. If they do not meet this criterion, they are of limited use for supporting a sustainable

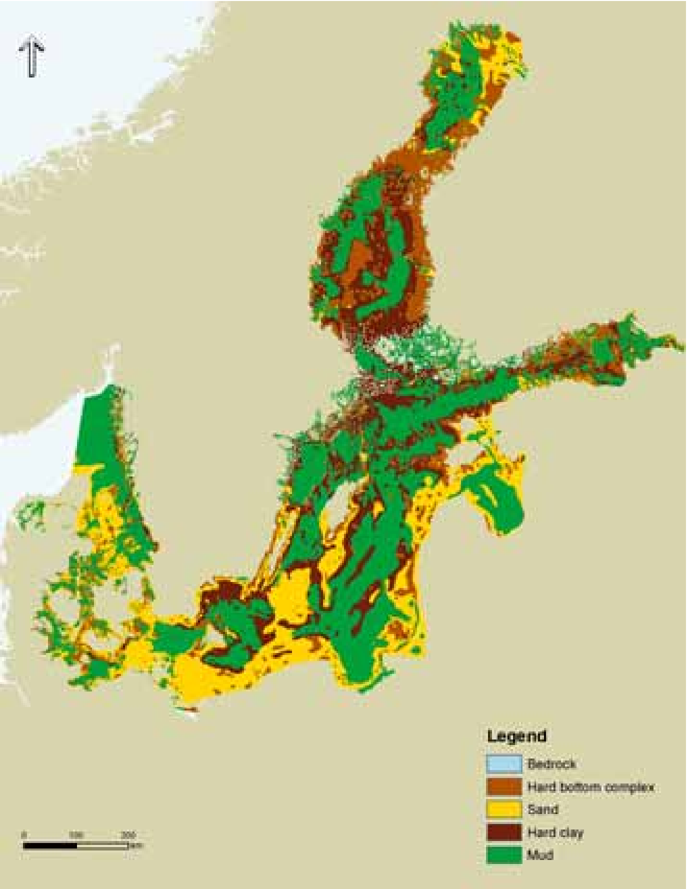

Figure 2.1.1a. Map of marine seabed sediments, as divided into five categories, in the Kattegat and Baltic Sea; compiled from sediment information from GEUS, GTK and SGU.

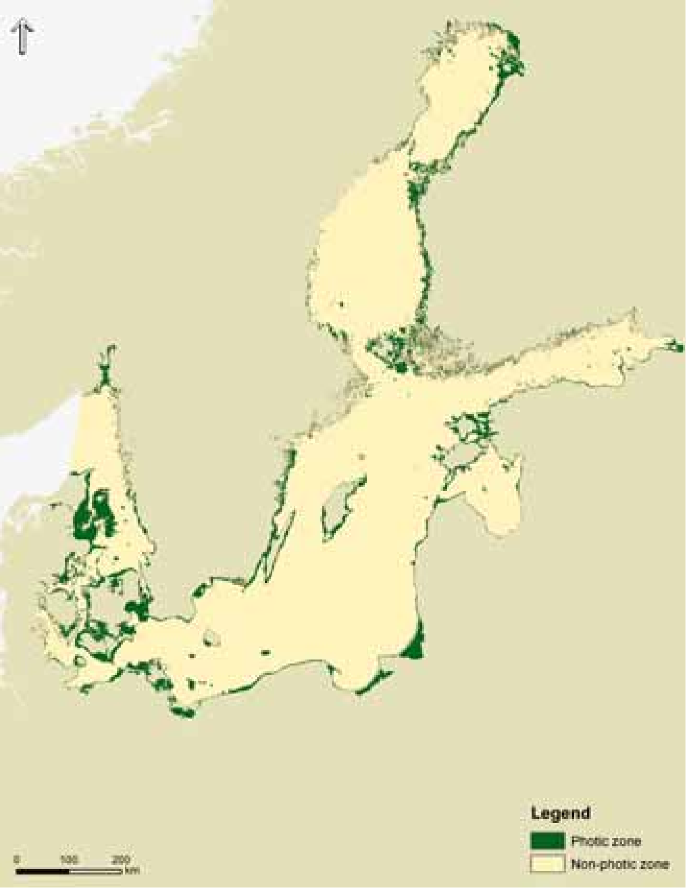

Figure 2.1.1b. Model results showing the distribution of areas where at least 1% of available light reaches the seabed (the photic zone) and the non-photic zone. Data source: DHI and ICES.

management of human activities in the marine environment. The benthic marine landscapes have been validated thus far through two initiatives, which have shown that even closely related landscapes represent significantly different biological communities. In the Kattegat, 106 stations were selected for sampling of the benthic communities. The area covered three closely related 'muddy' marine landscapes. A statistical analysis showed that there was a significant difference between the species assemblages present within the three marine landscapes surveyed (Al-Hamdani & Reker 2007). If marine landscapes with another dominant sediment type, e.g., photic rock, were to be compared to these marine landscapes, it can be assumed that the difference would be even more significant. However, a thorough validation and refinement process should be continued based on national monitoring data by those Contracting Parties who might wish to adopt this approach as an environmental characterization of the Baltic Sea Marine Region *sensu* the EU MSFD. Ideally, the marine landscape map should be supported by detailed habitat mapping applying the classification system of the EU European Nature Information System (EUNIS).

The top three levels of the EUNIS system, which describe the physical environment, use an approach similar to that of the marine landscapes. To be able to map EUNIS habitats at the detailed levels 4 and 5, coherent species information, including species lists and their abundances, is needed to develop a hierarchical classification of marine habitats.

Marine landscapes are used to provide a coherent, albeit coarse, broad-scale ecologically relevant map for marine areas. They are developed using the physical environmental parameters identified by the EU MSFD. These physical environmental parameters structure the distribution

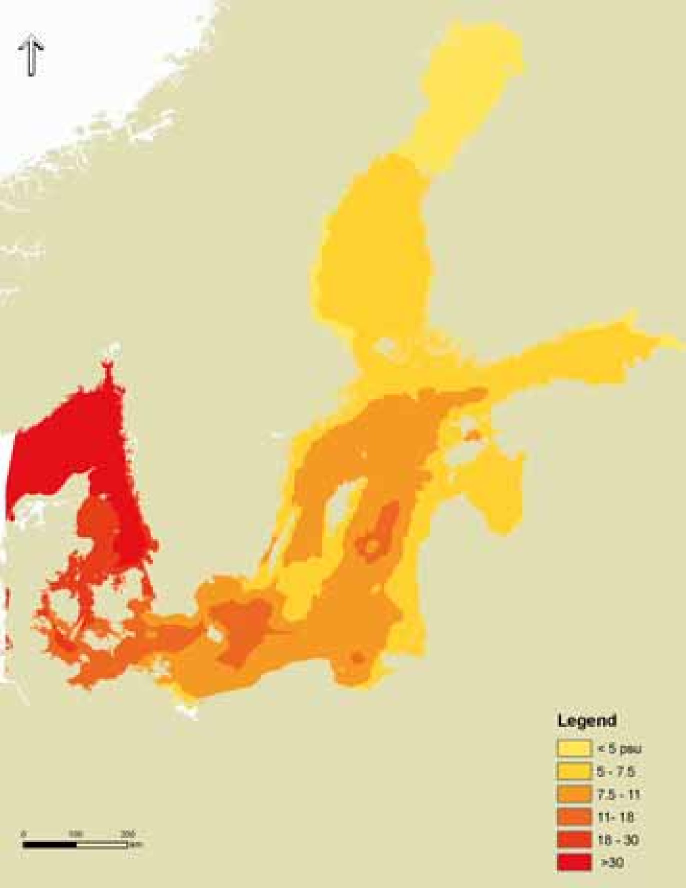

Figure 2.1.1c. Model results showing the bottom-water salinity (psu) field in the Baltic Sea. Data source: NERI.

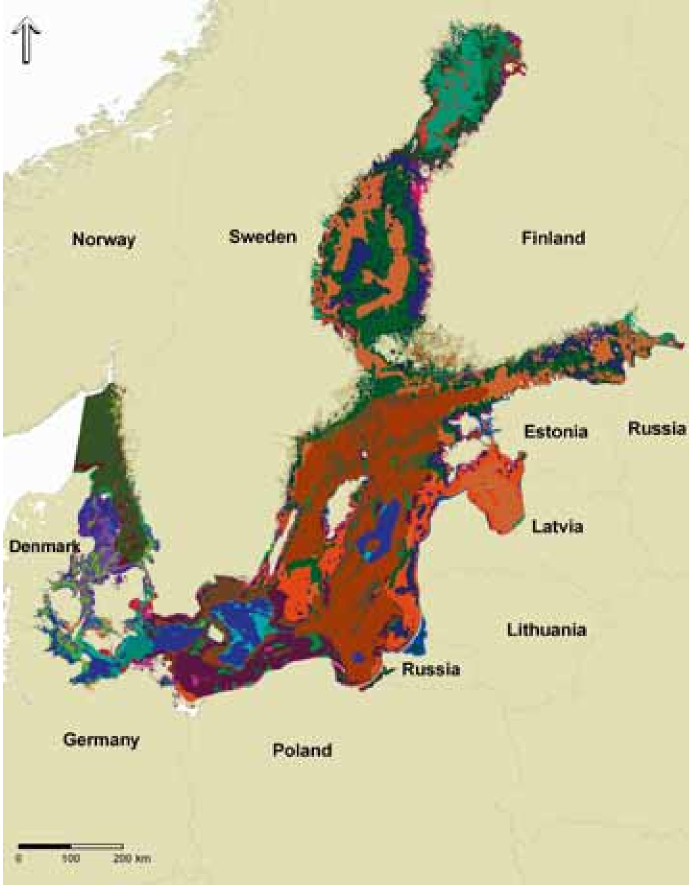

Figure 2.1.1d. Benthic marine landscape map of the Baltic Sea. The different colour codes of the marine landscape reflects different combinations of the three basic maps (Figures 2.1.1a, b and c) which were used to produce the marine landscape map by using map algebra. Source: BALANCE, see Al-Hamdani & Reker 2007 for details.

Box 2.1.2. The Baltic marine landscapes

Sixty benthic marine landscapes have been identified for the Baltic Sea.

The marine landscape 'non-photic mud at 7.5–11 psu' covers more than 58 000 km^2.

Eight marine landscapes cover 371 000 km^2 or more than 90% of the Baltic seafloor.

Forty marine landscapes cover less than 1% of the total seafloor area.

Species composition varies significantly between individual landscapes (where tested).

Table 2.1.1. Categories for sea bottom salinity and their justification based on expert judgement.

Category	Salinity range	Justification
Oligohaline I	< 5 psu	This occurs at the biogeographic boundary in the Quark area. This region has a higher number of freshwater species.
Oligohaline II	5 – 7.5 psu	7.5 psu equals roughly the area where *Fucus serratus* has its distributional boundary (Öland, SE) making *Fucus vesiculosus* the dominating sublittoral brown algae. This category also has the lowest number of species and is thus the most vulnerable part of the Baltic Sea.
Mesohaline I	7.5 – 11 psu	11 psu is the minimum requirement enabling cod (*Gadus morhua*) eggs to float. As cod is an important commercial species for the Baltic Sea region, this interval was chosen in order to increase applicability of the marine landscapes for environmental management. It also helps to separate the offshore environment from coastal areas in large parts of the Baltic Proper.
Mesohaline II	11 – 18 psu	18 psu is the approximate minimum requirement for sexual reproduction or limiting distribution of many marine macroalgae, e.g. *Laminaria digitata* and *Ascophyllum nodosum,* and of, e.g., echinoderms. It occurs at the biogeographic boundary in the Sound. 18 psu is also a boundary in the EU Water Framework Directive, further increasing the applicability of the marine landscape maps.
Polyhaline	18 – 30 psu	Most marine species are able to survive within this interval. It is also an interval defined by the EU Water Framework Directive.
Euhaline	> 30 psu	Requirement of truly stenohaline species separating the marine parts of the Skagerrak and North Sea from the freshwater-influenced water masses of the Kattegat and Baltic Sea region.

and biology of the species, and thereby ensure that marine landscapes are ecologically relevant, though only at the coarsest scale possible.

In summary, it is possible to produce a broad-scale, ecologically relevant map spanning an entire marine region consisting of multiple independent states, e.g., the benthic marine landscapes of the Baltic Sea.

2.1.3 Application in marine management and conservation

There are many potential uses and applications of marine landscape maps. Most importantly, they can be used as a basic ecological information layer in a marine spatial planning process or for ecosystem-wide assessments. In the BSAP, the Contracting Parties have agreed to use broad-scale, cross-sectoral maritime spatial planning as a tool to reduce the impact of human activities on the Baltic Sea. This could include assessing the total environmental impact of human activities, obtaining information about the total resources available, or providing valuable information for strategic planning in relation to large-scale infrastructures.

It is possible to develop an index of the relative seabed complexity based on the marine landscape map. Figure 2.1.2 illustrates the complexity of the seabed within a 20 km x 20 km area based on the number of marine landscapes present in that specific area. In the Baltic Sea, some areas are very homogeneous with only one marine landscape present within a 20-km grid, whereas other areas are more heterogeneous with up to 19 different marine landscapes present. It should be noted that even if there is only one marine landscape present (dark green in Figure 2.1.2), there may be a different landscape in the neighbouring grid and therefore the complexity map should always be used in close association with the marine landscape map. The index can be applied to illustrate, for example, potential 'hotspots' with a high complexity or many landscapes present within a small area compared to areas with less complexity. Such information provides planners and environmental managers with a strategic tool to identify potential important areas or 'hotspots' that may need special attention during the planning process. Hotspot areas include the Swedish west coast, the Danish Straits and the Sound at the entrance to the Baltic Sea, the area around the northern part of the island of Gotland, and the Gulf of Finland.

Most importantly, the benthic marine landscape map provides a coherent ecologically relevant map of the HELCOM area. This map has been used (Piekäinen et al. 2008, Liman et al. 2008) and can be further used to assess ecological coherence and to select a representative network of marine protected areas in the Baltic Sea through a systematic approach. As such, the marine landscape map is an important tool for informed management of the marine environment. This is further discussed in Chapter 7 of this report.

2.1.4 Conclusions

In conclusion, marine landscape maps covering entire ecoregions are potentially a strong tool, providing a basis for a broad-scale spatial approach to the protection and management of human activities in the marine environment. The approach presented here is a fully applicable and usable ecologically relevant characterization of the Baltic Sea. However, end users may find it necessary to continue the refinement and improvement of the maps. Further refinements are necessary in order to fully exploit the potential application of the maps and to link them to the implementation of national legislation, EU directives and other policy documents such as the BSAP and the EU Maritime Policy. The future success of producing marine landscape maps with a higher accuracy and precision depends on the availability of and access to existing data as well as a transnational and cross-sectoral approach spanning the Baltic Sea. The work presented here and by the BALANCE project should be seen as a first step towards broad-scale mapping of the marine landscapes in the Baltic Sea; further developments should be made by EU Member States for implementing EU maritime policy and legislation.

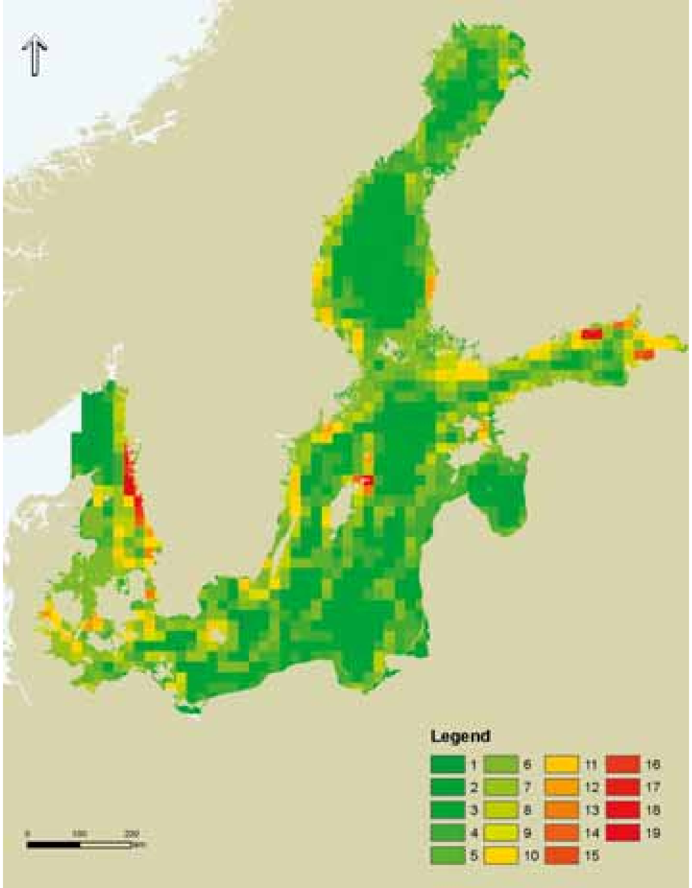

Figure 2.1.2. Map showing the number of benthic marine landscapes within a 20-km grid (deducted from the data used in figure 2.1.1d by using Map Algebra). Source: BALANCE, see Al-Hamdani & Reker 2007 for details.

2.1.5 Recommendations

The marine landscape approach is still new to the Baltic Sea region and, in order to make full use of the applications of the approach, there are a number of areas requiring further development. The following recommendations are made to improve the overall map quality:

- A coherent data set on benthic fauna and flora should be collated using the same sampling methodology, not just the same guidelines, covering the entire HELCOM area.
- The environmental parameters, e.g., the salinity categories, should be harmonized using a coherent set of benthic species data spanning the HELCOM area through a multivariate analysis.
- The benthic biological communities present within individual marine landscapes should be described in more detail.
- A thorough validation of the map should be conducted for each HELCOM sub-region. A step-wise approach using national territories or HELCOM sub-regions could be considered.

The following recommendations are made regarding the application of the marine landscape maps for management of the marine environment:

- Thresholds should be established for individual landscapes, such as determining the proportion of a marine landscape that can be affected by a single pressure (e.g., oxygen depletion) or a sum of pressures and still retain the provision of ecological services.
- Targets based on the marine landscapes should be developed and tested at the regional scale. For example, is the area influenced by oxygen depletion decreasing over a period of time?
- The marine landscape maps should be used in systematic regional assessments to enable an objective comparison and status evaluation between periodic assessments.
- The use of ecologically relevant maps should be further developed for maritime spatial planning as a tool for securing long-term sustainable development.
- Pelagic landscape maps should be developed following the same ecologically relevant principles as for the benthic marine landscape maps.
- The continued development of the marine landscapes should be kept within an international context covering the entire HELCOM area in order to enable the development of a coherent harmonized map. National approaches will not provide the tool needed.

2.2 Habitats

The term habitat is defined by ICES (2006c) as *"a particular environment which can be distinguished by its abiotic characteristics and associated biological assemblage, operating at particular but dynamic spatial and temporal scales in a recognizable geographic area"*. Within HELCOM, the term biotope is commonly used as a synonym to this description of habitat.

Coastal lagoon, Salzhaff, Germany

The Baltic Sea Action Plan (BSAP) includes the following target related to habitats and biotopes: *"By 2010 to halt the degradation of threatened and/or declining marine biotopes/habitats in the Baltic Sea, and by 2021 to ensure that threatened and/or declining marine biotopes/habitats in the Baltic Sea have largely recovered"*. At this time, there are no long-term data available allowing an analysis of trends in the status of the habitats of the Baltic Sea. This section provides an overview of the threat and conservation status of Baltic Sea marine habitats as reported to HELCOM and by EU Member States to the European Commission.

2.2.1 Conservation and threat status of habitats/biotopes

In 1998, HELCOM published the Red List of Marine and Coastal Biotopes of the Baltic Sea (HELCOM 1998) as the result of a HELCOM project with experts from all Contracting Parties. Based on a comprehensive classification of marine and coastal biotopes, it was the first threat assessment of all marine and coastal biotopes for an entire regional sea area in the world. Every biotope was classified into one of five fixed threat categories and the human impacts that caused the threat or decline were also assessed. The reported threat status gave cause for concern: 83% of the biotopes were assessed either as 'heavily endangered' (15%) or as 'endangered' (68%).

With respect to adverse human impacts, all coastal and marine biotopes in the Baltic Sea region were assessed as threatened by different kinds of pollution and, in particular, most biotopes were affected by eutrophication. Among other factors, agriculture, industry and transport were identified as important sources of eutrophication and pollution. In addition, various marine construction activities, dredging and dumping of dredged material, and some fishery practices and mariculture were reported to have heavy, but primarily local, negative impacts on pelagic and especially benthic biotopes. Furthermore, it was assessed that coastal defence measures often hinder or even interrupt the complex interactions of coastal dynamics by, for example, preventing beaches as well as cliffs from being abraded, which results in an obstruction of sand supply for necessary natural beach nourishment elsewhere. HELCOM Recommendation 16/3 can be seen as a code of conduct for coastal defence measures. In most Baltic Sea regions, construction activities for recreational purposes such as large camping grounds, marinas, summer houses or hotel complexes at or near the beach, but also the construction of harbours and ship yards, have caused problems and regularly result in permanent direct destruction or fragmentation of biotopes (see also HELCOM 1998, Figure 18). To mitigate these destructive activites, HELCOM Contracting Parties have committed themselves to legally protect the most threatened biotopes on the Red List (Recommendation 21/4[1]).

In addition to the HELCOM Red List, this chapter uses as background material the HELCOM Lists of Threatened and/or Declining Species and Biotopes/Habitats in the Baltic Sea Area (hereafter the HELCOM List, HELCOM 2007b), and the 2001–2007 reports on the conservation status of the habitats listed in the Habitats Directive from Baltic Sea EU Member States to the European Commission according to Article 17 of the Directive. For the HELCOM List, the species and biotopes/habitats were selected by international Baltic Sea experts for national Red Lists. Their selections were examined by the HELCOM Contracting Parties. In the HELCOM List the word biotope and habitat are used as synonyms. Only species and biotopes/habitats which have a clear relation to the Baltic Sea marine area or depend on it are included on the lists. In contrast the main aim of the EU Habitat Directive is to protect biodiversity at a pan European scale. In the frame of this Directive, Member States shall therefore maintain or restore natural habitat types and species of Community Interest (as of Annexes 1 and 2 of the Habitats Directive) to a Favourable Conservation Status. Marine Natural habitats of Annex 1 of the Habitats Directive are included in the HELCOM List. Baltic Sea EU Member States report on the biotopes/habitats to both EC and HELCOM and sometimes there is a discrepancy in the information.

Habitat-by-habitat assessment

The HELCOM List (HELCOM 2007b) forms the core of this assessment. It includes, *inter alia*, all marine Natura 2000 natural habitat types as listed

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[1] Protection of Heavily Endangered or Immediately Threatened Marine and Coastal Biotopes in the Baltic Sea Area (Adopted 20 March 2000).

	Denmark		Estonia		Finland		Germany		Latvia		Lithuania		Poland		Russia	Sweden	
	N2K	HEL	N2K	HEL	N2K	HEL	N2K	HEL	N2K	HEL	N2K	HEL	N2K	HEL	HEL	N2K	HEL
Sandbanks	🔴	3	🟢	3	🟠	3	XX	2	🟢				🟢	3	2-3	🟠	3
Estuaries	🟢	3	🟢	3	🔴	3	🔴	2		2	🟢	3	🟠	3	2-3	🟠	2
Mudflats or sandflats	🔴	3	🟢	3		3	🟠	3		3		P		3	2-3	🟠	
Coastal lagoons	🔴	3*	🟢	3*	🟠	2	🔴	2*	🟢	2*	🟢	2*	🟠	2*	2-3*	🔴	3
Large shallow inlets	🔴	3	🟢		🟠	3	🟠	2					🟠		3	🟠	
Reefs	🔴	3	🟢	3	🟠	3	XX	2	🟢	3	🟢		🟢		🟩	🔴	3
Submarine structures	🔴	2-3															
Baltic esker islands		P			🟠	2									🟩	🟢	3
Baltic narrow inlets					🟠	3										🟠	3

* These results represents the assessment of biotope complex Lagoons

N2K: Conservation status of Natura 2000 habitat types. 🔴 Bad 🟠 Inadequate 🟢 Favourable

HEL: Threat status according to HELCOM 1998. 0 Completely destroyed 1 Immediately threatened 2 Heavily endangered 3 Endangered P Potentially endangered 🟩 Presumably not endangered

Table 2.2.1. Overview of the conservation status of the Baltic Sea marine Natura 2000 habitats in comparison to the HELCOM threat assessment (HELCOM 1998). For a more detailed assessment, see Annex III.

in Annex I of the EU Habitats Directive (European Commission 2007). The first comprehensive reporting of Baltic Sea EU Member States on the conservation status of Natura 2000 natural marine habitat types[2] to the European Commission is summarized in Table 2.2.1. A more detailed description of the comparison is provided in Annex III of this report.

In the same table, these results are compared to the threat assessments given in the HELCOM Red List of Biotopes (HELCOM 1998). The assessment of HELCOM biotopes includes all Baltic Sea littoral countries, i.e., all nine countries including Russia. The most important results of the assessment according to Table 2.2.1 are:

Sandbanks: The conservation status is favourable in three EU Member States, inadequate in two, and bad and unknown in one each. According to the EC reports and HELCOM (1998), this natural habitat type is not present in Lithuania. The threat situation is heavily endangered in one country, endangered in five, and between endangered and heavily endangered in another country. According to HELCOM (2007b), sandbanks are widespread throughout the whole Baltic Sea area and occur in all HELCOM sub-regions. They are threatened and/or declining mainly in the southern Baltic Sea area.

Estuaries: The conservation status is favourable in three EU Member States, and inadequate or bad in two each. According to the EC reports, this natural habitat type is not present in Latvia. The threat situation is heavily endangered in three countries and endangered in five. In one case, the threat category was assessed as between endangered and heavily endangered. According to HELCOM (2007b), estuaries are present around the whole

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[2] According to the Habitats Directive, the status of a habitat is favourable when (1) its natural range and the areas it covers within that range are stable or increasing, and (2) the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and (3) the conservation status of its typical species is favourable.

Baltic Sea area and occur in all HELCOM sub-regions. They are threatened and/or declining in many sub-regions of the Baltic Sea area.

Mudflats and sandflats: The conservation status is favourable in one EU Member State, inadequate in two, and bad in one. According to the EC reports, this natural habitat type is not present in Finland, Latvia, Lithuania, or Poland. The threat situation is endangered in six countries and potentially endangered in one. In one case, the threat category is between endangered and heavily endangered. According to HELCOM (2007b), mudflats and sandflats are widespread throughout the whole Baltic Sea area and occur in all HELCOM sub-regions. They are threatened and/or declining in almost all sub-regions of the Baltic Sea area.

Coastal lagoons: For HELCOM, the respective biotope complex includes several specific types of lagoons such as some sub-types of Bodden, Barrier Lagoons and Fladas. The biotope type Coastal Lake (HELCOM 1998) also belongs to the coastal lagoon complex. The threat situation is as follows:

Biotope complex Lagoons: heavily endangered in five countries, endangered in three and potentially endangered in one. In one case, the threat category is between endangered and heavily endangered. In the Russian part of the Gulf of Finland, this biotope complex is presumably not endangered at present.

Biotope type Coastal Lakes: immediately threatened in one country, heavily endangered in one, and potentially endangered in six. In one case, this biotope type is presumably not endangered at present. According to HELCOM (2007b), lagoons are widespread throughout the whole Baltic Sea area and occur in all HELCOM sub-regions. They are threatened and/or declining in all sub-regions of the Baltic Sea area.

The conservation status of the Natura 2000 natural habitat type 'Coastal Lagoons' is favourable in three EU Member States, inadequate in two, and bad in three. It is the only Baltic Sea marine priority habitat within the EU. They are in immediate threat to become completely changed from an EU-wide perspective, and therefore enjoy a strict EU protection regime.

Large shallow inlets and bays: The conservation status is favourable in one EU Member State, inadequate in four, and bad in one. According to the EC reports, this natural habitat type is not present in Latvia or Lithuania. In comparison with HELCOM biotopes, this biotope cannot be exactly matched to biotopes of the HELCOM Red List. From the HELCOM biotope complexes, only fjards/fjord-like bays fit into this natural habitat type as well as some types of Bodden, and their appearance is restricted to the southern part of the Baltic Sea area. The threat situation is heavily endangered in one country and endangered in three (HELCOM 1998). According to HELCOM (2007b), however, this habitat type is present around the whole Baltic Sea area and occurs in all HELCOM sub-regions. It is threatened and/or declining along many central and southern Baltic Sea coasts.

Reefs: The conservation status of Reefs is favourable in four EU Member States, inadequate in one, bad in two and unknown in one. The threat situation is heavily endangered in one country, endangered in five, and in one case, presumably not endangered at present. According to HELCOM (2007b), reefs are widespread throughout the whole Baltic Sea area and occur in all HELCOM sub-regions. They are threatened and/or declining mainly in the southern Baltic Sea area.

Submarine structures made by leaking gases are only reported as sub-type 'Bubbling Reefs' in Danish waters of the Kattegat. The conservation status is bad. The HELCOM (1998) threat category is between endangered and heavily endangered. Although, according to HELCOM (2007b), submarine structures made by leaking gases appear only in the Kattegat sub-region of the Baltic Sea area, the other sub-type of this Natura 2000 natural habitat type—Pockmarks—may be more widespread in the Baltic Sea area. This needs to be further investigated by EU Member States.

Baltic esker islands are only reported from Finland (inadequate) and Sweden (favourable). For the implementation of the EU Habitats Directive, they are only assessed in the EU Boreal Region. According to HELCOM (1998), they also appear in the marine areas of other Baltic Sea littoral countries, but their status has not been assessed.


Mud-sandflat, Greifswald Lagoon, Germany

Boreal Baltic narrow inlets are only reported from Finland and Sweden. In both cases, the conservation status is inadequate. For the implementation of the EU Habitats Directive, they are only assessed in the EU Boreal Region. According to HELCOM (1998), they are assessed as endangered in Finland and Sweden.

Country-by-country assessment

In Estonia, Latvia and Lithuania, the conservation status of all habitat types reported under the Habitats Directive is favourable. In Denmark, Finland, Germany and Sweden, the conservation status is predominantly unfavourable. In Poland, the conservation status of reported natural habitat types is inadequate in three and favourable in two habitat types.

For Russia, it is only possible to consider the HELCOM Red List of Biotopes because the Russian Federation is not an EU Member State. The threat categories for most biotope types and complexes in Russian waters in and off the Kaliningrad oblast are between endangered and heavily endangered (2–3), whereas in the Gulf of Finland many are presumably in the category Not Endangered at present.

In conclusion, the conservation status of the natural habitat types in the HELCOM List and in Annex 1 of the Habitats Directive is assessed very differently by HELCOM EU Member States. Table 2.2.1 makes it clear that some countries judge habitat types as being in a favourable conservation status even though they are threatened according to the HELCOM List of Biotopes. Moreover, it is obvious that some HELCOM EU countries have reported some natural habitat types as being not present in their marine or coastal area to the European Commission, although they have been assessed as being threatened in their country according to HELCOM (1998).

Assessment of other habitats/biotopes

In addition to the above Natura 2000 natural habitat types, the HELCOM List (HELCOM 2007b) includes the following habitat/biotope types: (1) Offshore (deep) waters below the halocline, (2) Shell gravel bottoms, (3) Seagrass beds, (4) Macrophyte meadows and beds, (5) Gravel bottoms with *Ophelia* species, (6) Maerl beds, and (7) Sea pens with burrowing megafauna.

Offshore (deep) waters below the halocline occur in all main basins of the Baltic Sea area. They are threatened where they appear and are assessed for the whole area as heavily endangered (HELCOM 1998). Seagrass beds with *Zostera marina* occur in the Baltic Sea area south of the Bothnian Sea, whereas seagrass beds with *Zostera noltii* are restricted to the southwestern and southern parts of the Baltic Sea area including the Bay of Mecklenburg and the Gulf of Gdansk. Seagrass beds are among the most threatened marine biotopes in the Baltic Sea area. They are part of the heavily endangered HELCOM biotope type 'Level sandy bottoms dominated by macrophyte vegetation' (HELCOM 1998). Macrophyte meadows and beds (other than seagrass beds) occur on soft and hard bottoms in the whole Baltic Sea area (HELCOM 2007b). From a Baltic-wide perspective, the exact status of threat and/or decline is not yet known. However the biotope is threatened and declining where it appears, because characteristic species are not recorded at the same water depths as before. They are part of many endangered or heavily endangered HELCOM biotope types that are dominated by macrophyte vegetation (HELCOM 1998) (see also Chapter 3, Habitat-forming species).

In the southern and southwestern parts of the Baltic Sea area, there are habitat types characterized by species that require more saline waters. Shell gravel bottoms, Maerl beds, Gravel bottoms with *Ophelia* species, and Sea pens and burrowing megafauna communities are all very rare. Although they are threatened where they appear (HELCOM 2007b), their status of threat and/or decline is not known. These biotopes are, however, considered to occur in limited areas, and are therefore potentially endangered. Maerl beds occur only on offshore banks in the Kattegat (e.g., Lilla Middelgrund and Fladen). The presence of dead maerl at some offshore banks indicates that the habitat must have been more widespread in the past (see OSPAR 2006). Sea pens and burrowing megafauna communities are found only in the deeper parts of the Kattegat (HELCOM 2007b).

2.2.2 Conclusions

The biotopes/habitats in the HELCOM List are all to a certain degree threatened and/or declining, although not necessarily in all sub-regions of the Baltic Sea area or in all Baltic maritime areas of HELCOM Contracting Parties. Even if the exact level of threat and/or decline is not always known, the above assessment makes it clear that from a Baltic-wide perspective, none of the habitats/biotopes assessed by HELCOM can be considered as being in a favourable conservation status. For most of them, the conservation status is inadequate or even bad and they are all in urgent need of protective measures (HELCOM 2007b). According to the HELCOM Red List of Biotopes (HELCOM 1998), the situation is troubling in particular for biotope complexes such as offshore (deep) waters below the halocline, lagoons and estuaries, as well as for some benthic biotope types such as seagrass beds and macrophyte meadows and beds. Additionally, all habitats/biotopes that are potentially endangered have always been rare or exist only in a small distribution area. Therefore, they are continuously in potential danger of demise (HELCOM 1998).

The HELCOM BSAP calls for a favourable status of marine biodiversity. In order to reach the target of the BSAP related to habitats and biotopes, there is an urgent need for actions to protect and restore them. As the first step and in order to increase knowledge, the BSAP requires that the HELCOM Red List of Biotopes (HELCOM 1998) must be updated by 2013. Periodic updates of this List in the future will make it possible to assess trends in the threat status and thus to evaluate whether the target to halt the degradation and ensure the recovery of threatened and/or declining marine biotopes/habitats in the Baltic Sea is being fulfilled. In this sense, regularly updated red lists can be used as indicators for assessing the implementation of the BSAP.

2.2.3 Recommendations

This assessment shows that there are urgent needs for further analysis and clarification. Some EU Member States have not reported some Natura 2000 natural habitat types to the European Commission, although they are obviously present in their Baltic Sea marine area. In some cases, Red-Listed biotope types or complexes (HELCOM 1998) seem to be improperly reported as being of favourable conservation status to the European Commission. The protection of the Baltic Sea ecosystem and the management of human activities require descriptors of the different components of biodiversity that can be interpreted in an unambiguous manner. To enable holistic and consistent assessments of habitats in the Baltic Sea region, Contracting Parties should clarify and amend the necessary common information to guarantee unified reporting on the status of habitats, biotopes and biotope complexes.

Mixed sediments with eelgrass (*Zostera marina*), Puck Bay, Poland

3 COMMUNITIES

Communities are assemblages of species within an ecosystem. The composition of species within a community influences fundamental processes such as the productivity, stability and trophic interactions within the food web and thereby also the overall functioning of the ecosystem. The communities specifically addressed in this chapter are Baltic phytoplankton, habitat-forming species, zooplankton, benthic invertebrates, and fish. The different communities form an intricate web with predatory, competitive, synergistic and commensal interactions. Thus, changes in one community inevitably affect other components of the Baltic biodiversity (Figure 3.1).

The Baltic Sea Action Plan includes the ecological objective 'Thriving and balanced communities of plants and animals'. Owing to their fundamental role in the ecosystem, assessment of the composition of the communities as well as of their key species provides a central component for determining the conservation status of the Baltic Sea.

3.1 Phytoplankton communities

The Baltic Sea phytoplankton community is a diverse mixture of microscopic algae representing several taxonomic groups, with more than 1 700 species recorded (Hällfors 2004). The phytoplankton composition in different sub-basins of the Baltic Sea depends, among other things, on the salinity (Carstensen et al. 2004, Wasmund & Siegel 2008). Diatoms and dinoflagellates are characteristic in the saline waters of the southern Baltic Sea, the Belt Sea and the Kattegat, whereas phytoplankton groups preferring less saline water, such as cyanobacteria and chlorophytes, are commonly found in the northern Baltic Sea. The geographic distribution pattern complicates the use of certain phytoplankton groups as Baltic-wide indicators of the ecological state (Carstensen et al. 2004, Gasiūnaitė et al. 2005).

Phytoplankton are dominant primary producers in both the coastal and open Baltic Sea, and serve as the energy source for the higher components of the food web. The socio-economic importance of phytoplankton is largely associated with the negative impact of algal blooms and their potential toxicity (HELCOM 2006a). Algal blooms decrease water transparency and light availability, thus affecting submerged vegetation in the coastal areas. In addition, blooms increase the sedimentation of organic material, which, in turn, increases oxygen consumption in near-bottom waters and induces internal nutrient loading (HELCOM 2002). Dense and potentially toxic blooms reduce the recreational use of the water, pose a health risk, and have economic implications, e.g., for fisheries. Blooms of toxic phytoplankton species may also inhibit the growth and reproduction of other aquatic organisms (e.g., Uronen 2007).

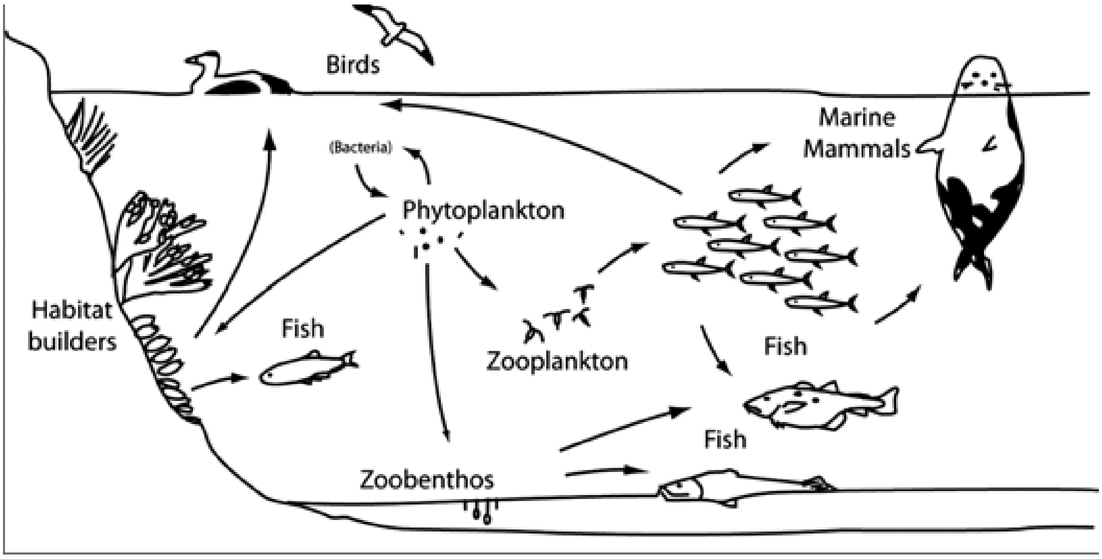


Figure 3.1. Food web illustration depicting the links among Baltic Sea communities (Hermanni Backer).

Phytoplankton are generally addressed in the Baltic Sea Action Plan (BSAP) by the target "*By 2021 all elements of the marine food webs, to the extent that they are known, should occur at natural and robust abundance and diversity*". In its eutrophication segment, the BSAP also includes the ecological objective 'Natural level of algal blooms'. Algal blooms imply reduced biodiversity of the phytoplankton community and also pose a risk to other components of biodiversity in the Baltic Sea ecosystem (cf. Uronen 2007, and references therein). It has recently been shown that phytoplankton biodiversity increases resource-use efficiency and stabilizes species composition and, thus, decreases the potential risk for algal species invasions and/or resource monopolization, e.g., by algal blooms (Ptacnik et al. 2008).

3.1.1 Status and trends

Nutrients and light control the growth of phytoplankton, but also other factors, such as water temperature, stratification, mixing conditions and grazing, influence the biomass and species composition (Wasmund & Siegel 2008). Phytoplankton communities in the Baltic Sea, therefore, reflect hydrological changes as well as the eutrophication process (e.g., Wasmund & Uhlig 2003, Suikkanen et al. 2007). Increased nutrient concentrations increase the bloom frequency and duration and, together with changes in the ratios of nitrogen, phosphorus and silicate, they also modify the species composition (Yurkovskis et al. 1999, Carstensen & Heiskanen 2007).

Phytoplankton respond rapidly to changes in environmental conditions, and can therefore be used to assess the ecological status of the water. To assess changes in the phytoplankton community and to detect long-term trends, indicators based on species composition and group dominance are predominantly used because traditional measures of diversity (e.g., richness and evenness) or chlorophyll (as a proxy of biomass) do not necessarily display the change from one community to another.

This assessment concentrates on a number of preliminary indicators that are typically sensitive to eutrophication and nutrient loading (HELCOM 2006a, Fleming-Lehtinen 2007): the ratio between diatoms and dinoflagellates in spring, the frequency and intensity of cyanobacterial blooms in summer, especially the biomass of the cyanobacterium *Aphanizomenon flos-aquae*, and the biomass of the dinoflagellate genus *Dinophysis*. The results are based on time series data of 20–30 years, depending on the indicator, covering the major basins and some coastal areas. With the exception of *Aphanizomenon*, reference conditions have not yet been determined for these phytoplankton indicators (HELCOM 2006a, Kuuppo 2007) and they are thus not used in the pilot testing of the Biodiversity Assessment Tool BEAT (Chapter 5). However, for smaller regions, historical literature may be used to define reference conditions, as shown by Wasmund et al. (2008) for the Kiel Bight.

Diatom-to-Dinoflagellate ratio in spring

The phytoplankton spring bloom is usually a short-term event that occurs annually in the Baltic Sea area. The bloom succession and intensity are closely linked to the nutrient availability, although light, water column mixing, and the timing of ice melting are also of importance (e.g., Yurkovskis et al. 1999, Wasmund & Siegel 2008).

The spring bloom in the Baltic Sea is dominated by diatoms and dinoflagellates (HELCOM 1996b, 2002). Long-term data from the Baltic Proper suggest that dinoflagellates are becoming more abundant in spring (Figure 3.1.1, Wasmund & Siegel 2008). The reason for the increased importance of dinoflagellates is not clear, but it may be linked to changes in climatic conditions and stratification patterns (Wasmund et al. 1998, Tamelander & Heiskanen 2004, Toming & Jaanus 2007).

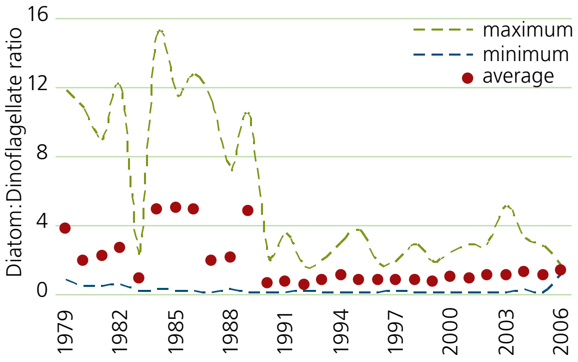


Figure 3.1.1. Mean (average), maximum, and minimum diatom-to-dinoflagellate biomass ratios in February–May in the southern and central Baltic Proper. The dinoflagellate biomass includes all auto- and mixo-trophic species, but excludes heterotrophs. HELCOM BMP station data.

The shift from diatoms to dinoflagellates may have implications for the nutrient dynamics in the summer and the input of organic matter to the sediment, as diatoms usually sediment to the seabed at the end of the bloom, whereas dinoflagellates are mostly remineralized in the upper water layers (Tamelander & Heiskanen 2004). However, a general decrease in diatoms has not yet been found in the Belt Sea, as confirmed by Wasmund et al. (2008) for the Kiel Bight for the past 100 years.

Based on high-frequency monitoring data on chlorophyll-*a* collected on merchant ships, the spring bloom intensity has been monitored since 1992 in the Arkona Basin, the northern Baltic Proper and the western Gulf of Finland (Fleming & Kaitala 2006). The index values of 0–1 060 from the period 2000–2006 are comparable to those in previous years and do not indicate any clear trends, although the average values have been slightly higher in the 2000s, particularly in the Gulf of Finland (Figure 3.1.2; Fleming & Kaitala 2006).

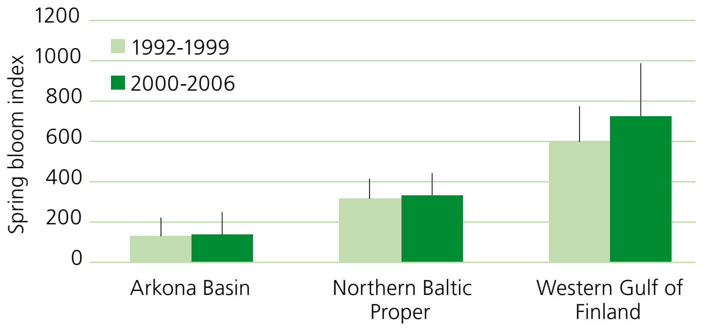


Figure 3.1.2. Phytoplankton spring bloom index in the open western Gulf of Finland, northern Baltic Proper and Arkona Basin. The bars represent average values with standard deviations for the periods 1992–1999 and 2000–2006. Alg@Line data modified from Fleming & Kaitala (2006).

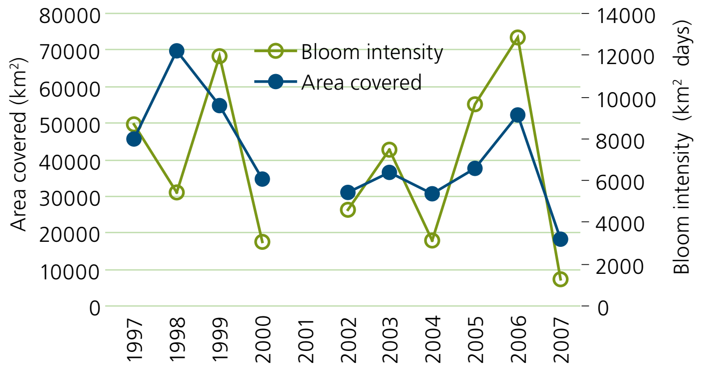


Figure 3.1.3. Area coverage and intensity of cyanobacterial blooms, as integrated for the Baltic Sea for 1997–2007. Annual summary values are based on the analysis of satellite image data. Modified from Hansson (2007).

Cyanobacterial blooms

Cyanobacteria are a natural component of the phytoplankton community in most parts of the Baltic Sea area (HELCOM 1996b, Hajdu et al. 2008). They usually dominate in summer in the coastal and open areas of most sub-basins of the Baltic Sea, with the exception of the Belt Sea and the Kattegat (e.g. Jaanus et al. 2007, Wasmund & Siegel 2008).

The cyanobacterial biomass has been lower in the 2000s than in the 1980s–1990s in the Gulf of Riga, Eastern Gotland Basin and Arkona Basin (Jaanus et al. 2007). In contrast, late-summer biomass of cyanobacteria has been reported to have increased in the open northern Baltic Sea since the late 1970s (Suikkanen et al. 2007; see also Kahru et al. 2007).

Cyanobacterial blooms in the Baltic Proper are typically formed by the diazotrophic species *Aphanizomenon flos-aquae*, *Anabaena* spp. and *Nodularia spumigena* that can fix molecular nitrogen (Laamanen & Kuosa 2005, Mazur-Marzec et al. 2006, Hajdu et al. 2007). *N. spumigena* blooms are potentially toxic, whereas no toxic blooms of *A. flos-aquae* have been recorded in the Baltic Sea. The blooms of N_2-fixing cyanobacteria as such do not necessarily indicate strengthened eutrophication (Gasiūnaitė et al. 2005, Toming & Jaanus 2007).

Satellite images covering the Baltic Sea area show that the frequency and magnitude of the accumulation of cyanobacteria on the surface water have varied during 1997–2007, but without a clear trend (Figure 3.1.3, Hansson 2007). However, the average frequency of cyanobacterial accumulations was 39% higher in 1998–2006 than in 1979–1984, although the difference is not significant (Kahru et al. 2007). It should be noted that satellite images describe the surface accumulation of *N. spumigena* relatively well, but mostly ignore *A. flos-aquae* which generally locates deeper in the water column (Kahru et al. 2007).

The surface blooms are typically short in duration, i.e., from days to a few weeks (Hansson 2007), but their influence may last longer through the effects on near-bottom oxygen conditions and potential food-web effects (Vahtera et al. 2007). A low nitrogen-to-phosphorus ratio and calm and warm

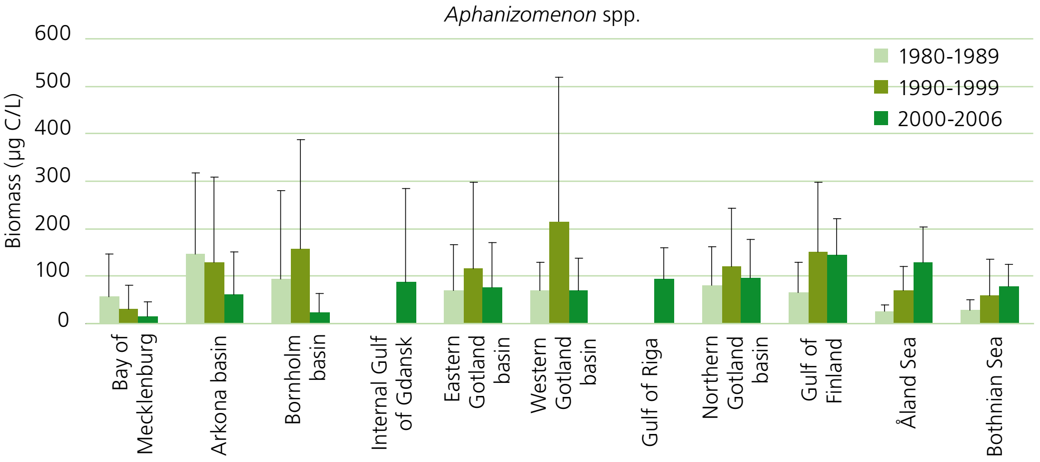


Figure 3.1.4. Mean biomass (µg C/L) of the cyanobacterium *Aphanizomenon* spp. in June–September in the 1980s, 1990s, and 2000s in different parts of the open and coastal Baltic Sea. The whiskers show the standard deviation. HELCOM BMP station data.

weather typically favour the surface accumulation of cyanobacteria (Wasmund & Siegel 2008).

The cyanobacteria bloom index integrates the rank abundance of *A. flos-aquae* and *N. spumigena* during the growing season (April–October) along the ferry route sampling points between Helsinki and Travemünde (Kaitala & Hällfors 2007). The value of the bloom index remained at the same level from 2001 to 2006, but it was above the mean of 1997–2006 in 1999 and 2000 and below in 1997 and 1998.

A. flos-aquae was reported to increase in the surface water (0–10 m) in the open and coastal Gulf of Finland from 1968–2004, which can be linked to strong internal nutrient loading in the area (Fleming-Lehtinen 2007, Suikkanen et al. 2007). *A. flos-aquae* has also increased since 2003 in the coastal areas of Askö (Hajdu et al. 2007). However, a long-term change in *A. flos-aquae* biomass was not evident in all sub-basins of the Baltic Sea in the 1980s–2000s (Figure 3.1.4), e.g., in the southern Baltic Sea, the *Aphanizomenon* biomass has been lower in the 2000s.

N. spumigena has been reported to increase in the open northern Baltic Proper in summer (Suikkanen et al. 2007, Hajdu et al. 2007). In the coastal waters of the Gulf of Gdańsk, intensive blooms of *N. spumigena* have been recorded frequently since 1994, and the largest *Nodularia* blooms occurred in 1994, 2001, 2003, and 2004 (Mazur-Marzek et al. 2006).

The dinoflagellate *Dinophysis*

It has been suggested that the toxic dinoflagellate genus *Dinophysis* reflects increased nutrient status and climate-induced changes in salinity and mixing conditions. It has been shown that the toxins of, for example, *Dinophysis acuminata* can be transferred in the pelagic food chain (Setälä et al. 2009) and sediment to the benthic ecosystem (Kuuppo et al. 2006). However, the effects of the *Dinophysis* species on the ecosystem are not clear.

A comparative study from the western Gulf of Finland and the northern Baltic Proper with data from 1903–1911 and 1993–2005 showed that *Dinophysis acuminata*, *D. norvegica* and *D. rotundata* occur more frequently now than in the beginning of the 20th century (Hällfors et al. 2008). However, the results from the past 30 years show that in the sub-basins studied, the spring and summer biomass of the *Dinophysis* species has been lower in the 2000s than in the 1980s–1990s in the Arkona Basin, the Bornholm Basin, the Bay of Mecklenburg and the Eastern Gotland Basin (data not shown). For example, the biomass of *Dinophysis norvegica* has decreased significantly since the 1990s in the Landsort Deep and in the coastal areas (Askö) in the northern Baltic Proper (Hajdu et al. 2007). In the Gulf of Finland and the Bothnian Bay, the *Dinophysis* biomass in summer has remained rather stable in the 1990s and 2000s. *Dinophysis* species occur frequently in the inner and outer Kattegat and the inner Skagerrak, and their abundance in these areas is mostly associated with stratification conditions (Håkansson 2007).

Unusual events and new species invasions

Unusual events in the phytoplankton community of the Baltic Sea are associated with hydrology, the invasion of alien species, immense loading of nutrients and extreme weather events (Hajdu et al. 2006). During the 2000s the potentially toxic dinoflagellate, *Alexandrium ostenfeldii*, has developed larger populations than previously noted, and blooms have been recorded in the Gulf of Gdańsk and the Swedish coast of the northern Baltic Proper (Hajdu et al. 2006). *A. ostenfeldii* has previously mainly occupied the Kattegat and the southern Baltic Proper (e.g., Håkansson 2007). Another toxic dinoflagellate, *Prorocentrum minimum*, is also becoming established in the Baltic coastal areas (Hajdu et al. 2005). *P. minimum* has, however, not been recorded in high abundance in the northern Baltic Proper or the Gulf of Finland since 2003. The step-wise pattern of the invasion of the species supports the natural transport theory and adaptation to a new environment.

Blooms of the toxic dictyochophyte *Verrucophora* spp. (previously named *Chattonella*) occurred in the Skagerrak-Kattegat area in 2000, 2001, 2004 and 2006. *Verrucophora* is a new problem genus in the area and has caused damage to wild and farmed fish (Håkansson 2007). Mass occurrences of certain phytoplankton species (e.g., the dinoflagellate *Gyrodinium aureolum* in 1982; the toxic haptophyte *Chrysochromulina polylepis* in May–June 1988; the toxic diatom *Pseudonitzschia pseudodelicatissima* in autumn 1999) in the Skagerrak and the Kattegat area have been related to intrusions of nutrient-rich water into the pycnocline (e.g., Håkansson 2007). Accordingly, it has been proposed that many recent changes in the phytoplankton could be related to climatic variation and climate change which influence directly and indirectly water temperature, salinity, and nutrient loading from the catchment in the Baltic Sea area (e.g., Hajdu et al. 2007).

Analysis of historical and present-day phytoplankton composition data shows that many phytoplankton taxa now occur more frequently, and their seasonal dynamics have changed compared to the situation in the early 1900s (Hällfors et al. 2008, Wasmund et al. 2008). In addition to cyanobacteria (e.g., Hajdu et al. 2007), long-term records provide evidence that the biomass of chrysophytes and chlorophytes in the surface water has increased significantly in the open northern Baltic Sea (Suikkanen et al. 2007). In the coastal waters, the shifts in the phytoplankton composition are typically gradual and the changes are rather small if the increases in nutrient levels are small or moderate (Carstensen & Heiskanen 2007).

3.1.2 Conclusions

Long-term data sets (Hällfors et al. 2008, Wasmund et al. 2008) indicate that the phytoplankton species composition has experienced changes during the past 100 years in parts of the Baltic Sea. Although there are few clear trends in recent decades, the reported long-term increases in cyanobacteria and the blooms of problem species indicate that the Baltic Sea phytoplankton is not at its 'natural level' as targeted in the BSAP. At present, enhanced internal loading of phosphorus and the removal of dissolved inorganic nitrogen, e.g., by denitrification and anammox, result in lower nitrogen-to-phosphorus ratios, which favour blooms of N_2-fixing cyanobacteria (Vahtera et al. 2007). This complicates the target for a short-term reduction in blooms.

The establishment of new species and observed changes in the species composition indicate changes in phytoplankton biodiversity. However, the reasons behind the biodiversity changes are not fully understood. Thus, the preliminary indicators used in this assessment and other phytoplankton data should be further evaluated so that the causes behind observed changes can be better distinguished. In addition, the effects of the biodiversity changes on the Baltic Sea ecosystem cannot yet be determined. The changing climate, with among others a higher probability of extreme weather events, is likely to increase the risk of new species introductions and unexpected blooms in the Baltic Sea area.

3.1.3 Recommendations

Sustaining phytoplankton biodiversity in the Baltic Sea and reaching the targets of the BSAP related to phytoplankton are linked to the reduction of eutrophication and minimizing the introduction of new harmful species to the Baltic Sea by ballast water.

The detection of possible changes in the phytoplankton communities necessitates a long-term and representative biological monitoring programme in all sub-basins of the Baltic Sea, the use of up-to-date monitoring methods, and quality-assured species identification at high taxonomic resolution.

3.2 Habitat-forming species

The Baltic Sea, as a waterbody with harsh environmental conditions and steep environmental gradients, provides a home to a variety of benthic species. A small number of species have a special role in the ecosystem by providing with their physical structure or physiological performance a necessary environmental support for other species. These species are able to physically modify the environment and structure the habitat to provide suitable conditions for a large number of species. In the Baltic Sea, such special, structuring species are usually large perennial macroalgae on hard bottoms and phanerogams and charophytes on soft bottoms. In sea bottom areas without access to direct sunlight, mussels are the structuring component for main habitat characteristics. These species are extremely important for the functioning of the whole Baltic Sea ecosystem and for maintaining the benthic biodiversity.

The importance of these species for maintaining a healthy status of the Baltic Sea is also recognized in the Baltic Sea Action Plan (BSAP), which sets several environmental targets and designates actions to preserve the favourable status of these species and communities, e.g., *"By 2021, that the spatial distribution, abundance and quality of the characteristic habitat-forming species, specific for each Baltic Sea sub-region, extends close to its natural range"*. Several habitat-forming species are also declining in certain areas of the Baltic and are therefore embraced by the target *"By 2010 to halt the degradation of threatened and/or declining marine biotopes/habitats in the Baltic Sea, and by 2021 to ensure that [they] have largely recovered"*.

3.2.1 Status and trends

At present, 442 species of macroalgae are found in the Baltic Sea including the Kattegat area (Nielsen et al. 1995). The number of marine species decreases with the salinity gradient, as salinity is the main environmental factor controlling the distribution of species on a Baltic-wide scale, while exposure, substrate type, and light availability determine the structure of vegetation communities on the local scale. This assessment presents the status of four main habitat-forming species of vegetation and one habitat-forming mussel species and also describes modelling tools for predicting their distribution in the Baltic Sea.

Fucus vesiculosus (Bladder wrack)

Bladder wrack *(Fucus vesiculosus)* is often characterized as the most important of all phytobenthic species in the Baltic coastal zone. This is due to its wide distribution and high biomass and productivity along rocky and stony coasts where *Fucus* belts play an important structuring role and have a positive effect on biodiversity, providing habitats for species-rich epiphytic and epibenthic communities (Figure 3.2.1, e.g., Kautsky & Kautsky 1989). As a result, fluctuations in the distribution and abundance of bladder wrack are likely to influence the state of biodiversity of coastal Baltic ecosystems on all trophic levels.

Bladder wrack is widely distributed in the northern hemisphere. In the Baltic, it penetrates up into

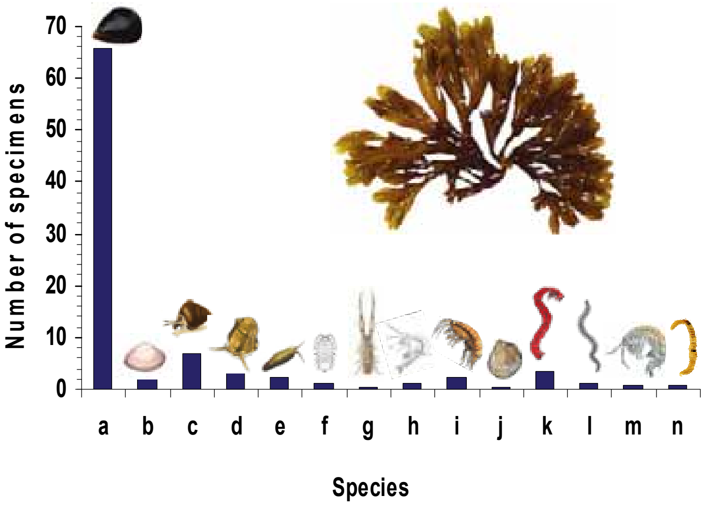


Figure 3.2.1. **Number of associated species living on one *F. vesiculosus* plant (collected from west coast of Saaremaa Island from a depth of 5.8 m in 2007). Figure prepared by Liis Rostin. a – *Mytilus trossulus*, b – *Macoma balthica*, c – *Hydrobia ulvae*, d – *Theodoxus fluvitailis*, e – *Idotea baltica*, f – *Jaera albifrons*, g – *Corophium volutator, h – Gammarus juv.*, i – *Gammarus salinus*, j – *Cerastoderma glaucum*, k – Chironomidae, l – *Hediste diversicolor*, m – *Gammarus oceanicus*, n – Oligochaeta.**

the Gulf of Bothnia in the north and the Gulf of Finland in the east, where it lives at its salinity tolerance limit. This limit is around a salinity of 4 psu, with occasional reports of isolated and sparse populations (individuals) at salinities down to 2 psu, although these are special cases in sites with heavy nutrient loads and probably a higher local salinity (Waern 1952, Pekkari 1956). Although the habitat requirements of *F. vesiculosus* with respect to salinity are fulfilled almost everywhere in the Baltic Sea, the alga also requires a firm substrate and low to moderate exposure to ice and waves in order to form stable and healthy communities. The distribution of the species has a strong biological control through competition for space with other perennial macroalgae in the southwestern parts of the Baltic Sea where salinity is higher, while this control disappears in areas with lower salinity where other perennial macroalgae are not able to compete for the substrate. Thus, in the inner Baltic Sea, the distribution of the species is mainly controlled by environmental variables such as light availability (Figure 3.2.2).

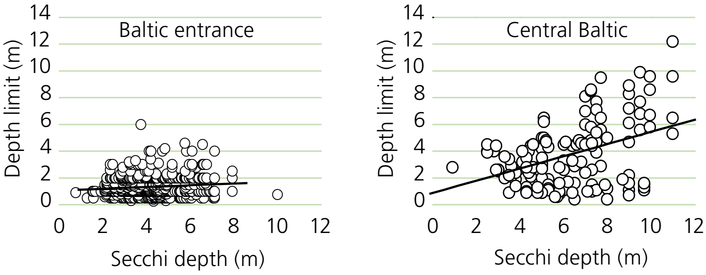


Figure 3.2.2. Relation between depth distribution of *Fucus vesiculosus* and water transparency in the Baltic Sea entrance area (including data from Kattegat, the Danish Belts Øresund and the Baltic between Zealand, Denmark and Scania, Sweden) and the central Baltic (including data from the Kiel Bight, Hanö Bay, the Arkona Sea, the Baltic Proper, the Gulf of Riga and the Gulf of Finland). Modified from Torn et al. 2006.

Several studies indicate that *F. vesiculosus* in the Baltic Sea is threatened by pollution both locally close to point sources and on a larger scale owing to a general eutrophication of the Baltic Sea (e.g. Kautsky et al. 1992, Schramm 1996). Decreases in distribution and the disappearance of *F. vesiculosus* have been reported from locally polluted areas such as the inner Stockholm Archipelago, Tallinn Bay, the Gulf of Gdańsk, the Helsinki Archipelago, and the Gulf of Riga. Decreases have also been reported from areas with little local pollution, e.g., the Lagskär skerries, the Tvärminne area and the Öregrund Archipelago, and it has been suggested that large-scale hydrographic changes may have contributed to the negative development in *Fucus* communities (Torn et al. 2006). However, in recent years bladder wrack has increased its depth extension in the northern Baltic Proper and Åland Sea (Gräsö area). It has also re-established on several sites where it was absent in the early 1990s (H. Kautsky, pers. comm., in prep.).

Zostera marina (Eelgrass)

Seagrasses are marine angiosperms providing important ecological components of coastal ecosystems worldwide. Out of 66 known large seagrass species, only two inhabit the Baltic Sea and only one, eelgrass *Zostera marina* L., is found to the northern limit of the Baltic Proper. This species provides a structure for the benthic environment and associated communities on soft, sandy bottoms.

Zostera marina inhabits mixed and sandy substrates with moderate wave exposure. Wave and ice prevent this species from inhabiting the shallowest parts (< 2 m) of the coastal slope, while light availability limits its depth distribution.

The depth distribution of eelgrass is not dependent on the salinity in the Baltic Sea (Baden & Boström 2001). This is not surprising because eelgrass can tolerate a broad range in salinity (5–35 psu, den Hartog 1970). A study in the Kattegat/Belt region on eelgrass maximum depth limit also found no correlation with salinity (Greve & Krause-Jensen 2003). Nonetheless, it takes longer to re-establish deep eelgrass communities at the lower salinity limit in the inner Baltic where eelgrass mainly grows vegetatively (Reusch et al. 1999) than at the entrance of the Baltic where seeds play an important role in its dispersal (Nielsen & Olesen 1994).

In the Baltic Sea, there have been considerable changes in the distribution characteristics of eelgrass in the past. The wasting diseases almost eliminated the species from the southern Baltic Sea in the 1930s. In most of the areas on the Danish and German coasts, the former distribution range has not recovered or the conditions have deteriorated during recent decades. At present, there is a near-complete lack of the species on the Polish, Lithuanian, and Latvian coasts. The area and abundance

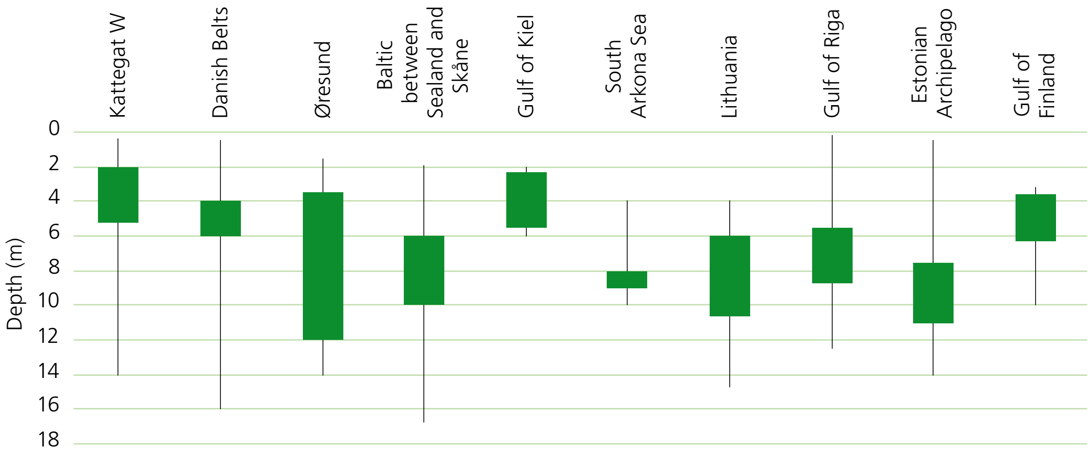


Figure 3.2.3. Maximum depth penetration of *Furcellaria lumbricalis* in different sea areas of the Baltic Sea. Boxes delimit the 25% and 75% percentiles and whiskers the minimum and maximum values. Data from 1989 to 2007 (CHARM database, national monitoring data).

of this species on other coasts have fluctuated considerably, and a lack of comprehensive monitoring data makes the assessment of the current conservation status of this species difficult. The main threats to the eelgrass communities today are eutrophication and mechanical disturbance of the seafloor, both of which significantly decrease the light climate on the seafloor and destroy the quality of the habitat.

Furcellaria lumbricalis

In the Baltic Sea, at least two ecologically distinguishable forms of the red algal species *Furcellaria lumbricalis* (Huds.) Lamour are found. The attached form of this species is very common on the hard bottoms of the lower part of the phytobenthic zone of the Baltic Sea (Nielsen et al. 1995). Large amounts of loose-lying *F. lumbricalis* are rarer. Only three localities have been described with large communities of this form in the Baltic Sea. One of these (Puck Bay) has already lost its population owing to eutrophication and pollution problems (Kruk-Dowgiałło & Ciszewski 1994). Austin (1959) described a similar agglomeration of loose *Furcellaria* in the central Kattegat area. The sea area of the West Estonian Archipelago hosts the largest known community of this kind, where a mixed community of loose-lying *Furcellaria lumbricalis* and *Coccothylus truncatus* covers up to 120 km^2 of sea bottom with more than 140 000 tonnes of wet biomass in Kassari Bay (Martin et al. 2006a,b). Loose *Furcellaria* communities 'entangled' with *Coccothylus* and *Mytilus edulis* are frequently found on levelled seafloors (mixed, sandy and soft substrates) in the Baltic Proper but not in the large volume described above.

Owing to its physiology, this species can tolerate low light intensities and therefore penetrates to depths where a majority of other species are not able to survive. According to recent monitoring data, this species penetrates to depths of 6 to 10 m in most of the Baltic Sea area, with the absolute maximum depth value of 16.5 m in the entrance area of the Baltic Sea (Figure 3.2.3). This species usually forms a belt deeper than bladder wrack, but the biomass of the communities is much lower, usually not exceeding 300–400 g m^{-2} dry weight. Adaptation to larger depths also enables this species to occupy extremely exposed coastal areas such as the Latvian, Lithuania and Polish coasts. The main threats to this species are associated with increased levels of eutrophication and mechanical stress to the bottom caused, for example, by dredging and dumping activities.

Charales (Stoneworts)

In the Baltic Sea, charophytes may dominate soft substrates within the photic zone together with phanerogams; they are common in shallow sheltered bays (Mathieson & Nienhuis 1991). Charophytes are found in all parts of the Baltic Sea area. Since 1981, twelve species belonging to the genus *Chara* have been recognized in the Baltic Sea area. A number of freshwater charophytes can occasionally be found in river estuaries and adjacent sea areas, but these species usually do not spread further to the sea. The largest number of charophytes is found in the easternmost and northernmost areas of the Baltic Sea (Figure 3.2.4.). The most common species in the Baltic Sea is *Chara aspera* Willd. *Chara baltica* Bruzelius is also distributed all over the Baltic Sea area and can be found on both sheltered and moderately exposed coastlines. One of the rare species, *Chara connivens* Salzm. Ex A. Braun, is considered to have been brought to the Baltic Sea by ballast sand and boulders in the sailing ship era; it has a limited distribution in the Baltic Sea, but is abundant in the areas in which it is found (Figure 3.2.5).

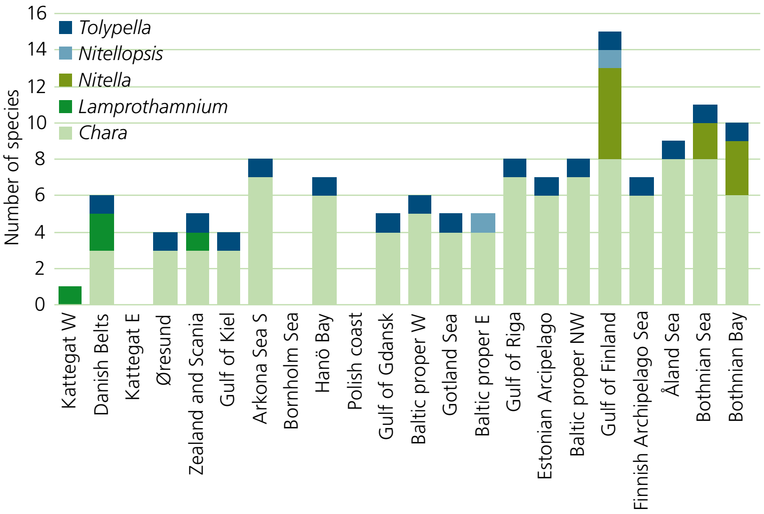


Figure 3.2.4. Number of Charophyte species in different areas of the Baltic Sea. Data from Schubert & Blindow 2003, Torn 2008. Division of the Baltic Sea after Nielsen et al. 1995.

Figure 3.2.5. Present distribution of invasive *Chara connivens* in the Baltic Sea (Torn 2008).

In the Baltic Sea, charophytes inhabit mostly sheltered coastal areas, where their distribution pattern is primarily controlled by the salinity regime, settlement depth, sediment type and exposure (Schubert & Blindow 2003).

In recent decades, the number of species, distribution area and biomass of charophytes have declined significantly in the Baltic Sea (Schubert & Blindow 2003). Most of the records on the considerable decline of charophyte populations are from coastal waters of Schleswig-Holstein, the Swedish west coast and the coastal waters of Hanko peninsula in southwestern Finland (Shubert & Blindow 2003). The decline of charophytes is mainly caused by mechanical stress, combined with the destruction of habitats and human-induced pressures such as eutrophication.

Mytilus trossulus (Blue mussel)

Two species of blue mussels can be found in the Baltic Sea area. *Mytilus edulis* is distributed in the North Atlantic and penetrates into most of the Kattegat. In the Baltic Sea, *Mytilus trossulus* dominates the shallow, hard substrates in the deeper vegetation belt and below, with abundances up to 36 000–156 000 individuals m^{-2} (Kautsky 1982). In the northern Baltic Proper, blue mussels are most often found in the depth range 0–25 m (Westerbom 2006); they have their maximum between 10–15 m depth (Littorin 1998) and usually start to decline after 30 m depth. Blue mussels dominate the animal biomass on hard substrates and, owing to their dominance, are considered to be one of key functioning species in the Baltic Proper. Quantitatively, the blue mussel constitutes up to 80–90% of total animal biomass in the shallow areas of the Baltic Sea (Kautsky et al. 1990). The blue mussel is considered to be an important link between the benthic and pelagic components of the Baltic ecosystem, channelling the flow of energy and matter, and being able to filter annually an amount of water corresponding to the volume of the entire Baltic Sea (Kautsky & Kautsky 2000).

Considerable fluctuations in densities and biomass of blue mussel have been recorded at different locations in the Baltic Sea (Westerbom 2006, Estonian Marine Monitoring data). These fluctuations cannot be explained by variations in environmental conditions (e.g., salinity, nutrient concentrations). Instead, a virus disease or periodic oxygen deficiency might have an influence on *Mytilus* abundance on a local scale, especially in areas with eutrophication problems. A decline of the *Mytilus* population in the Askö area in 1994, which was also seen in most parts of the Baltic Proper, was most probably due to unusually high temperatures down to 20 m depth for a long period in summer and a simultaneous low pelagic primary production (e.g., Axén 1999). Due to the lack of food, the mussels respired themselves to death.

3.2.2 Modelling habitat and species distribution

Maps showing the distribution of species and habitats are important instruments for an effective spatial planning and management in relation to ecosystems. Until recently, there has been a lack of such maps for marine environments, largely owing to the difficulty of obtaining biological data with a good spatial coverage. Because remote sensing techniques are not applicable for benthic habitats, except for shallow areas down to a few metres' depth, information on species and habitats is generally restricted to a few points in space, representing diving surveys and sediment samples. In most cases, these points cover only a tiny fraction of the area of interest (Figure 3.2.6).

Spatial modelling is a useful tool for transferring such point information to underwater maps showing the distribution of species and habitats (Figure 3.2.6). Briefly, spatial modelling works by finding a statistical relationship between the presence of a certain species or habitat and a number of environmental conditions, such as depth, wave exposure, type of substrate, etc. The presence of the focal species or habitat in each part of a map can then be predicted using data layers describing environmental conditions. Maps produced by spatial modelling can thus visualize the distribution of species or habitats in an entire area of interest and provide a quantitative estimate of how much of that area is covered by a certain species or habitat. They can also be used as an input in spatial planning with GIS tools including establishing conservation values (Isæus et al. 2007, Figure 3.2.7) or spatial planning of marine protected areas using,

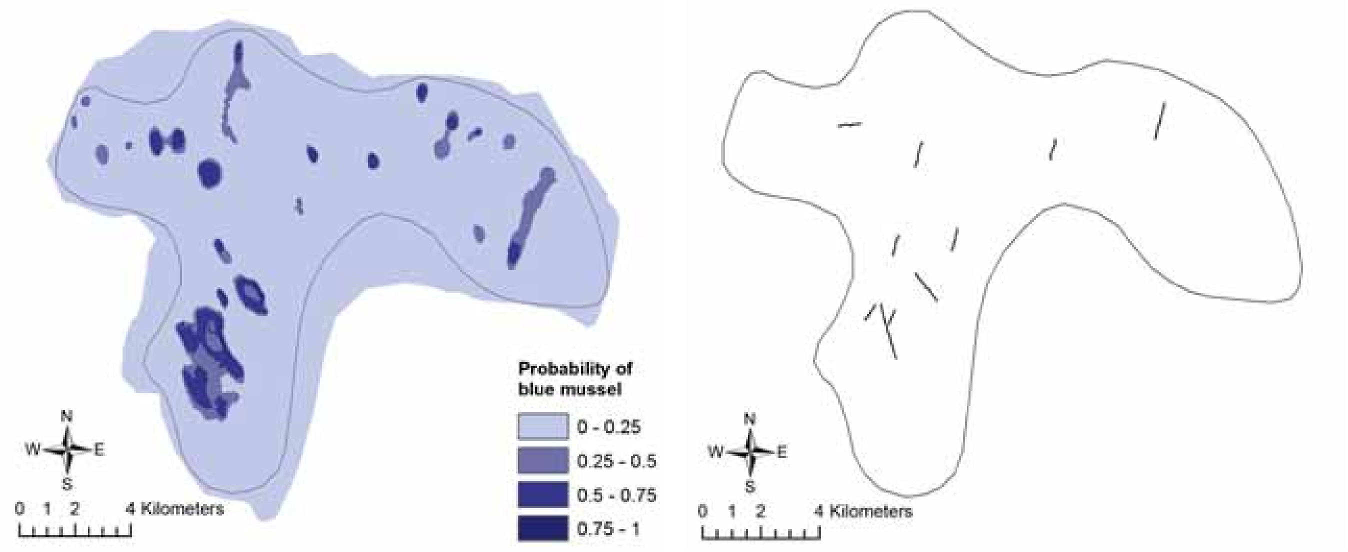


Figure 3.2.6. The modelled distribution of blue mussel on the Vänta litets Grund, Bothnian Sea. The map shows the predicted likelihood (between 0 and 1) for the occurrence of blue mussel. The right panel shows the video transects that were used as input for the spatial modelling, in themselves conveying much less information on the spatial distribution of the species. The map was produced by AquaBiota Water Research for a report on species distribution on Baltic offshore banks (SEPA 2008). Reprinted with permission from the Swedish EPA.

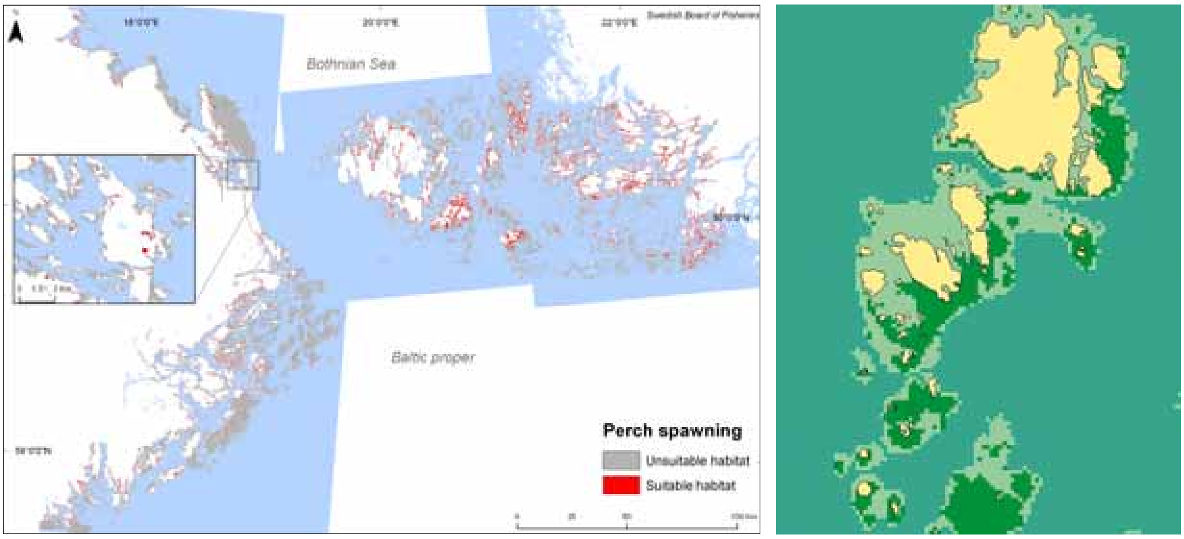


Figure 3.2.7. Left panel shows prediction of perch spawning habitats in the southern Quark area (by U. Bergström, A. Sandström and G. Sundblad, in Dinesen et al. 2008). The right panel shows classes of marine conservation values at Svenska Högarna, Stockholm Archipelago (Isæus et al. 2007). The map is constructed from overlay analyses of eight layers of species and habitat distributions. Light green shows high conservation values and dark green very high conservation values. Permission for reprinting the images has been given by the Swedish Board of Fisheries and Stockholm Administrative County Board.

for example, the software MARXAN (Ball & Possingham 2000, see Chapter 7).

Along with the many advantages of maps produced by spatial modelling, it is important to acknowledge that for the production of reliable maps it is crucial to have high-quality background data. The quality and resolution of predictive maps can never be better than the underlying data layers. The first step for predictive spatial modelling must, therefore, always be to assemble high-quality maps of the environmental factors that are expected to explain the distribution of the species or habitats of interest.

There are a number of successful examples of maps of benthic seaweeds, plants, sessile animals, fish, and habitats that have been produced using these techniques. A table with references to a number of habitat or species distribution models is given in Annex IV of this report. The examples mainly include detailed models at a local scale, but also some overview modelling examples including the whole Baltic Sea. Many of the studies were performed within the BALANCE project and are found in the BALANCE interim reports 11 (Bergström et al. 2007), 21 (Dahl et al. 2007), 23 (Müller-Karulis et al. 2007), and 27 (Dinesen et al. 2008). These modelling examples are located from the southern Quark to the Skagerrak. There are also examples of modelled benthic species and habitats on Swedish offshore banks in the Gulf of Bothnia and the Bothnian Sea (SEPA 2008). In Latvia and Lithuania, habitat modelling has been combined with the EUNIS classification to produce national benthic maps also including mussel-dominated habitats. In Estonia, spatial modelling is used as a standard technique for mapping the distribution of key species and habitats in the inventories of marine Natura 2000 sites (Martin et al. 2009). See also Box 3.2.1 for an example of modelling changes in *Fucus vesiculosus* distribution in the Askö area, Stockholm archipelago.

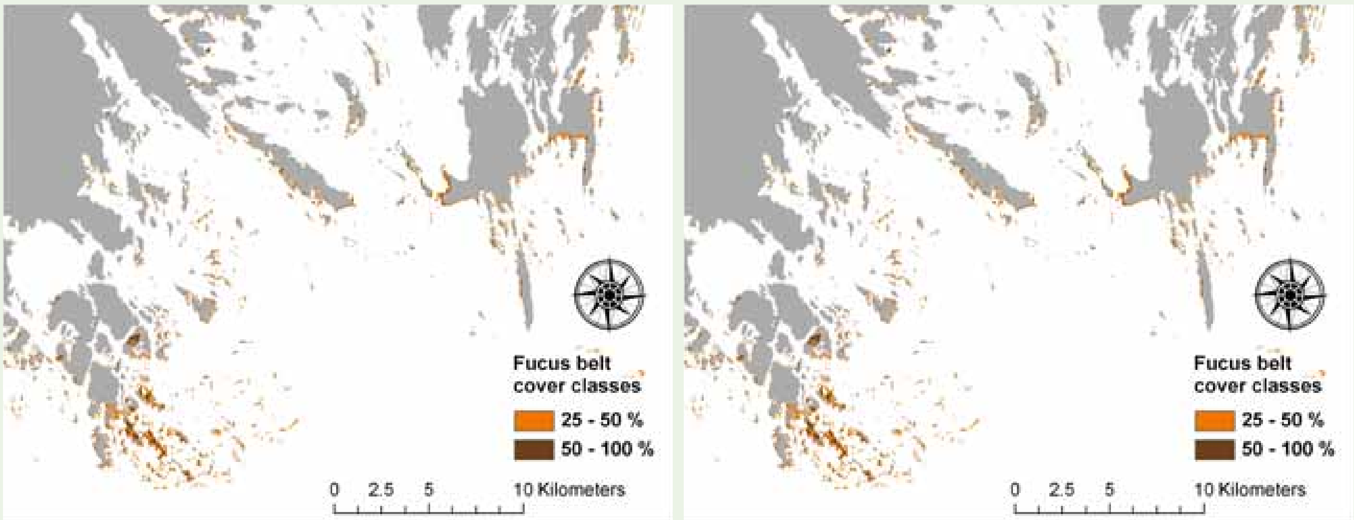
Several additional activities were completed during 2008 or early 2009. In Sweden, detailed maps of species distributions have been produced for three pilot areas in the Bothnian Bay, the Bothnian Sea, and the Baltic Proper. A first attempt has also been made to model the distribution of habitat-forming species on the scale of the entire Baltic Sea within the project MOPODECO, funded by the Nordic Council of Ministers. Experience from this first application of large-scale species modelling shows that the results vary in quality owing to variations in the abundance and quality of the input data.

Box 3.2.1. Changes in *Fucus vesiculosus* distribution—a modelling example

After a period of poor water transparency in the Stockholm Archipelago, the Secchi depth has improved during the past decade. Although the variation in water transparency is large, the trend at the phytobenthic monitoring stations in the Askö area shows an increase of about 1 m in Secchi-depth values measured during the annual inventories in August. The water transparency influences the light conditions at the seafloor and is thereby a determinant of the maximum depth distribution of macroalgae and other plants. As a part of the HELCOM BIO project, a model was constructed to calculate a quantitative measure of the changes in bladder wrack (*Fucus vesiculosus*) distribution in a habitat perspective. The model was constructed in cooperation with Stockholm University (Wallin et al. unpublished).

Using statistical modelling (GRASP, Lehmann et al. 2002), predictions of *F. vesiculosus* distribution were produced for 1993 and 2006 in the Askö area, northern Baltic Proper. The modelling was based on data from 30 stations in the Swedish phytobenthic monitoring programme (data from Swedish Environmental Protection Board, monitoring data, Hans Kautsky), wave exposure at the seafloor (Isæus 2004, Bekkby et al. 2008), light availability at the seafloor (Bekkby et al. in prep), reclassified marine geology (Cato et al. 2003), and slope and aspect derived from nautical charts via a TIN-DEM.

The resulting maps showing the distribution of *F. vesiculosus* belts in the two abundance classes, 25–50% cover and 50–100% cover, look similar at a first glance (see figure). However, by using a summarizing tool in GIS, the area of each class can be calculated showing that both classes have increased their distribution area during the period, by 17% and 2%, respectively. An integrated analysis of *Fucus* belts with 25% cover or higher shows a 12% increased belt area (see table). The depth distribution of *F. vesiculosus* decreased during the period 1943–1984, and decreased Secchi depth was given as the most likely explanation (Kautsky et al. 1986). Correspondingly, the increase of *F. vesiculosus* depth penetration and area coverage shown in this study is probably an effect of improved water transparency in Askö archipelago owing to improved sewage water treatment at the Swedish coast. The same trend may also be seen along the Swedish coast of the Baltic Proper. Unfortunately, this trend of improved water quality is not generally found in the Baltic Sea.



Distribution of *F. vesiculosus* belt classes modelled from a) 1993 field monitoring data, and b) from 2006 field data in the Askö area, northern Baltic Proper.

Modelled *F. vesiculosus* distribution in the Askö area, Stockholm archipelago in 1993 and 2006. During this period the estimated area of *F. vesiculosus* belts with more than 25% cover increased by 12%.

1993	Modelled area (m^2)	2006	Modelled area (m^2)	Difference (m^2)	Increase
25–50%	11 491 875	25–50%	13 454 375	1 962 500	17%
50–100%	5 306 875	50–100%	5 419 375	112 500	2%
25–100%	16 798 750	25–100%	18 873 750	2 075 000	12%

Implications for the Baltic Sea Action Plan
HELCOM has acknowledged the need for the mapping of important marine species and habitats in the Baltic Sea. The BSAP states that the goal is, by 2013, to identify and map the distribution of a number of habitat-forming species, including bladder wrack (*Fucus vesiculosus*), eelgrass (*Zostera marina*) and blue mussel (*Mytilus trossulus*). This work has already been initiated and the experiences to date suggest that spatial modelling is a promising tool, even though a large effort is still needed to provide better input data for the models.

In order to achieve the goal of the BSAP by 2013, it may be necessary in some cases to produce a first generation of somewhat coarser maps if the input maps are not of sufficient quality or detail. During the production of these maps, the shortcomings in the input data should be analysed and efforts to improve the data sets should be suggested. A second generation of maps with higher quality and detail may be produced when the input data sets have been improved.

3.2.3 Conclusions

The conservation status of several habitat-forming species (e.g., bladder wrack, stoneworts and eelgrass) in the Baltic Sea as a whole is unfavourable. Declines in species abundances as well as distribution area have been recorded recently. The most problematic areas seem to be the southernmost areas of the Baltic Sea. In contrast, coastal areas of the northern Baltic Proper show recent improvements and here the natural distribution of several functionally and structurally important species has almost been achieved.


***Chara* sp., Archipelago Sea, Finland**

The use of spatial modelling in marine applications has increased rapidly in recent years and is now a key tool in mapping the marine environment. Modelling will be used not only to map the current state, but also the changes in the distribution of species and habitats in response to environmental changes. To be able to use the full potential of this tool, much effort must also be put into collating existing data and collecting new data on species and environmental parameters covering the Baltic Sea.

3.2.4 Recommendations

The number of habitat-forming species in the Baltic Sea is relatively low and, in case of decline or disappearance, there are no other species that can fully replace their function in the ecosystem. In order to achieve the targets set by the BSAP and to reach a favourable conservation status of all habitat-forming species, the most important human pressures that should be mitigated are eutrophication caused by anthropogenic nutrient enrichment, and physical damage and fragmentation of the coastal zone caused by numerous human activities. To follow up progress towards the targets of the BSAP, it is crucial to establish effective monitoring as well as a system of regular assessment of the status of habitat-forming species.

It is recommended that effort be put into the production of high-quality maps of structuring environmental factors. This includes environmental factors that are important at the local scale (bathymetry, wave exposure, surface sediment, etc.), but also additional factors that are known to influence the species distributions on the regional scale, including salinity and climatic factors.

There is also a need for additional geographically representative field data on species, providing good coverage of all existing environments. Many data can likely be assembled from existing data sets collected by national inventory and monitoring programmes. If the data abundance is low in certain habitat types or regions, there will also be a need for more data collection based on identified data deficiencies.

3.3 Zooplankton communities

Zooplankton form an important link in the ecosystem by transferring energy from primary producers to fish. Zooplankton are suitable as indicators of pelagic ecosystem conditions because, in addition to their key role in energy transfer, they are short-lived (maximum 1 year) and directly affected by changes in hydrography. Hence, changes in zooplankton assemblages are reflected directly and rapidly in fish growth and stock conditions. Factors that influence zooplankton may be bottom-up processes, in which abiotic factors such as salinity or temperature regulate the food web from lower to higher levels. On the other hand, zooplankton may also be affected by top-down processes, whereby predators such as sprat or herring control their abundance. These processes at higher levels of the Baltic pelagic food web have been demonstrated recently, also highlighting the top-down control (e.g., Flinkman et al. 1998, Möllmann & Köster 1999, Möllmann et al. 2005, Casini et al. 2006).

There are no targets of the Baltic Sea Action Plan (BSAP) that directly address zooplankton. However, several targets are linked to the state of the zooplankton community, primarily the overaching goal *"By 2021 all elements of the marine food webs, to the extent that they are known, occur at natural and robust abundance and diversity"*. In addition, all fish are planktivorous as larvae, and some species remain as such all their lives. This is the case for Baltic herring and sprat, both of which are essential food sources for salmon and gadoid fish in the Baltic. The BSAP also aims at 50–80% of potential production of wild salmon in river populations by 2015. Furthermore, viable Baltic cod populations in their natural distribution area should be reached by the same year. This will be difficult to achieve if high-energy marine copepods continue to decline, as discussed in this section.

3.3.1 Status and trends

The Baltic Sea zooplankton community is a mixture of neritic and euryhaline marine species and purely freshwater species. Zooplankton are often classified by size as nanoplankton 2–20 µm (flagellates), microplankton 20–200 µm (ciliates, small rotifers), mesoplankton 0.2–2 mm (big rotifers, cladocera, copepods, different meroplanktic larvae), or macroplankton >2 mm (mysids, juvenile fish). Almost 800 ciliate species are found in open and coastal waters of the Baltic Sea and the open Baltic also harbours about 200 meso- and macrozooplankton species (Telesh et al. 2008). Mesozooplankton is the dominant group in the Baltic Sea in terms of biomass.

Crustacean mesozooplankton, i.e., copepods and cladocerans, are of particular interest because they are key components of the pelagic food web, and form the staple diet of planktivorous fish. Altogether, there are fewer than 15 copepod genuses and fewer than 20 cladoceran genuses present in the Baltic Sea. As these species have different adaptation capabilities in relation to salinity and temperature, their distribution differs considerably. A general trend of decreasing marine species and increasing freshwater species towards the north and east can be observed. A comprehensive description of the Baltic Sea zooplankton is available in Telesh et al. (2008).

Of copepods, truly marine species such as the large-size genus *Calanus* do not occur in the Baltic Sea, while in the North Sea, Northeast Atlantic, and Polar Seas they are key species as food for planktiovorous fish. Marine copepods found in the Baltic are neritic, coastal, and estuarine small-sized species, which all share a common feature: the ability to adapt to low salinity. The most pronounced marine species are *Pseudocalanus acuspes* and *P. elongatus*, which thrive in deep, saline water below the halocline. Other neritic species are *Centropages hamatus* and *Temora longicornis*, which are less dependent on sub-halocline habitat than *Pseudocalanus* spp. *Acartia* and *Eurytemora* are coastal and estuarine marine species, but have even better adaptation capabilities to the freshwater environment. *Limnocalanus macrurus* is a stenothermic freshwater species occurring in low-salinity deep water in the Gulf of Finland, Åland Sea and Bay of Bothnia ecosystems.

Most cladoceran species are of freshwater origin, except for genera *Evadne*, *Podon* and *Pleopis*, which are found in coastal ecosystems of adjacent marine environments. A recent invader, *Cercopagis pengoi* from the Pontocaspian region, is a brackish-water species.

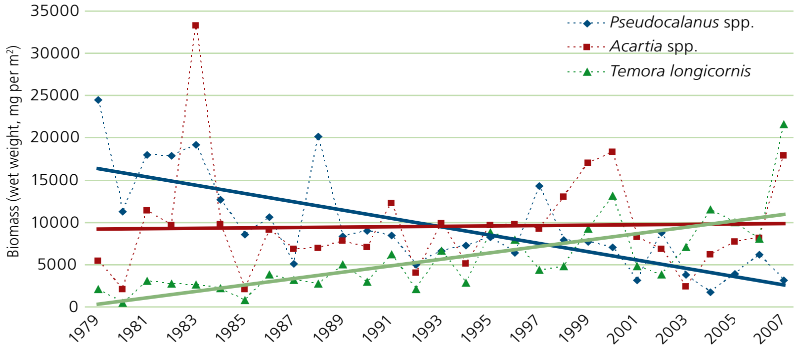


Figure 3.3.1. Biomass of copepods *Pseudocalanus* spp., *Temora longicornis* and *Acartia* spp. in the northern Baltic Proper. FIMR monitoring data 1979–2007, annual sampling (August) of HELCOM monitoring stations.

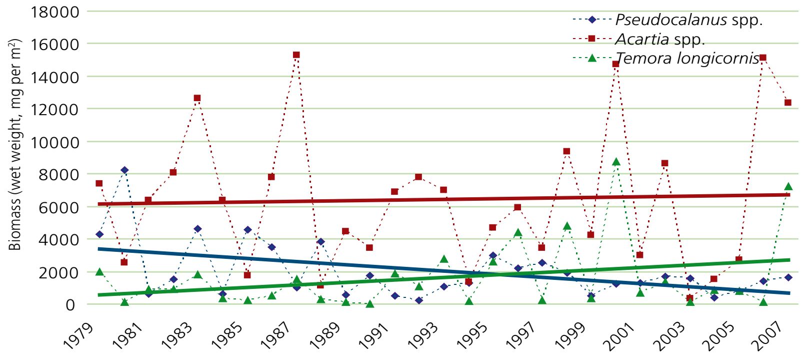


Figure 3.3.2. Biomass of copepods *Pseudocalanus* spp., *Temora longicornis* and *Acartia* spp. in the Gulf of Finland. FIMR monitoring data 1979–2007, annual sampling (August) of HELCOM monitoring stations.

Copepods, which are important food sources for economically valuable fish species, are proposed as useful indicators for monitoring the health of the Baltic Sea pelagic food web. Species that have been given particular attention in this assessment are: 1) *Pseudocalanus* spp., which are very sensitive to salinity changes and deep-water oxygen content, and are also a significantly selected, high-energy food item for herring, 2) *Temora longicornis*, which is less sensitive to abiotic changes, is still positively selected by herring, but has a lower energy content than *Pseudocalanus* spp., and 3) *Acartia* spp., which have low energy content, are not preferred by herring, and in addition are perhaps the least sensitive to abiotic changes (Flinkman et al. 1998). The assessment of these species is restricted to the northern Baltic Proper, the Gulf of Finland, and the southern Baltic Sea.

Northern Baltic Proper and Gulf of Finland

The available monitoring data from the past 28 years showed no significant trend in overall abundance or biomass development of zooplankton in the northern Baltic Proper. Of the main zooplankton groups, copepods showed no distinct trend, while cladocerans displayed a downward trend. However, there are distinct changes in abundance among copepod species. The copepod genus *Pseudocalanus* significantly declined during the observation period ($p<0.001$), whereas other copepod species such as *Temora longicornis*, *Eurytemora* spp., *Centropages hamatus* and *Limnocalanus macrurus* increased (Figure 3.3.1). The *Acartia* spp. group showed no clear trend over the observation period (Figure 3.3.1).

Zooplankton communities in the Gulf of Finland showed similar trends to those of the Baltic Proper, although not as clearly. There was no significant trend in overall zooplankton biomass, but at the species level, the copepod *Pseudocalanus* spp. displayed a decreasing trend ($p<0.05$), while *T. longicornis* and *Acartia* spp. were increasing (Figure 3.3.2).

Southern Baltic Sea

The changes in abundances of calanoid copepods in the central and southern Baltic Sea are not as clear as in the Gulf of Finland and northern Baltic Proper. In these areas, data are available from 1995 and between the years 2000–2005. The annual maximum abundance of all species was relatively constant during this period. A peak standing stock of about 30 000 individuals per m^3 was achieved annually, possibly indicating the maximum carrying capacity of the region (Wasmund et al. 2007). However, there was a clear change in the relative abundances of different species during the observation period. In comparison to *Acartia* spp. and *T. longicornis*, the abundance of *Pseudocalanus* spp. was up to one order of magnitude lower in 1995 and 2000–2005. This is opposite to the situation in the 1980s, when *Pseudocalanus* spp. was the dominant calanoid copepod in the Baltic Proper south of Gotland (Postel et al. 1996, Witek 1995, Telesh et al. 2008).

The same general trend with decreasing abundance of *Pseudocalanus* spp. counterbalanced by *Acartia* spp. and *Temora longicornis* has also been observed in the entrance of Gdańsk Bay (Witek 1995) as well as in the 28-year data record from the Bornholm Basin (Figure 3.3.3a–c).

3.3.2 Factors influencing and explaining the status of Baltic copepods

Changes in the abundance of copepod species during the period of observation can be attributed to a complex interaction between salinity, temperature, predation, and possibly also eutrophication.

Pseudocalanus and *Centropages* are the two genera that are most sensitive to decreasing salinity among the copepods studied. In the Bornholm Basin, the decline of *Pseudocalanus* lasted until the mid-1990s (Figure 3.3.3a). Saline inflows in 1993 and 2003 increased the salinity and oxygen content of the deep water (Figure 3.3.4a,b, Feistel et al. 2004) and caused a subsequent reverse trend in *Pseudocalanus* spp. abundance in the central Bornholm Basin. However, *Pseudocalanus* spp. never reached their peak concentration of 1984. This could be a result of the higher frequency of hypoxic and anaerobic conditions in the late 1990s and in 2004, which has reduced the volume of the preferred habitat layer of *Pseudocalanus* spp. between the top of the anoxic bottom layer and under the 8 psu salinity layer (Postel 2005). There seems to be a relationship between the habitat layer thickness and *Pseudocalanus* abundance.

While the decline in *Pseudocalanus* abundance can at least partly be linked to the decreasing salinity during the study period, *Centropages* is also sensitive to decreasing salinity and still showed an increase during the period. This can possibly be explained by the food preference of the main copepod predators. *Pseudocalanus* is perhaps the most preferred prey of Baltic planktivorous fish (e.g., Kornilovs et al. 1992, Flinkman et al. 1998, Möllmann et al. 2003, Casini et al. 2006). Thus, the decrease in *Pseudocalanus* abundance may periodically be enhanced by top-down control from the increased sprat stock during the observation period. *Centropages*, on

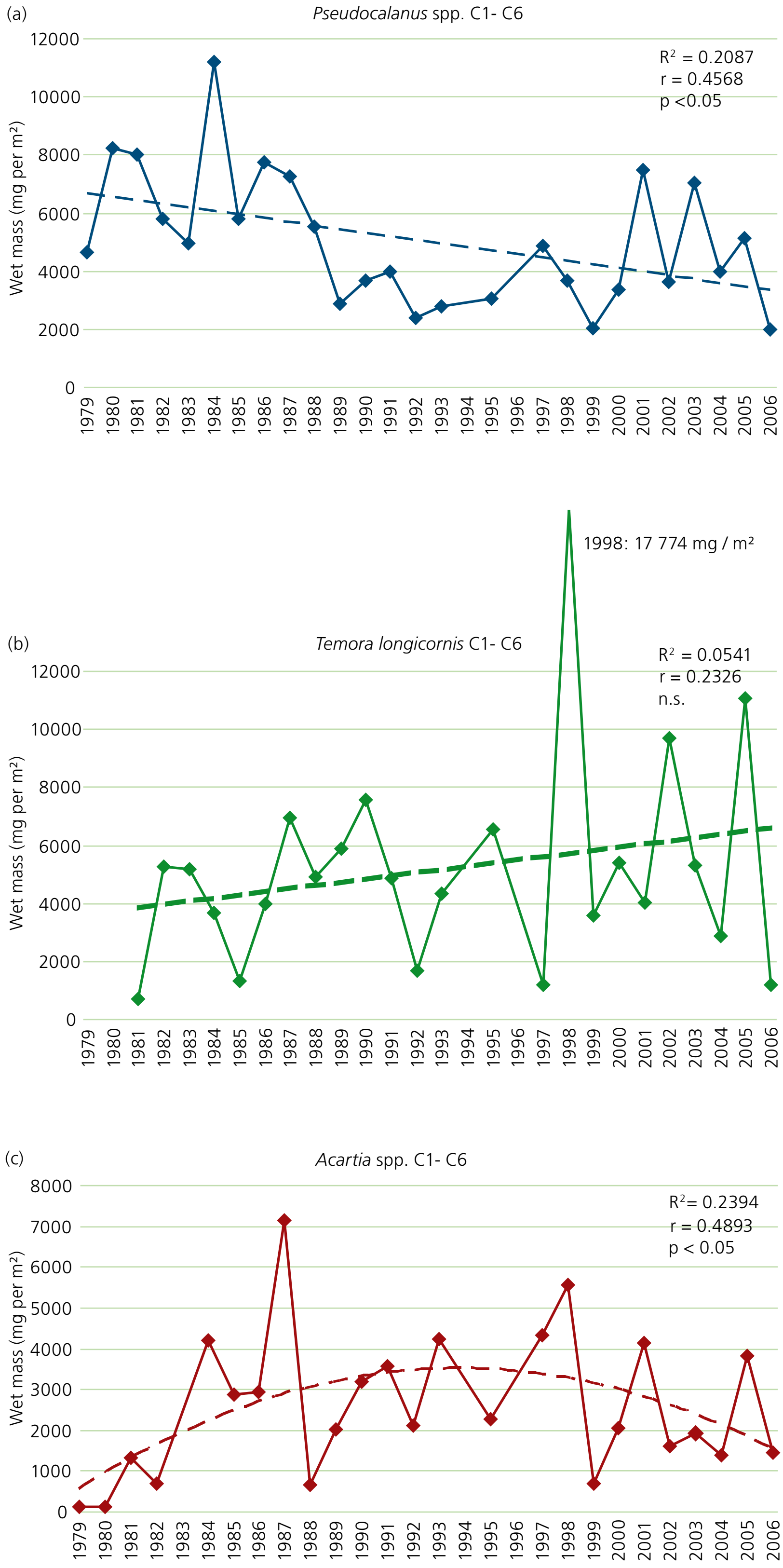


Figure 3.3.3. Wet mass concentration (mg m^{-2}) of (a) *Pseudocalanus* spp., (b) *Temora longicornis*, and (c) *Acartia* spp. in the central Bornholm Basin during summer between 1976 and 2007, calculated from data (HELCOM and IOW sources) and by use of biomass factors according to Hernroth 1985, after Postel, in prep.

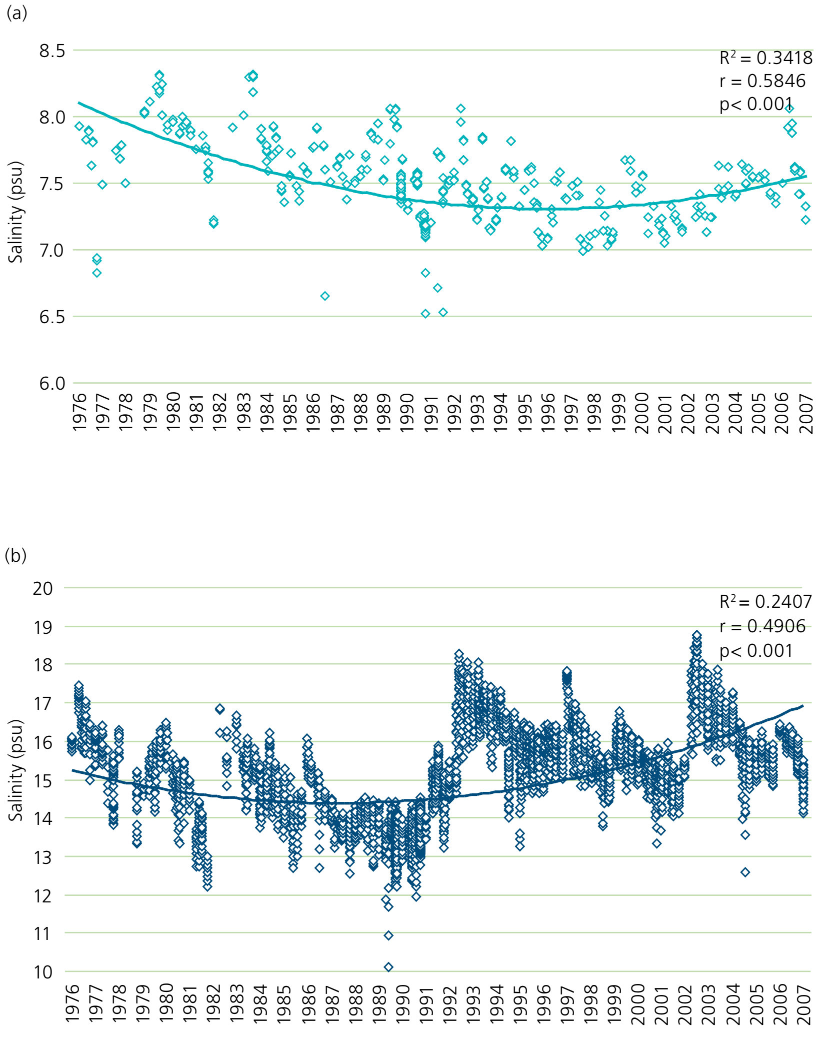
the other hand, is not selected by herring or sprat and, in fact, has a very effective escape reaction (Viitasalo et al. 1998).

Temora longicornis, which increased during the period, is also strongly selected by clupeids (cf. references given above). However, *T. longicornis* is not as sensitive to salinity changes as *Pseudocalanus* and the species is furthermore a thermophile and may possibly have been stimulated by the increasing summer temperatures during the period (Figure 3.3.4c) (Hernroth & Ackefors 1979).

The increasing trend in biomass concentrations of *T. longicornis* and partly *Acartia* spp. may also have other complex reasons. It could be the result of a potential carrying capacity for calanoids. In addition, decreasing eutrophication may affect the smallest calanoids in the Baltic Sea, the *Acartia* spp. (Figure 3.3.3c), as the biomass concentrations of the *Acartia* spp. follow a decadal course of the winter concentrations of nitrate in the upper 10 m of the central Bornholm Basin (Figure 3.3.4d). The causal mechanisms are unclear at the moment but are probably related to food web interactions.

During the observation period the Baltic Proper, with the exception of the Åland Sea, has suffered from severe oxygen depletion periods in deep basins. This has significantly decreased the water volume available for species that thrive in the deep saline water under the halocline. As discussed above, this affects *Pseudocalanus* spp., perhaps the most important zooplanktonic prey item for Baltic herring. Hence, it may well be that human-induced

Figure 3.3.4. (a) Salinity in the upper 3 m, (b) salinity in the layer between 70 m and 80 m, (c) temperature in the upper 3 m in July–August, and (d) winter nitrate concentrations (February, March) in the upper 10 m in the central Bornholm Basin between 1976 and 2007 (from IOW database) after Postel, in prep.



eutrophication and subsequent oxygen deficiency have a role in regulating zooplankton in the Baltic Proper as well.

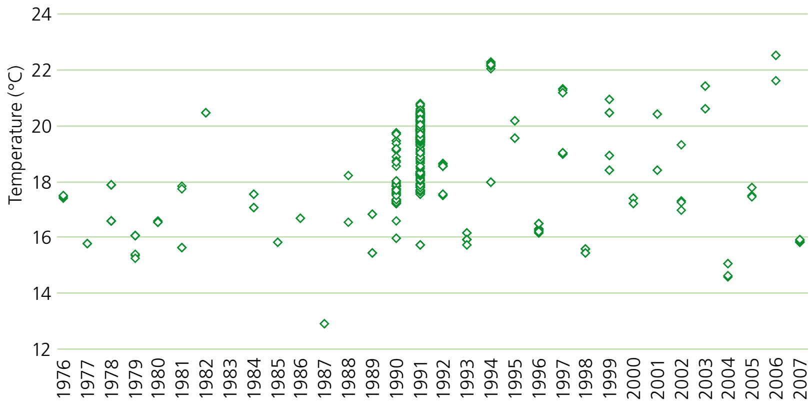
3.3.3 Conclusions

During the past 20–30 years, the copepod communities in the Baltic Sea have undergone considerable changes. The causes behind the changes, as well as their eventual effects, are at present difficult to define and distinguish. Climate variability with subsequent influence on salinity and temperature can likely explain some of the observed changes, while human pressures such as eutrophication also may have contributed. The observed changes in zooplankton communities have had cascading trophic effects which can be observed as reduced weight at age, general condition, and reproduction of Baltic herring and sprat. Furthermore, these changes combined with subsequent effects on planktivorous fish stocks have affected the growth, condition and reproduction of Baltic salmonids (e.g., Ikonen 2006), emphasizing the socio-economic impact of changes in Baltic zooplankton communities.

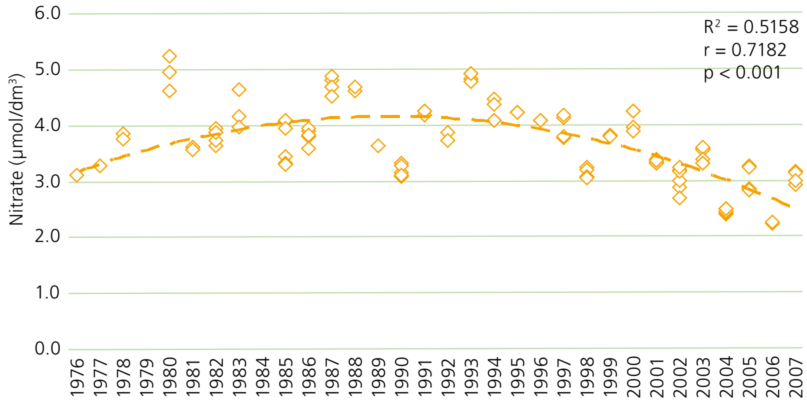
3.3.4 Recommendations

Abiotic factors, such as decreasing salinity and increasing temperature, can substantially change the Baltic Sea zooplankton communities. Furthermore, anthropogenic eutrophication and subsequent deep-water oxygen deficiency have altered the species composition of zooplankton communities, often towards a state less favorable to their grazers, clupeid fish. The complex interactions that

(c)



(d)



Limnocalanus macrurus

determine the abundance and composition of the zooplankton make it difficult to recommend specific actions. Nevertheless, a reduction of eutrophication and implementation of sustainable fisheries practices are important measures that will safeguard the future diversity of this organism group.

Zooplankton are currently not a core variable in the HELCOM COMBINE monitoring programme. Based on the important role of zooplankton in the Baltic Sea food web and their usefulness as an indicator for pelagic ecosystem conditions, it is recommended that zooplankton be included as a core variable in this monitoring.

3.4 Benthic invertebrate communities

Soft-sediment macrofaunal communities are central elements of Baltic Sea ecosystems and provide important ecosystem functions and services. These functions include, for example, the provision of food for higher trophic levels and through the processing, reworking and irrigation of the sediments, benthic macrofauna enhance oxygen penetration and biogeochemical degradation of organic matter in the sediments. Most macrobenthic animals are relatively long-lived (several years) and thus integrate changes and fluctuations in the environment over a longer period of time. Hence, variations in species composition, abundance and biomass can be used to assess environmental conditions and disturbance events.

In the context of the Baltic Sea Action Plan (BSAP), benthic invertebrate communities relate to the ecological objectives of the BSAP that aim for ‘Thriving and balanced communities of plants and animals’ and ‘Viable populations of species’ in order to secure a favourable conservation status of Baltic Sea biodiversity. Specifically, these objectives relate to restoring and maintaining seafloor integrity at a level that safeguards the functions of ecosystems. The relevant BSAP targets include that by 2021 (a) a ‘natural’ range in the distribution and abundance of habitat-forming species should be obtained, (b) degradation should be halted and recovery of marine biotopes/habitats ensured, and (c) a natural abundance and diversity of all elements of the marine food web should be secured.

3.4.1 Status and trends

The distribution and diversity of brackish-water macrobenthic communities in the Baltic Sea are constrained by the distinctive salinity and oxygen gradients present (Segerstråle 1957, Rumohr et al. 1996, Laine 2003). Owing to the overall low salinity, benthic communities in the Baltic Sea are substantially less diverse than in fully marine environments and comprise a mix of species of marine, brackish–water, and limnic origin (Remane 1934, Bonsdorff 2006). The characteristic salinity range in most of the Baltic Sea coincides with the species diversity minimum for aquatic habitats as described by Remane (1934), i.e., where the distributions of marine and limnic species meet.

The latitudinal distribution of marine macrozoobenthos in the Baltic Sea is limited by the gradient of decreasing salinity towards the north. The decreasing salinity reduces macrozoobenthic diversity, affecting both the structure and function of benthic communities (Elmgren 1989, Ruhmohr et al. 1996, Bonsdorff & Pearson 1999). In addition, the distribution of benthic communities is driven by strong vertical gradients. Generally, the more species-rich and abundant communities in shallow-water habitats (with higher habitat diversity) differ from the deep-water communities, which are dominated by only a few species (Andersin et al. 1978). The Baltic Proper has a more or less permanent halocline at 60–80 m, whereas in the Gulf of Bothnia stratification is weak or absent. The halocline in deeper waters or seasonal pycnoclines in coastal waters restrict vertical water exchange, which may result in oxygen deficiency and a severe reduction or complete elimination of macrozoobenthic communities. Oxygen deficiency is without question the most significant threat to the biodiversity of Baltic Sea benthos.

In this assessment, a brief overview of the status of structural and functional biodiversity of benthic macrofaunal communities is provided for the major basins of the open-sea areas of the Baltic Sea. While biodiversity-environment relationships are increasingly well understood in the context of species richness and composition, functional diversity has received much less attention. The implications of changes in functional diversity and how they might translate into information on ecosystem functioning are important, and a challenge for studies of biodiversity. These aspects are perhaps particularly critical in the Baltic Sea, where functional redundancy is predicted to be low owing to the low overall species and functional diversity.

Patterns in structural biodiversity

Different diversity indices were calculated as measures of structural diversity in macrobenthic communities for the period 2000–2006. A simple measure of average species diversity (gamma-diversity) was used to define reference conditions and current status for the major sub-basins in the Baltic Sea (see HELCOM 2009a for a detailed description). The reference values calculated for this measure are based on data obtained from multiple monitoring stations per sea area over the period 1965–2006, collected by the Finnish Institute of Marine Research since 1965. Additional data from Sweden were received for the Bornholm and Arkona Basins. In assessments of diversity, it is important to recognize that the Baltic Sea ecosystem is a young and continuously evolving system, still undergoing post-glacial succession (Bonsdorff 2006). Hence, decadal time-scale fluctuations in salinity regimes and consequent changes in benthic communities continuously shift the baseline for assessing reference conditions, and this needs to be considered. This obviously creates difficulties for setting absolute and fixed reference communities for the benthic fauna in the Baltic Sea. To account for the influence of successional dynamics, it is also important to consider the turnover, or β-diversity, of the communities. Hence, in addition to characterizing the average species diversity for different open-sea areas, the β-diversity was also calculated for selected stations, as well as traditional basic diversity indices, in the respective sea areas.

Benthic invertebrate communities in the majority of the Baltic Sea open-sea basins are dominated by only a few species. These species include, for example, the polychaete *Bylgides* (*Harmothoe*) *sarsi*, the isopod *Saduria entomon*, the amphipods *Monoporeia affinis* and *Pontoporeia femorata*, and the bivalve *Macoma balthica*. A markedly different species composition is found in the southwestern Baltic, in the Bornholm Basin and the Arkona Basin, which are characterized by more typical marine species. These communities, at least historically, have typically been dominated by numerous polychaete species and larger deep-dwelling bivalves. Important phyla such as echinoderms are constrained to the western reaches of the Baltic Proper and the Danish Straits.

As illustrated by the average number of species/taxa of benthic invertebrates per sea area, reference conditions contrast markedly between sub-basins owing to the gradient in salinity, which con-

Saduria entomon

strains species distributions (Figure 3.4.1). In this broad-scale assessment, eight basins were evaluated and reference conditions, i.e., the average number of species that should be found, varied between 18.3 in the Arkona Basin and 2.0 in the Bothnian Bay. For the years 2000–2006, benthic invertebrate status varied considerably between sub-basins and was related to the widespread occurrence of hypoxia and anoxia in the Baltic Proper and the Gulf of Finland (Figure 3.4.1). None of the sub-basins can be regarded as pristine, even though the Gulf of Bothnia and the Arkona Basin are in a reasonable condition (as defined by the good-moderate border set by acceptable deviation; see HELCOM 2009a). The entire Baltic Proper, from the Bornholm Basin to the northern Baltic Proper, and the Gulf of Finland are in a severely disturbed state (Figure 3.4.1).

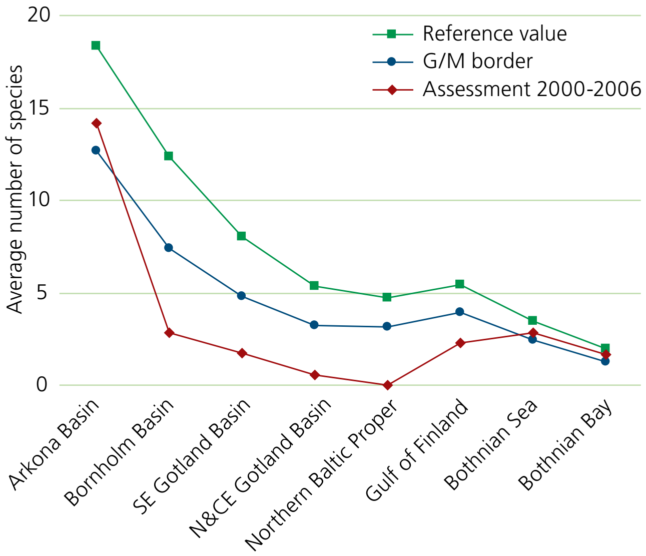


Figure 3.4.1. Reference values and the border between good and moderate (G/M) ecological status in the different sub-basins of the open-sea areas in the Baltic Sea depicted as Ecological Quality Ratio (EQR) and the average number of species. Benthic invertebrate status is described as an average for the period (2000–2006).

Some univariate measures of biodiversity were calculated for selected representative stations in each sea area, which highlight the nature of the overall diversity gradient in the Baltic Sea (Table 3.4.1). The total number of species recorded for the assessment period 2000–2006 ranged from 27 in the Arkona Basin (BY2) to only 3 in the Bothnian Bay (BO3), while average species diversity ranged from 13.7 to 1.4. Correspondingly, the Shannon-Wiener diversity index ranged from 2.4 to 0.02 (Table 3.4.1). In the low-diversity Baltic Sea, these traditional measures, such as Shannon-Wiener, are not very informative (Magurran 2008). Several stations, in particular, the Bornholm Basin (BY5) and the northern Baltic Proper (IBSV9), demonstrate the degraded state of macrobenthic communities over the assessment period. Interestingly, Cody's measure of species turnover (β_c; beta diversity) provides useful insights into the transient and dynamic nature of the benthic communities in the southern Baltic Sea (Table 3.4.1). In the Arkona Basin (BY2), Cody's measure reached 4.4 (which translates into an average actual species turnover of 8.8 between the years 2000–2006). In contrast, species turnover in the Bothnian Bay (BO3) gave an index value of 0.5. This obviously reflects the large differences in available species pools as well as the overall difference in biodiversity along the gradient. In addition, the dynamic nature of the southern Baltic is intimately linked to the periodic salt-water inflows.

Table 3.4.1. Stations from each sea area provide examples of the benthic communities during the assessment period 2000–2006. Diversity is measured as the total and average number of species ± std (standard deviation) and Cody's measure (β) represents the average species turnover ± std. Diversity is also calculated as the Shannon & Wiener (H' ($\log_2$)) index (Shannon & Weaver 1963).

Sea area	Station	Depth m	Total nr of species	Average nr of species		Shannon-Wiener H' ($\log_2$)		Cody's measure β_c	
				x	std	x	std	x	std
Bothnian Bay	BO3	110	3	1,43	0,53	0,02	0,03	0,50	0,32
Bothnian Sea, north	US6B	82	3	2,14	0,69	0,07	0,06	0,25	0,42
Bothnian Sea, south	SR5	125	5	3,86	0,90	0,88	0,37	0,17	0,26
Gulf of Finland	LL11	67	7	3,14	1,21	0,34	0,16	0,83	0,93
Gulf of Finland	LL4A	58	10	5,86	1,86	1,46	0,39	1,33	0,68
N Baltic Proper	IBSV9	88	0	0,00	0,00	0,00	0,00	0,00	0,00
NE Gotland basin	LF1	67	7	3,43	1,27	0,57	0,22	0,75	0,52
SE Gotland basin	BCSIII10	90	3	1,71	0,76	0,33	0,47	0,42	0,38
Bornholm basin	BY5	89	0	0,00	0,00	0,00	0,00	0,00	0,00
Bornholm basin	HBP216	53	13	10,00	1,63	2,16	0,40	1,33	0,58
Arkona basin	BY2	48	27	13,67	3,01	2,37	0,24	4,40	0,74

Long-term trends in biodiversity

Long-term trends in benthic community composition from the mid-1960s to 2006 for four of the selected stations are illustrated in Figure 3.4.2.

The patterns in these long-term trends exemplify the 'shifting baseline' of macrobenthic communities, especially in the southern Baltic (BCSIII10) and at the entrance to the Gulf of Finland (LL11),

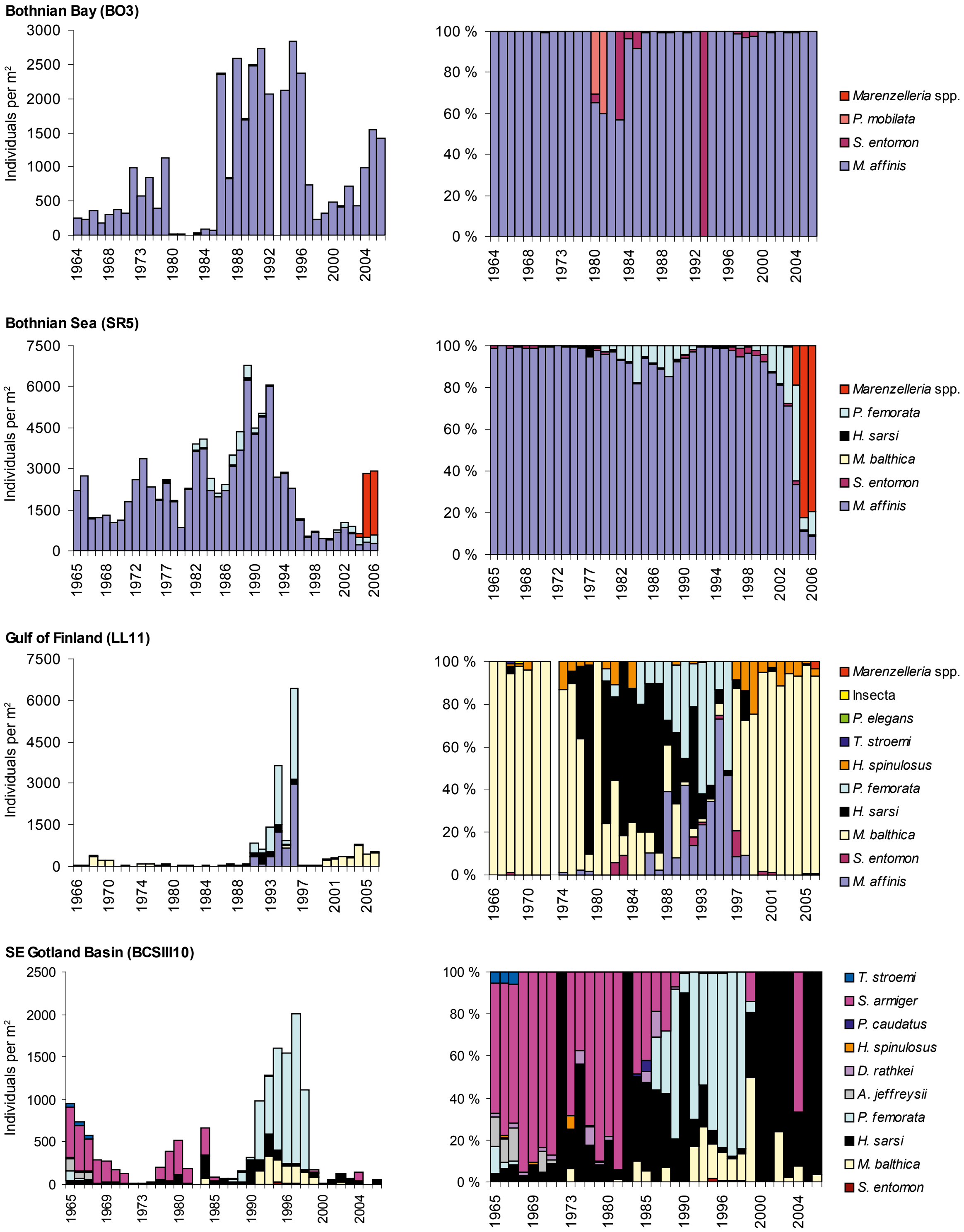


Figure 3.4.2. Long-term changes in benthic community abundance (individuals per m^2) and composition (illustrating species turnover) are depicted for stations BO3 (Bothnian Bay), SR5 (Bothnian Sea), LL11 (at the entrance to the Gulf of Finland) and BCSIII10 (SE Gotland Basin). Note the different x- and y-axes.

Macoma baltica

where the influence of periodic salt-water inflows is tangible. These patterns are more distinct closer to the Danish Straits and the proximity to the inflows. Since the largest recorded inflow in the 1950s, salinity has decreased in the entire Baltic Proper and the dominance has changed from marine species to typical brackish-water species in the southeastern Gotland Basin (Figure 3.4.2). Similarly, the 'marine' elements of the community in the Gulf of Finland, such as the polychaete *Terebellides stroemi*, have disappeared altogether. The nature and magnitude of the salt-water inflows have a direct influence on the strength of the halocline and, hence, the oxygen dynamics in the Baltic. Stratification of the water column in combination with an increased organic loading (which has been exacerbated by eutrophication) has resulted in widespread hypoxia and anoxia. This poses a severe threat to the biodiversity of benthic invertebrate communities, which is illustrated in the periodically very poor and low diversity communities recorded in the southeastern Gotland Basin and Gulf of Finland (Figure 3.4.2). During the mid-1990s, benthic communities recovered owing to the stagnation period that weakened stratification; however, with the large salt-water intrusion in 1993, the halocline strengthened and oxygen conditions deteriorated (Laine et al. 2007, Norkko et al. 2007). In contrast, changes in species composition are small in the southern Bothnian Sea (SR5) and virtually absent in the Bothnian Bay (BO3). This is due to overall low species diversity. Nevertheless, invasive species, such as the polychaete *Marenzelleria* spp., are conspicuous elements of the system and have established viable populations in many areas of the Baltic Sea, as exemplified in southern Bothnian Sea. In the Bothnian Sea, large natural variations in abundance of the dominant species, the amphipod *Monoporeia affinis*, are typical. In this area, the influence of salt-water inflows is minimal and there is not a strong halocline, which would promote the formation of hypoxia. In the Bothnian Sea, the *Monoporeia* populations have been declining since the mid-1990s for reasons that have not been clarified. However, recent monitoring suggests that these populations may be recovering.

When examining long-term trends from data collected in 1965–2006, it becomes immediately obvious that conditions were already disturbed in the mid-1960s. Benthic invertebrate status in the central parts of the Baltic Sea, in particular, is more or less entirely controlled by the presence or absence of hypoxia/anoxia. Already in Hessle's (1924) seminal work, hypoxia/anoxia was reported in both coastal and open-sea areas. However, he also reported on the presence of species such as the polychaete *Scoloplos armiger* at over 140 m depth in the eastern Gotland Basin, which indicates that the spatial extent of hypoxic bottom waters was limited at that time. Current evidence suggests that the spatial and temporal extent of oxygen deficiency has increased over the past decades. In the light of historical work (Hessle 1924), it is also likely that reference conditions defined for open-sea areas in this assessment are underestimates. Generally, Baltic benthic macrofauna are characterized by small, shallow-dwelling species owing to low salinity and transient hypoxia; historically, it was only in the southern Baltic, where more mature communities composed of deeper-dwelling larger species, e.g., some long-lived bivalves and large polychaetes, could have developed (Tulkki 1965, Rumohr et al. 1996). However, currently macrobenthic communities are severely degraded and abundances are below a 40-year average in the entire Baltic Sea (Norkko et al. 2007).

Functional aspects of biodiversity

The broad-scale patterns and changes in structural biodiversity also translate into differences in functional biodiversity. While the actual relationship between changes in the functional biodiversity and ecosystem function is difficult to quantify, it is apparent that there is a strong gradient in functional biodiversity in the Baltic Sea (Bonsdorff & Pearson 1999), which affects the trophic structure and energy flow in the ecosystem.

Biological trait analysis can be useful to identify functions that are important for ecosystem function or may help interpret the effects of disturbances (e.g., Bremner et al. 2003). Traits can be exemplified by the longevity or size of particular species and their developmental mechanisms and mobility, which are all species characteristics that play important roles in classifying the state of benthic communities or reflect their potential for recovery after disturbance and are therefore important in defining resilience.

The differences in benthic functional diversity between sub-basins during the period 2000–2006 are illustrated in a basic classification at some representative stations along the Baltic Sea salinity gradient (Table 3.4.2, Figure 3.4.3). Biological traits (BT) were used to describe the characteristic functions of individual benthic infaunal species. The main BT included were feeding type, feeding habit, mobility, size, adult longevity, larval development, living habit and environmental position. Existing BT at each station are expressed as a percentage of

Table 3.4.2. Biological traits (BT) at selected stations in the Baltic Sea, expressed as a percentage of the total number of BT identified for the respective main group during 2000–2006. The following main traits were included: feeding type, degree of mobility, feeding habit, size, adult longevity, developmental mechanism (larvae), living habit and environmental position.

🟨 31-45 %
🟨 46-60 %
🟧 61-75 %
🟥 76-90 %
🟥 >90 %

	Bothnian Bay	Bothnian Sea		Gulf of Finland		NE Gotland Basin	SE Gotland Basin	Bornholm Basin	Arkona Basin
Biological trait/Stations	BO3	US6B	SR5	LL11	LL4A	LF1	BCSIII10	HBP216	BY2
Feeding type	57 %	57 %	57 %	57 %	86 %	71 %	57 %	86 %	71 %
Mobility	75 %	75 %	75 %	100 %	100 %	100 %	100 %	100 %	100 %
Feeding habit	75 %	75 %	100 %	100 %	100 %	100 %	75 %	100 %	100 %
Size	40 %	40 %	60 %	80 %	60 %	80 %	40 %	80 %	100 %
Adult longevity	40 %	40 %	40 %	60 %	80 %	80 %	40 %	80 %	100 %
Development	75 %	75 %	75 %	100 %	75 %	100 %	50 %	100 %	75 %
Living habit	75 %	75 %	75 %	100 %	75 %	100 %	50 %	100 %	75 %
Environmental position	80 %	80 %	80 %	80 %	80 %	80 %	40 %	100 %	100 %

Increasing salinity

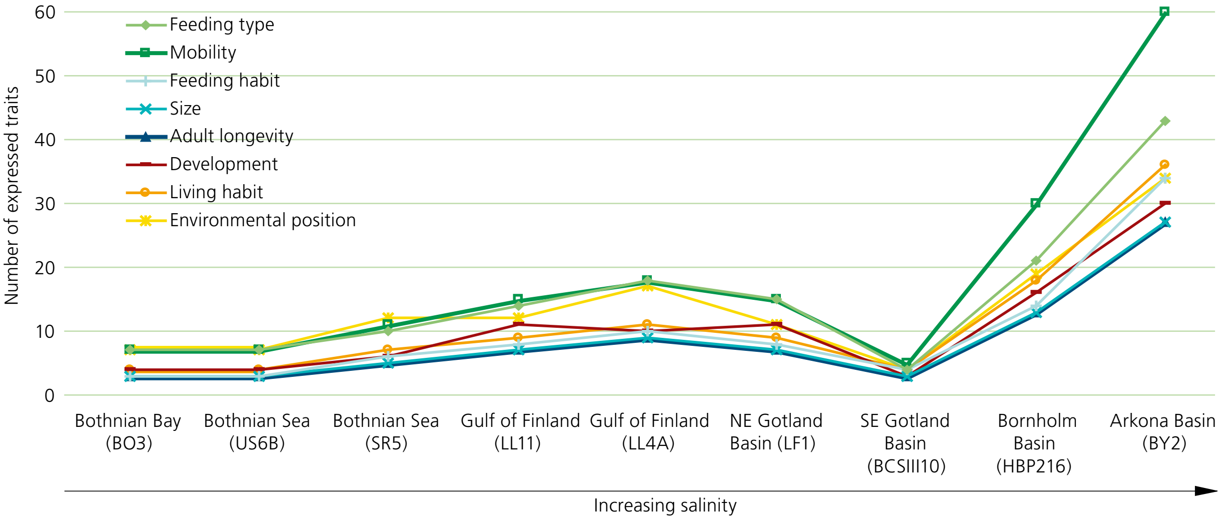


Figure 3.4.3. The number of biological traits expressed in each main group (feeding type, mobility, feeding habit, size, adult longevity, development, living habit and environmental position) during 2000–2006 for selected stations (Villnäs & Norkko, unpublished). Note that one species may express several traits; hence, the number of traits often exceeds the total number of species at a station. Biological traits include: (a) **feeding type**: suspension feeder, surface detritivore, burrowing detritivore, omnivore, carnivore, scavenger, herbivore; (b) **degree of mobility**: stationary, swim, crawl, burrow (c) **feeding habit**: jawed, tentaculate, pharynx/proboscis, other mechanism; (d) **size (measured in biomass)**: xs, s, m, l, xl; (e) **adult longevity (years)**: 1–2, 2–3, 3–5, 5–10, >10; (f) developmental mechanism: planktotrophic, lecitotrophic, direct (brood protection), other; (g) **living habit**: tube-dweller, burrow dweller, crevice dweller, free living; and (h) **environmental position**: epifaunal, infaunal, pelagic, epibenthic, nectobenthic.

the total BT identified for each main group of traits (Table 3.4.2), and the total number of biological traits expressed in each main group during 2000–2006 is also presented for the selected stations (Figure 3.4.3). Because one species may express several traits, the number of traits often exceeds the total number of species at a station.

The results from this analysis highlight the increase in the number of expressed traits from the Bothnian Bay in the north towards the southern parts of the Baltic (Figure 3.4.3). The gradient is particularly clear for traits such as adult longevity and size, which reflect the successional stages described by Rumohr et al. (1996). Only at the comparatively more marine areas of the Arkona Basin does the functional diversity increase substantially. Importantly, the analysis highlights the limited functional diversity of benthic communities in the Baltic main basins.

The loss of entire functional groups and traits owing to widespread hypoxia has obvious implications for the functioning of Baltic Sea ecosystems. While no permanent species extinctions in the benthos have necessarily occurred in the Baltic, it is clear that abundances over great expanses have been reduced to such a level that they may be viewed as functionally extinct, i.e., with severely reduced or no functional importance.

3.4.2 Conclusions

Soft-sediment macrofaunal communities in the open-sea areas of the Baltic Sea are naturally constrained by the strong horizontal and vertical gradients in salinity. These conditions result in strong gradients in species and functional diversity throughout the Baltic Sea.

Obviously multiple stressors affect benthic communities in the Baltic. However, eutrophication has emerged as the major stressor, with symptoms of disturbance apparent at all trophic levels in the ecosystem. The increased prevalence of oxygen-depleted deep water is perhaps the single most important factor influencing the structural and functional biodiversity of benthic communities in the open-sea areas of the Baltic Sea (Andersin et al. 1978, Karlson et al. 2002). While hypoxia is to some degree a natural phenomenon in the Baltic, it is also clear that the spatial and temporal extent of oxygen deficiency has increased over the past decades owing to eutrophication (Karlson et al. 2002, Diaz & Rosenberg 2008).

It seems unrealistic that BSAP targets can be reached within the given time frame. Recovery is likely to take decades even though initial recovery may be rapid in areas where nutrients are dramatically reduced and oxygen conditions improve.

3.4.3 Recommendations

Benthic invertebrates form well-defined and structured communities that are an important component of the Baltic Sea biodiversity. The measures that are needed to improve the living conditions of these organisms include reduction of eutrophication through decreasing nutrient loads to the sea to alleviate oxygen depletion, as well as restrictions to physical disturbance of the environment (dredging and trawling).

Existing fairly long time-series of data on zoobenthic communities will be invaluable for future assessments of the environmental impacts of human activities and climate change research. Thus, it is important to continue broad-scale monitoring of benthic macrofaunal communities in the Baltic and to maintain the frequency and intensity of current activities.

3.5 Fish communities

Baltic Sea fish communities consist of representatives of various origins: marine species, freshwater species, migratory species, glacial relicts and alien species. Representatives of these categories have different preferences for environmental conditions and the composition of fish communities therefore varies in different regions of the Baltic Sea, primarily depending on salinity, water temperature, oxygen content and nutrient concentrations.

Fish perform several important roles in the ecosystem: they act as essential consumers of planktonic and benthic invertebrates, thus structuring the lower food web; they serve as a food for marine top predators (for mammals, other fish species and fish-eating birds); they substantially facilitate pelagic-benthic coupling; and they may also serve as transmitters of parasites. While commercial fish species receive high attention owing to their role as human food and trade commodities, non-commercial species may act as habitat and food competitors for commercial fish and serve as essential food or predators for them. At present, many of the Baltic Sea fish species are threatened according to the 'HELCOM Red List of Threatened and Declining Species of Lampreys and Fishes of the Baltic Sea' (HELCOM 2007c).

The Baltic Sea Action Plan (BSAP) addresses several issues related to fish communities (HELCOM 2007a). Among the biodiversity targets, the following two can be highlighted: *"By 2015, to achieve viable Baltic cod populations in their natural distribution area in the Baltic Proper"* and *"By 2015, improved conservation status of species included in the HELCOM lists of threatened and/or declining species and habitats of the Baltic Sea area, with the final target to reach and ensure favourable conservation status of all species"*.

3.5.1 Status and trends

The total number of fish species in the Baltic Sea area is around 100. They consist of about 70 marine species, seven diadromous species (including sea and river lamprey), and 33 freshwater species. Whereas the number of marine fish species in the North Sea is around 120, there are around 70 in the Kiel Bight and Bay of Mecklenburg, 40–50 in the Baltic Proper, 20 in the Gulfs of Finland and Bothnia, and only 10 in the northernmost part of the Bothnian Bay. This distribution pattern is similar to that of other fauna and flora in the Baltic Sea area and is due to brackish water conditions with decreasing salinity from the south to the north (Nellen & Thiel 1996).

Marine fish such as plaice (*Pleuronectes platessa*), cod (*Gadus morhua*), and flounder (*Platichthys flesus*) prefer more saline areas and are therefore more abundant in the southern and/or open Baltic. Freshwater fish such as perch (*Perca fluviatilis*), pike (*Esox lucius*), bream (*Abramis brama*), and roach (*Rutilus rutilus*) mainly colonize coastal areas, but also the northeastern Baltic (including the large gulfs) where the salinity is lower. Glacial relicts, for example, eelpout (*Zoarces viviparus*), lumpsucker (*Cyclopterus lumpus*), fourhorned sculpin (*Triglopsis quadricornis*), and sea snail (*Liparis liparis*) are more abundant in the cold-water layers in deeper areas and in the northeastern Baltic Sea with a sufficient amount of oxygen. In addition, various fish species from the North Sea occasionally migrate into the Baltic Sea. Owing to unfavourable environmental factors (essentially low salinity and temperature), these fish are unable to form self-sustaining populations in the Baltic Sea; they include, for example, such species as whiting (*Merlangus merlangus*), European anchovy (*Engraulis encrasicolus*), mackrel (*Scomber scombrus*), and the grey mullets *Liza ramada* and *Chelon labrosus*.

Marine fish

Herring (*Clupea harengus membras*), sprat (*Sprattus sprattus*) and cod are the major commercial fish species in the Baltic Sea. The status of these stocks has been monitored for decades, with the longest record available for the eastern Baltic cod since the mid-1940s. The eastern Baltic cod stock peaked in the late 1970s and early 1980s (Eero et al. 2007). Since the 1980s, a climate-induced decrease in the cod reproductive volume, i.e., the amount of water with favourable conditions for successful

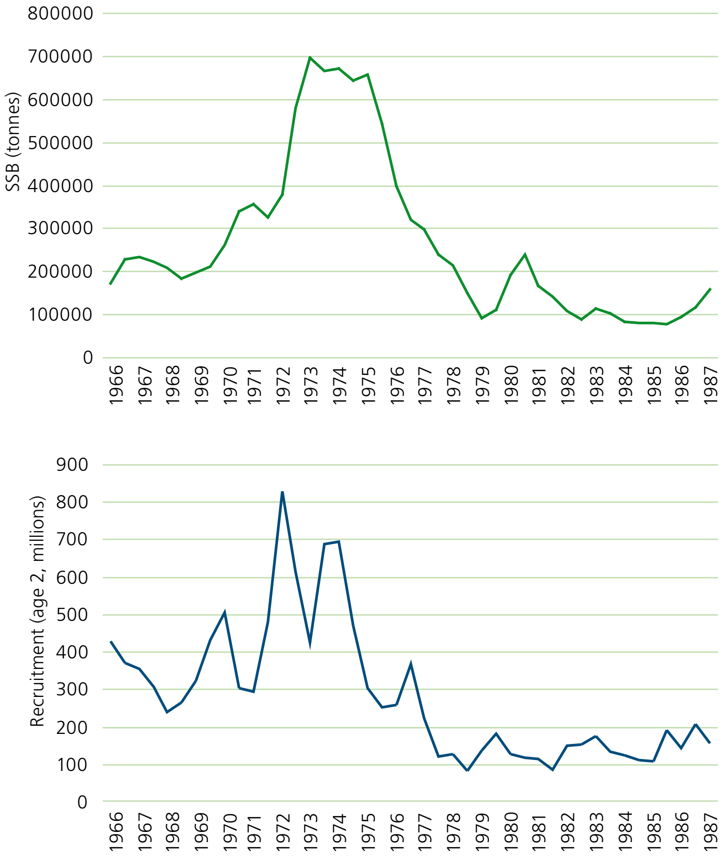


Figure 3.5.1. Spawning stock biomass (SSB, in tonnes) and recruitment (age 2, millions) of cod in ICES subdivisions 25–32 and from the mid-1960s. A map of ICES subdivisions is provided in Chapter 6, Fisheries, Figure 6.1.1.

hatching of cod eggs, has caused high cod egg mortality (Köster et al. 2003). This, together with very high fishing pressure, has resulted in historically low values of the cod stock since the early 1990s (ICES 2008b, Figure 3.5.1) altough there has been an increase in the eastern cod spawning stock biomass during the past three years. This observed increase since 2005 has been a result of relatively strong year classes in 2003 and 2005 (ICES 2008d). Release of the predation pressure by cod, accompanied by favourable hydrographic conditions, has allowed the sprat stock to increase since the late 1980s, which together with herring has strongly dominated the Baltic fish communities since then (Figure 3.5.2 and Figure 3.5.3). This shift to domination by a pelagic fish community represents a profound change in the marine ecosystem, also called a 'regime shift' (e.g., Alheit et al. 2005).

In addition, there are several non-commercial marine fish present in the Baltic Sea, for example, gobies *Pomatoschistus* spp., three-spined stickleback (*Gasterosteus aculeatus*), nine-spined stickleback (*Pungitius pungitus*), and pipefish (*Nerophis ophidion*). These species are adapted mainly to low-salinity estuarine areas and play several significant roles in the ecosystem. Despite their importance, the knowledge on the spatio-temporal population dynamics of these fish species is relatively poor.

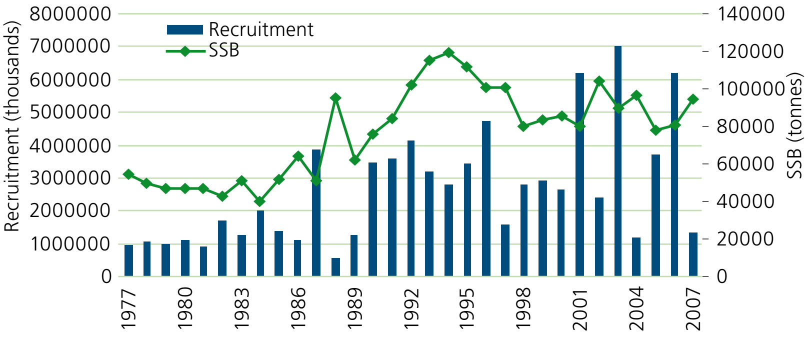


Figure 3.5.2. Recruitment (R, age 1 in thousands) and spawning stock biomass (SSB, in tonnes) of the Gulf of Riga herring during 1977–2007 (ICES 2008b).

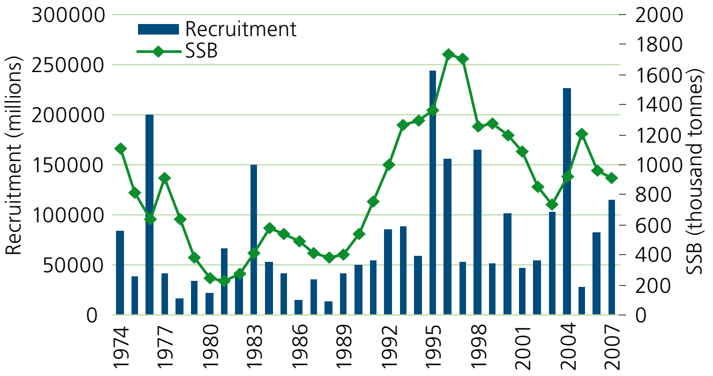


Figure 3.5.3. Recruitment (R, age 1 in millions) and spawning stock biomass (SSB, in thousand tonnes) of sprat in the Baltic Sea (ICES SD 22–32) during 1974–2007 (ICES 2008b).

Freshwater fish

The most common freshwater species that are found in a majority of coastal areas of the Baltic Sea are perch, roach, ruffe (*Gymnocephalus cernuus*), ide (*Leuciscus idus*), pike and whitebream (*Blicca bjoerkna*) (Ådjers et al. 2006). The most recent evidence suggests that freshwater species have exhibited different population dynamics in various parts of the Baltic Sea over the past 10–20 years for which monitoring data are available. For example, coastal fish surveys show a significant increase in perch and roach abundance in the Archipelago Sea (Figure 3.5.4, Finbo and Brunskär). This is thought to be caused by the ongoing coastal eutrophication, because these fish have been shown to be favoured by moderate eutrophication, as well as increased water temperatures (HELCOM 2006b). In other areas, such as the west Estonian Archipelago Sea (Hiiumaa), Daugava, Curoninan Lagoon and Kvädöfjärden, the same species have decreased significantly or even collapsed (Figure 3.5.4). This, as well as the decline in pike and pikeperch stocks in the Curonian lagoon, Daugava estuary and Pärnu Bay which all are characterized as having a high level of eutrophication, has occurred owing to a fishing pressure that has been too high (Ådjers et al. 2006, HELCOM 2006b).

A number of community-level (number of species, total biomass, species diversity, slope of size spectrum, and average trophic level of catch) and species-level (biomass, mean age, mortality, mean length, and slope of size spectrum) indicators for coastal fish were recently developed within HELCOM. Some of these indicators have been used in the pilot studies using the Biodiversity Assessment Tool BEAT (see Chapter 5).

Migratory species

Several migratory species in the Baltic Sea are of commercial value. These include salmon (*Salmo* *salar*), trout (*Salmo trutta*), eel (*Anguilla anguilla*), vimba bream (*Vimba vimba*) and smelt (*Osmerus eperlanus*).

Baltic salmon stocks started to decline already in the mid-19th century and at about the same time, artificial stocking activities were started. The decline of natural stocks has been rapid since the late 1940s owing to the construction of hydroelectric power plants, damming of rivers and potentially also poorer water quality. As a result of human activities, natural salmon production decreased substantially during the 20th century and several natural stocks have disappeared. Baltic salmon catches have continued to decline and they are now at their lowest level since recording joint catch statistics started in the 1970s. However, the natural smolt production of salmon populations has improved in the northern Baltic rivers in recent years. The former International Baltic Sea Fisheries Commission (IBSFC) established a management objective for wild salmon rivers to reach at least 50% of the potential smolt production by 2010. Most of the northernmost stocks are either likely or very likely to reach this objective, while the stocks in the more southern areas have slightly more varying, and on average poorer, status (ICES 2008c). Sea trout populations are currently in a precarious state in the Gulf of Bothnia and the Gulf of Finland, while the populations have improved in the western part of the Baltic Sea (ICES 2008c).

The European eel stock has declined in most of its distribution area, as also evidenced by substantial declines in landings in several countries around the Baltic Sea (FAO & ICES 2007). The decline is a result of a combination of many factors among them fisheries and man-made obstacles to migration in river systems, i.e., hydropower plants. The stock is currently outside safe biological limits, with low recruitment indicating no obvious sign of recovery. Therefore, the current levels of anthropogenic mortality are not sustainable and should be reduced to close to zero as soon as possible (FAO & ICES 2007).

Sturgeon was a very important component of local exploited fish fauna for centuries, especially in the southern Baltic (e.g., Makowiecki 2000). In the 11th–12th centuries, the sturgeon population started to decline, but it was still mentioned as a commercial species in several localities in the northern Baltic Sea in the 19th–early 20th century (e.g., Schneider 1912). Currently, sturgeon is a red-listed fish in the Baltic Sea and a reintroduction programme has been initiated (Box 3.5.1).

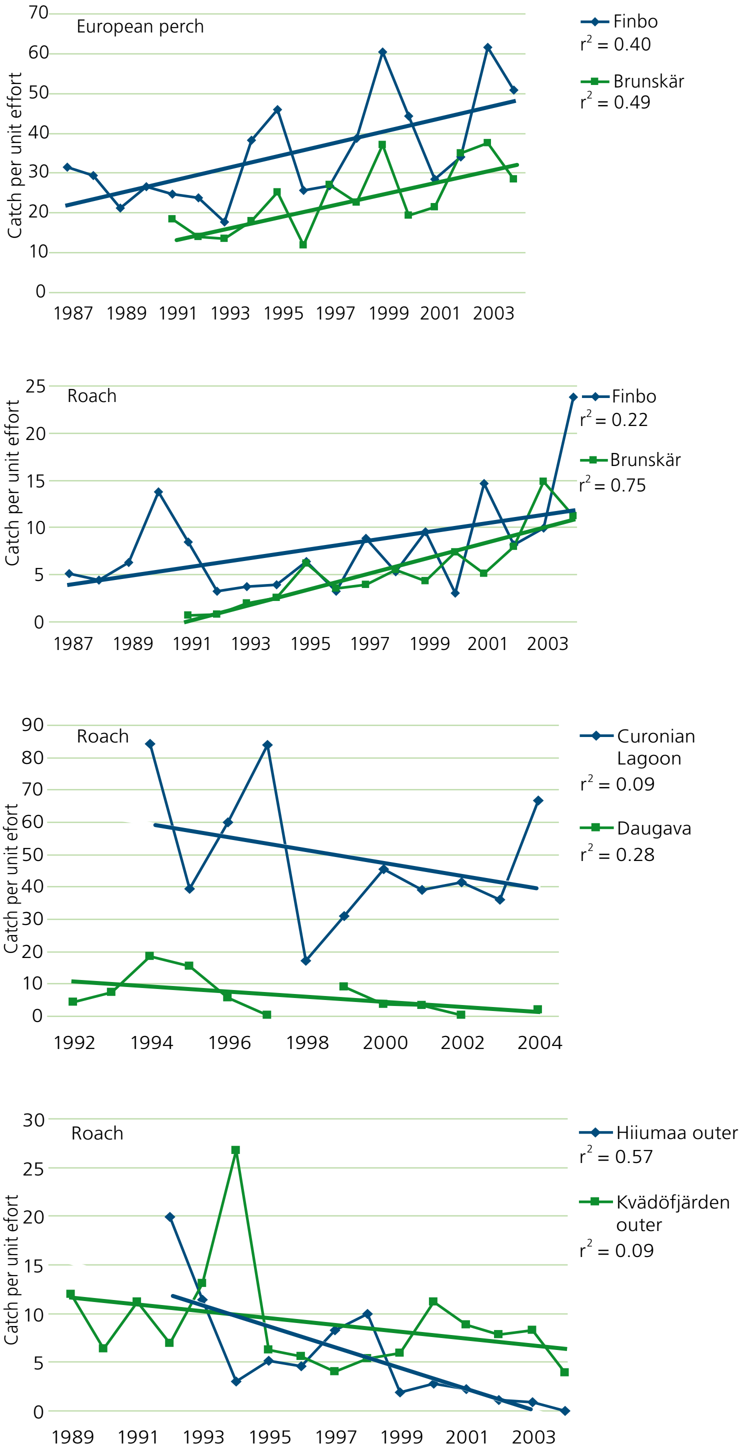


Figure 3.5.4. Significant trends (Mann-Kendall trend analysis, $p<0.05$) in catch per unit effort (CPUE) of perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) in various localities of the Baltic Sea (from HELCOM 2006b).

Alien species

Several alien fish species (e.g., rainbow trout (*Oncorhynchus mykiss*), gibel carp (*Carassius gibelio*), and round goby (*Neogobius melanostomus*)) are common and found in exploitable quantities in various sub-systems of the Baltic Sea. Many alien fish species were introduced into the Baltic Sea during the 1950s–1970s. The list includes sterlet (*Acipenser ruthenus*), beluga (*Huso huso*), Siberian sturgeon (*A. baeri*) and Russian sturgeon (*A. gueldenstaedtii*), chum salmon (*Oncorhynchus keta*) and pink salmon (*O. gorbusha*). In addition, species such as *Coregonus autumnalis migratorius*, *C. nasus*, *C. muksun*, *C. peled*, *Catostomus catostomus*, *Perccottus glenii*, silver carp (*Hypophthalmichthys molitrix*) and spotted silver carp (*Aristichthys nobilis*) have only been reported as rare findings (Repečka 2003, Leppäkoski et al. 2002, Ojaveer 1995). However, none of these species has been able to form a self-sustaining population. There are, however, two fish species that are of concern: the round goby (introduced in the early 1990s) and the Prussian carp *C. gibelio* (present in the Baltic Sea since the early 1950s). They have been shown to reproduce in the Baltic Sea, have colonized new areas during recent decades, are increasing in abundance in various parts of the Baltic Sea and have achieved commercial status (Vetemaa et al. 2005, Corkum et al. 2004).

Glacial relicts

Our present knowledge of the population status and trends of glacial relict fish species is very scarce. These species require cold, oxygen-rich water and are present in relatively low abundances, with their main distribution in deep areas of the northeastern Baltic Sea. In the Baltic Sea, these fish species are mostly non-commercial with the exception of eelpout, which has some commercial importance. There is evidence that the abundance dynamics of these species are negatively influenced by excessive eutrophication, contamination by toxic substances, and the presence of large marine predators (Ojaveer 1995). It should be stressed here that this category of fish represents a specific trophic function in the Baltic Sea as the only permanent potentially abundant vertebrate predator in the cold-water environment in deep areas.

3.5.2 Conclusions

Fish communities are not currently in balance in several areas of the Baltic Sea. This is evidenced by significant declines in or, in some cases, a complete lack of large predatory fish in the system, a further increase in eutrophication-tolerant species, and a decrease in several valuable commercial fish stocks. The status of several fish species is of concern, mainly in relation to the BSAP community-level targets. The concern is especially valid for the most valuable exploited species in both the open and coastal sea, owing to intensive fishing. It should be stressed that the present knowledge on non-commercial fish is relatively scarce and deserves further attention. Several presently threatened or declining species are highly susceptible to eutrophication and pollution, problems that are still considerable in many areas of the Baltic Sea. In order to achieve the community- and species-level targets of the BSAP, the factors listed above (i.e., fishing pressure and eutrophication/pollution), together with natural factors (climate variability) and bioinvasions, need to be taken into account when managing fisheries. However, a more detailed evaluation is needed to determine whether the entire list of fish-related targets of the BSAP is achievable within the indicated time frame.

3.5.3 Recommendations

One of the critical limitations to a proper assessment of the structure and function of the Baltic fish communities is a shortage or, in some cases, almost complete lack of information on non-commercial fish. Thus, it is recommended that the knowledge base on this category of fish be enhanced by the development of relevant sampling methodology to study, amongst others, their distribution, abundance, structure and trophic interactions.

In addition, the actions and targets of the BSAP related to fisheries and fish populations must be implemented individually and jointly by the competent authorities according to the given time shedule. Being successful in this, the Baltic Sea area would become a model region for good management of human activities based on the Ecosystem Approach.

Box 3.5.1. Sturgeon re-introduction programme

Until the 19th century, sturgeons were widely distributed in the Baltic Sea and its southern tributaries. Their decline became obvious already in the 18th century and was caused by overfishing, as well as the increasing pollution and regulation of rivers. As a result, the species was considered missing or extinct throughout the range states and the last sturgeon in the Baltic Sea was caught in Estonia in 1996 (Paaver 1997).

Attempts to remediate the sturgeon population in the Baltic Sea started under the auspices of HELCOM in 1996. While focusing on *Acipenser sturio* in the first years, genetic and morphological evidence revealed that the sturgeon present in the Baltic until the 20th century resulted from colonization by the American Atlantic sturgeon (*Acipenser oxyrinchus*) approximately 1 200 years before present (Ludwig et al. 2002). These findings resulted in a shift to remediation of the Atlantic sturgeon. The remediation attempts were facilitated by shipments of early life stages of fish both for building up a broodstock as well as for experimental release. Furthermore, transfer of adult fish for broodstock development has taken place since 2006. In both cases, the fish originated from the natural population of the St. John River, which is genetically closely related to the historic sturgeon that used to occupy the Baltic Sea.

Along with broodstock rearing, research on the behaviour of juveniles in their natural habitat has been carried out in experimental release programmes since 2006. For these purposes, mainly the Drawa (Odra River tributary) and the Drwęca (Vistula River tributary) rivers have been utilized. In the past, these rivers included sturgeon reproduction sites and habitat for early life stages and these ecological conditions have been maintained until today.

Under the bilateral Polish-German cooperation, more than 7 000 individuals of Atlantic sturgeon were released into the Odra and the Vistula tributaries in 2007, while in 2008 more than 35 000 sturgeons were stocked. The sizes varied from 1.5 cm to 70 cm in an attempt to identify their respective suitability for release. Released fish were equipped with Floy or Carlin tags. An additional 150 fish were marked with transmitters to determine their migration routes.

All marked sturgeons regardless of size released in the upriver sections had a tendency to migrate downstream immediately, entering coastal waters. Pronounced individual differences were observed with regard to migration speed, both in telemetry studies as well as in fisheries reports. The presence of the first sturgeon in the Gulf of Gdańsk as well as in the Pomeranian Bay was noted only 10 days after the release, with maximum distances of 400 km covered during this time span. According to the information from the fishery, sturgeons spent two or more weeks at the river mouth foraging intensively. This resulted in rapid growth, providing clear evidence for the abundance of available food resources (Kolman & Kapusta 2008). Atlantic sturgeon, similar to a majority of other sturgeons, is a typical benthic species feeding mainly on a variety of invertebrate species. Because it used to be the only fish species with this feeding characteristic in the Baltic Sea, there is little probability of competition for food resources with other fish species following its re-introduction.

The results of the Polish-German project suggest that there is a significant chance for a successful re-introduction if natural reproduction and limitation of by-catch can be ensured.


Sturgeon release, Odra River 2006

4 SPECIES

The number of species in the Baltic Sea, excluding bacteria, amounts to several thousand, with the majority belonging to the planktonic community. The diversity of the smallest organisms, i.e., bacteria and viruses, is largely unknown. This evaluation of Baltic Sea diversity is primarily focused on indicators that are often represented by selected species.

The Baltic Sea Action Plan includes the ecological objective 'Viable populations of species'. In this assessment, species have mainly been addressed as representatives of the Baltic Sea communities (see Chapter 3). This chapter includes a special set of species that are either threatened (Box 4.1) or associated with specific targets in the BSAP. Particular attention is given to the populations of the harbour porpoise, seals, and a selection of birds. The specific targets of the action plan related to the respective species or species group are discussed and recommendations provided accordingly.

4.1 Harbour porpoise

The harbour porpoise (*Phocoena phocoena*) occurs in the temperate and sub-arctic zone of the northern hemisphere. It is the only cetacean species inhabiting, i.e., reproducing in, the Baltic Sea. As a top predator, the harbour porpoise is an indicator species for past and present environmental conditions in the Baltic Sea. The population living in the Baltic Sea is genetically distinct from the North Sea population (reviewed in Palmé et al. 2004). Furthermore, genetic, morphological and contaminant studies indicate that distinct populations can be differentiated within the Baltic Sea (e.g., Berggren et al. 1999, Huggenberger et al. 2002, Tiedemann 2001): one population inhabits the Kattegat and Belt Sea, whereas the other population inhabits the Baltic Proper. According to Tiedemann (2001), the distribution of the Kattegat/Belt Sea population might extend into the Arkona Basin, while the northern

Box 4.1. Threatened and/or declining species in the Baltic Sea

The Baltic Sea is a unique marine ecosystem—home to both marine and freshwater species adapted to the brackish-water conditions. After decades of continuing human pressure, many of the species have been pushed to their tolerance limits, resulting in population declines, severe population crashes and even a case of extinction. The Baltic Sea Action Plan (BSAP) sets the goal to achieve "*Thriving and balanced communities of plants and animals*" as well as "*Viable populations of species*". With this as a background, HELCOM's work regarding endangered or threatened species is of high priority to fulfil the biodiversity segment of the BSAP. To reach the goal, HELCOM has taken initial steps to identify the threatened species and the species that are threatened or show a declining population trend owing to direct or indirect human pressures.

The HELCOM lists of threatened and/or declining species and biotopes/habitats in the Baltic Sea area were adopted in 2008 (HELCOM 2007b). The species list concentrates on species that have a clear relation to the Baltic marine environment; therefore, it does not include freshwater species. Even with these limitations, the list grew alarmingly long: 14 plant species, seven species of invertebrates, 13 bird species, 23 fish species and four mammal species. Owing to varying environmental conditions in the different parts of the Baltic Sea area, the HELCOM list of threatened and/or declining species specifies the distribution and threat status for all 18 sub-regions (HELCOM 2007b). The aim of the list is to report on species that are in urgent need of protective measures.

According to the BSAP, a more comprehensive red list of Baltic Sea species must be produced by 2013. A comprehensive red list of threatened and declining species of lampreys and fish of the Baltic Sea already exists. It includes altogether 184 fish species from 15 monitoring areas. Based on abundance data and known pressures on the species, the fish assessment considered 34 species (18.5%) to be of high priority for conservation (HELCOM 2007c). However, many of the high priority species are still inadequately protected or monitored, even within marine protected areas. This first Baltic Sea-wide red list for a species group will be updated by 2013. Before that, by 2011, the conservation status of non-commercial fish species will be assessed. Because coastal fish, in particular, have a structuring role in coastal food webs, the BSAP recommends that countries protect, monitor and sustainably manage these species and that they develop by 2012 region-specific reference values in order to assess the status of the populations in future.

boundary appears to be the Skagerrak/Kattegat transition (Teilmann et al. 2008a, Tiedemann 2001). Research on the boundaries and distribution of the separate populations is still ongoing.

Up until the early 20th century, the harbour porpoise was common and widely distributed throughout the Baltic Sea (Tomilin 1957, cited in Koschinski 2002). Concurrent with a declining population, the distribution limits gradually receded west and southward over the past decades (Koschinski 2002). The recent abundance of this species in the Baltic Proper is low.

International bodies such as the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), the International Whaling Commission (IWC), the International Union for Conservation of Nature (IUCN) and HELCOM have recognized the need for an action plan to recover the Baltic harbour porpoise. In 2002, the ASCOBANS recovery plan (termed the Jastarnia Plan) was created with an interim goal of restoring the population of harbour porpoises in the Baltic Sea to at least 80% of its carrying capacity (ASCOBANS 2002). The objectives of the recovery plan are to implement precautionary management measures, e.g., to reduce the by-catch rate to two or fewer porpoises per year.

The HELCOM Baltic Sea Action Plan (BSAP) targets an improved conservation status of the Baltic harbour porpoise by 2015. Its aim is a significant reduction of harbour porpoise by-catch rates to close to zero by 2015. In cooperation with ASCOBANS, a coordinated reporting system and a database on Baltic harbour porpoise sightings, by-catches and strandings will be developed to increase the knowledge on and protection of this species by 2010.

4.1.1 Status and trends

The harbour porpoise population inhabiting the Baltic Proper has been classified as ‘critically endangered’ by IUCN (Hammond et al. 2008), justified by the consideration that the current population size is fewer than 250 mature individuals and continues to decline. Although neither the original population size nor the carrying capacity of the Baltic Proper has been quantified, it appears likely that the population size decreased considerably in the 20th century owing to anthropogenic impacts. A drastic decline also occurred in the extremely severe winter of 1940 when nearly the whole Baltic Sea was frozen (Schulze 1996).


Harbour porpoise (*Phocoena phocoena*)

The harbour porpoise density and abundance in the southwestern Baltic Sea and the Kattegat have been estimated in a number of studies during the past 15 years, primarily by conducting visual surveys from ships or aircraft but also by using acoustic survey methods (for details see Table 4.1.1, Figure 4.1.1). Reported sightings and strandings provide additional information on the distribution of the harbour porpoise.

Abundance and distribution

For a survey area mainly covering the Skagerrak to the Belt Sea or Arkona Sea, respectively, the mean abundance of harbour porpoises was estimated to be about 36 000 animals in July 1994 (Hammond et al. 2002) and about 23 000 individuals in July 2005 (SCANS-II 2008). In the southern Baltic Proper, a mean abundance of 599 porpoise groups was estimated in June 1995 (Hiby & Lovell 1996, cited in Berggren et al. 2004). This survey was repeated in 2002, resulting in a mean estimate of 93 porpoise groups (Berggren et al. 2004)[3]. Neither the former

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[3] On average, harbour porpoise groups in the Belt Sea and Kattegat area are small and contained about 1.5 animals during the surveys of 1994 and 2005. In the Baltic Proper, porpoise sightings are so rare that group size estimates are somewhat unreliable. Therefore, the results of the 1995 and 2002 surveys in the Baltic Sea provided abundance estimates only for groups rather than for individuals.

Table 4.1.1. **Results of dedicated aerial and shipboard surveys (visual and acoustic), as well as stationary acoustic monitoring for harbour porpoises in the Baltic Sea. Study areas of the different investigations are given in Figure 4.1.1. CV: coefficient of variation, CI: confidence interval; SE: standard error.**

SOURCE	"PLATFORM, METHOD"	DATE	AREA	"Animal (A) / Pod (P) ABUNDANCE"			DENSITY	
			(see Fig. 1)	Mean (CV)	CI	A/P	Mean (SE)	Unit
Hammond et al. 2002	ship, visual	July 1994	I (incl. I')	36 046 (0.34)		A	0.725	animals/km²
	Plane		I'	5 262 (0.25)		Animal	0.644	animals / km²
	Plane		X	588 (0.48)		Animal	0.101	animals / km²
Siebert et al. 2006	plane, visual	October 1995	B	980	360-2 880	A		
	Plane		C	601	233-2 684	Animal		
	Plane	July 1996	B	1 830	960-3 840	Animal		
	Plane		C	0	-	Animal		
Hiby & Lovell, 1996	plane, visual	June 1995	tracklinesa	599 (0.57)	200-3 300	P		
Gillespie et al. 2005	ship, visual	June-August 2002	1				8.2	sighted groups/100 km
			2				1.03	
			3				0	
			4				0	
		August-September 2001	5				0.34	
Gillespie et al. 2005	ship, acoustic	June-August 2002	1				16.8 (3.71)	detections/100 km
			2				10.5 (1.96)	
			3				3.2 (0.75)	
			4				0.1 (0.08)	
		August-September 2001	5				0	
Berggren et al. 2004	plane, visual	July 2002	tracklines	93	10-460	P		
Gilles et al. 2008	plane, visual	June 2005	E+F+G	2 905 (0.41)	1 308-6 384	A		
SCANS-II, 2008	plane, ship, visual	July 2005	S	23 227 (0.36)		A	0.340	animals/km²

[b]The area covered by Hiby & Lovell (1996) is comparable to that covered by Berggren et al. (2004) excluding Polish coastal waters

nor the latter two estimates are significantly different from each other owing to the wide confidence intervals of all surveys, as well as the somewhat different boundaries of the survey areas (as depicted in Figure 4.1.1). These survey results, however, confirm the low population abundance in the Baltic Proper.

Harbour porpoises are highly mobile. Surveys in southern parts of the Belt Sea and Arkona Basin (summarized in Table 4.1.1 and Figure 4.1.1) recorded a high interannual variability (Scheidat et al. 2008) and annually recurring seasonal changes with low porpoise densities during winter and high densities during summer and autumn (Verfuß et al. 2007). Furthermore, a decrease in harbour porpoise densities from the Kattegat and Belt Sea eastward is obvious (e.g. Gillespie et al. 2005, Scheidat et al. 2008, Verfuß et al. 2007). In low density areas, acoustic survey methods appear to provide a better indication of porpoise densities and trends.

Sightings and strandings

Although porpoise density in the Baltic Proper is extremely low, it is important to point out that bycatches and occasional opportunistic sightings of harbour porpoises prove the continued presence of this species in nearly all parts of the Baltic Sea. Opportunistic sightings and strandings of harbour porpoises have been reported in almost all countries surrounding the Baltic Sea. A number of data banks collect information about incidental sight-

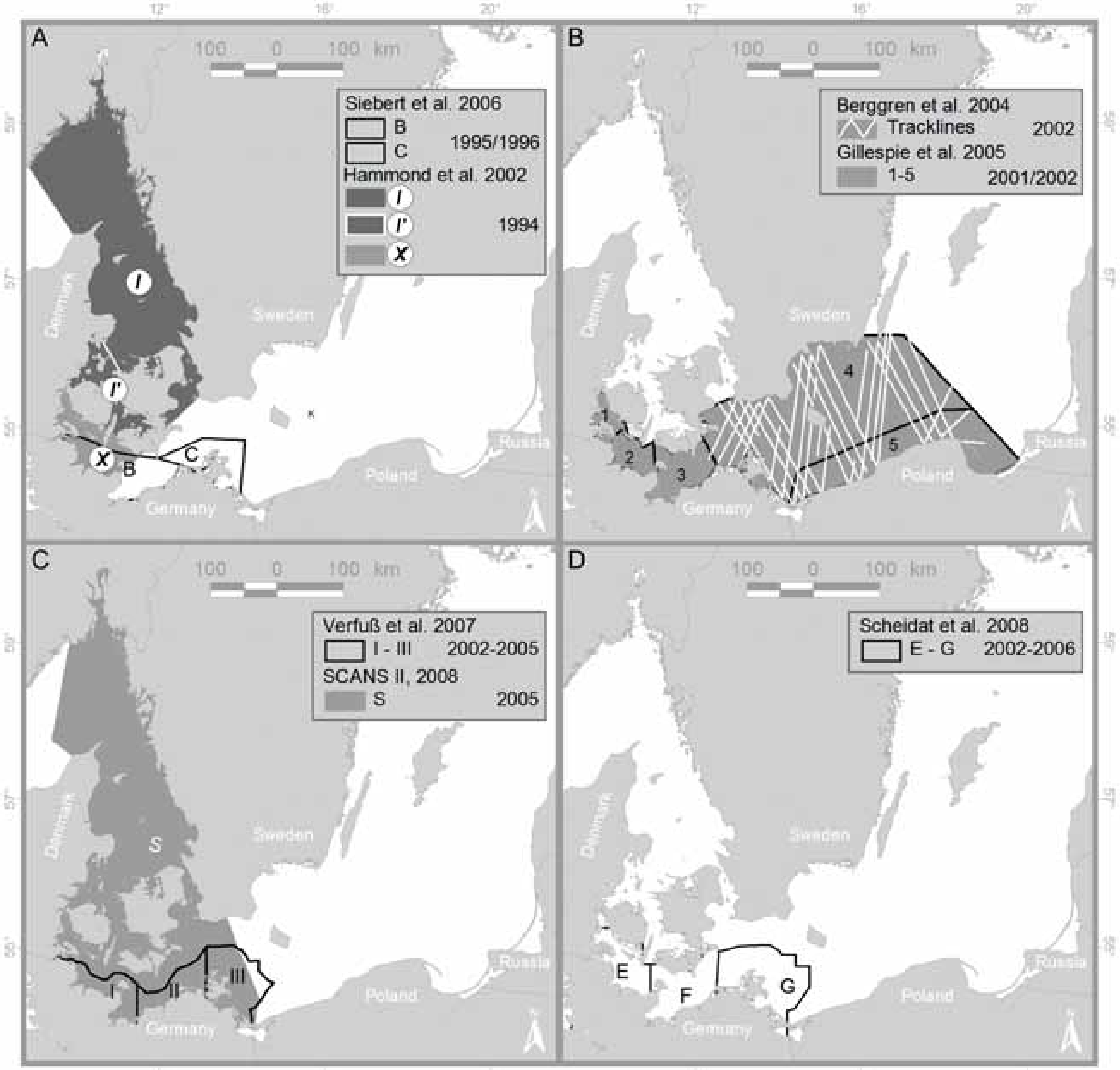

Figure 4.1.1. Survey areas for the studies listed in Table 4.1.1. The area of Hiby & Lovell (1996) (not shown) matches the survey area of Berggren et al. (2004) shown in (B) excluding a narrow area along the Polish coast. Survey area I' of Hammond et al. (2002) (in A) is part of survey area I.

Box 4.1.1. On-line resources for reporting of sighted or stranded harbour porpoises as of September 2008.

The Baltic Sea Porpoise project:
http://www.balticseaporpoise.org

Danish Society for Marine Mammals / Fisheries and Maritime Museum, Denmark: http://www.hvaler.dk

The Swedish Museum of Natural History:
http://www2.nrm.se/tumlare/

The Swedish Species Gateway: http://www.artportalen.se/

Society for the Conservation of Marine Mammals, Germany:
http://www.gsm-ev.de

German Oceanographic Museum, Stralsund:
http://www.meeresmuseum.de/wissenschaft/tierfunde.htm

Finnish Ministry of the Environment: http://www.pyoriainen.fi, http://www.environment.fi/default.asp?contentid=190711&lan=fi&clan=en)

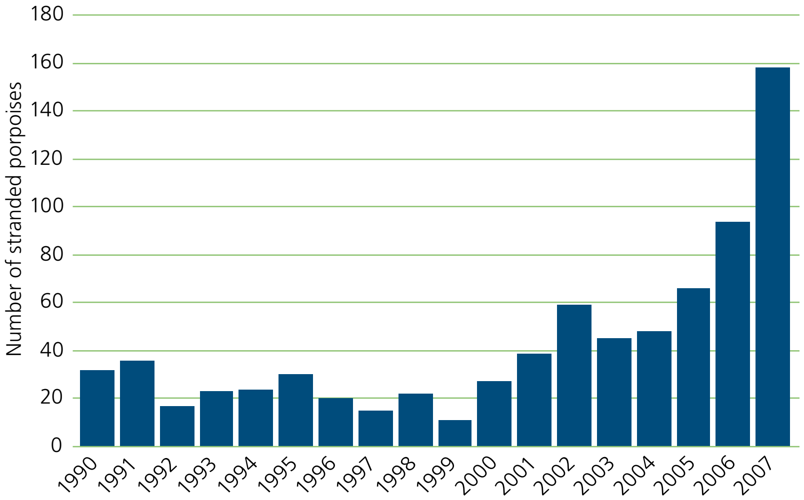

Figure 4.1.2. Number of stranded (including by-caught) harbour porpoises recorded at the German Baltic Sea coast for the years 1990 to 2007. Sources: Siebert et al., unpublished report to the Ministry for Agriculture, the Environment and Rural Areas (2008); as well as the database of the German Oceanographic Museum, Stralsund.

ings and strandings of harbour porpoises in the Baltic Sea (Box 4.1.1).

Carlén (2005) reported 146 live sightings of harbour porpoises in Swedish waters between May 2003 and September 2004, with three of these observations located along the Swedish coast of the Baltic Proper. In Finnish waters, a total of 23 harbour porpoise observations were reported during 2001–2007 (Finnish Environmental Administration 2008). In Polish waters, a total of 10 sightings was reported for 1990–1999 (Skóra & Kuklik 2003). Sighting rates in Danish and German waters are higher in summer than in winter (Kinze et al. 2003, Siebert et al. 2006).

Annual totals of 110, 139, and 107 strandings were reported for the Danish coasts (mostly in the HELCOM area) for the years 2000, 2001, and 2002, respectively (Kinze et al. 2003). Along the German Baltic coast, 11 to 158 stranded (including by-caught) individuals were reported annually for the years 1990–2007 (Figure 4.1.2). Skóra & Kuklik (2003) recorded seven strandings on the Polish coast during the years 1990–1999. Such information constitutes minimum numbers as not all sightings and strandings are reported. For the years 1950–2005, the non-governmental organization Coalition Clean Baltic for the Protection of the Baltic Sea (CCB) collated the numbers of dead porpoises reported per country (Table 4.1.2).

4.1.2 Factors influencing the status of the harbour porpoise

Several types of human activities negatively influence the status of the harbour porpoise. In recent decades, the most important anthropogenic threats to harbour porpoises are incidental by-catch, prey depletion, noise pollution and chemical toxins. Harbour porpoises have previously been severely hunted in the Baltic region (Lockyer & Kinze 2003).

Incidental by-catch in fishing gear is the most serious and lethal threat to harbour porpoises (for which reason driftnets have already been prohibited).
In general, by-catch rates depend on the fishing methods and the fishing effort employed, whereas the reported number of by-caught porpoises depends largely on the awareness and cooperation of fishermen. Currently, the minimum estimates of by-catches (see Table 4.1.2 and Chapter 6, Fisheries) far exceed the mortality limits for the population of the Baltic Proper, indicating that such by-catches will prevent recovery (Berggren et al. 2002).

Prey depletion owing to overfishing and habitat destruction is known to lead to starvation and the deterioration of health (e.g., MacLeod et al. 2007).

Table 4.1.2. Numbers of dead porpoises reported from the Baltic Sea by member countries to ASCOBANS in 1950–2005. Out of this, reported by-catch is given in brackets (Coalition Clean Baltic 2006).

Years	Sweden	Germany	Poland	Russia	Lithuania	Latvia	Estonia	Finland
1950–1959		7 (2)	8 (5)				5 (?)	
1960–1969	50 (50)	14 (?)	8 (2)			1 (1)	6 (?)	25 (?)
1970–1979	7 (6)	13 (2)	6 (3)			1 (1)		10 (6)
1980–1989	35 (27)	36 (2)	7 (6)	1 (1)	1 (0)		3 (3)	1 (?)
1990–1999	17 (14)	49 (2)	62 (45)			1 (1)		
2000–2005	16 (0)	40 (5)	25 (18)		2 (2)	1 (1)		17 (0)
Total	125 (97)	159 (139)	116 (79)	1 (1)	3 (2)	4 (4)	14 (?)	53 (?)

Noise pollution from industrial and military sources may lead to habitat exclusion, hearing loss or death (see Chapter 6, Noise pollution). Before-After-Control-Impact (BACI) studies during wind park construction in the Danish Baltic Sea showed a lasting reduction in acoustic porpoise detections mirroring a drastic reduction in their abundance in the area (Carstensen et al. 2006). Furthermore, noise simulations show that operating turbines may have a masking effect at short ranges in the open sea (Lucke et al. 2007).

Chemical toxins such as persistent organic pollutants and heavy metals may lead to reduced fertility, reduced immune response, and illness. Porpoises from the Baltic Sea have been shown to have accumulated PCB levels 0.4 to 2.5 times higher than those from the Kattegat and Skagerrak (Berggren et al. 1999). PCB-related reproductive failure is well known from Baltic grey seals (e.g., Bergman 1999). A strong increase in infectious disease mortality of British harbour porpoises was shown to correlate with PCB levels above 17 mg per kg lipid weight (Jepson et al. 2005). Beineke et al. (2005) also found indications of contaminant-induced immunosuppression in stranded harbour porpoises at the German Baltic coast.

4.1.3 Conclusions

The Baltic harbour porpoise density and distribution have declined considerably during the past several decades, leading to a critically endangered status of the harbour porpoise in the Baltic Proper. Several types of human activities negatively influence the status of the harbour porpoise and without a reduction in these anthropogenic impacts to tolerable levels, the targets for the Jastarnia Plan and BSAP appear unlikely to be reached.

The European Union has adopted some measures to protect the harbour porpoise within the Habitats Directive (1992) (European Commission 1992) and in EC Regulation No. 812/2004 (European Commission 2004). The former requests the introduction of marine protected areas as well as conservation measures in the entire porpoise distribution range, while the latter requires the elimination of drift-netting. For set-netting, however, only the introduction of pingers and observers in a tiny portion of the fishing fleet (5% of the vessels above 12 m and 15 m of hull length, respectively) is required. Strong doubts regarding the effectiveness of this EC Regulation exist both among fishermen as well as among conservationists (see Stralsund Recommendations 2007, ECS Resolution (European Cetacean Society 2008), and the recommendations of the Jastarnia Group).

4.1.4 Recommendations

A number of mitigation measures have been suggested for the threats harming the harbour porpoise population. These include the following:

By-catch reduction close to zero calls for the elimination of any contact of porpoises with the responsible gear. This can be done by a reduction of fishing effort to ecologically sustainable levels or by using fishing gear less prone to by-catch. The use of deterrent devices, so-called pingers, in set-nets either may not be very efficient or may lead to exclusion from key habitats if they work effectively. Therefore, ASCOBANS (2002) recommends their use only for up to three years to gain time for the development of proper mitigation measures. Onboard monitoring and reporting of data are prerequisites to obtain reliable by-catch numbers and to evaluate the efficiency of any mitigation measure.

A reduction of fishing effort in the responsible fisheries (at least at certain critical times) currently appears to be the only available mitigation measure to avoid prey depletion owing to overfishing.

Noise pollution may be reduced by limiting the maximum speed of vessels, as sound pressure levels increase with increasing vessel speed. Furthermore, fast ferries as well as jet skis should be prohibited in key porpoise areas. The latter measures would also help to avoid the danger of collisions, known as ship strikes. The identification of key areas, however, is inherently difficult in low density areas and requires either intensive research efforts or a rigorous application of the precautionary principle.

Information on the harbour porpoise population status is mainly available for the southwestern Baltic Sea and the western part of the southern Baltic Proper. For the harbour porpoise population in the Baltic Proper, information is scarce and increased monitoring and research are therefore strongly recommended. A long-term passive acoustic monitoring with stationary devices in the entire Baltic Proper is recommended to survey harbour porpoise densities and their trends. Continuation of post-mortem investigations will supply information on the impact of chemical toxins on this top predator. The monitoring of by-catch and the development of mitigation measures continue to be essential.

4.2 Seals

Ringed seals (*Phoca hispida*) were common in the Baltic Ice Lake (10 000–12 000 years ago), whereas it has been suggested that grey seals (*Halichoerus grypus*) colonized the basin during the Yoldia stage (9 500–10 000 years ago). Harbour seals (*Phoca vitulina*) and probably harp seals (*Phoca groenlandica*) entered into the system about 8 000 years ago, coinciding with the formation of the Litorina Sea. Except for the harp seal, which disappeared during the early Iron Age, the other species have remained important top consumers in the Baltic ecosystem (Härkönen et al. 2005, BACC 2008).

All Baltic seals have been hunted since the Stone Age, and it is evident that they formed an important role in the diet of settlers in coastal communities. During the 15th and 16th centuries, seals were mainly hunted for the production of seal oil, which was exported to the Hanseatic League. Seal oil shipped from Sweden-Finland in the 1560s constituted the third most important export product (after metals and tar) and it has been suggested that a minimum of 15 000 seals were killed each year for that purpose. Seal hunting remained important for coastal communities until the 1860s, when less expensive alternatives to seal oil became available. The intensive hunting during the first half of the 20th century was mainly driven by bounty systems, where the bounty for one seal initially was equivalent to a weekly wage for an industrial worker. The explicit aim of the campaign was to exterminate the seals, which were seen as competitors to the fishery.

The current HELCOM recommendation 27–28/2 from 2006 regarding seals states that the long-term objectives for the management of Baltic seals are a natural abundance and distribution and a health status that ensures their future persistence. There are also two targets in the Baltic Sea Action Plan (BSAP) directly linked to seals. The BSAP stipulates *"By 2015, improved conservation status of species included in the HELCOM lists of threatened and/or declining species and habitats of the Baltic Sea area, with the final target to reach and ensure favourable conservation status of all species"*. All three Baltic seal species are included in this list. An additional target is directly related to by-catches in fisheries, i.e., *"By 2015 by-catch of harbour porpoise, seals, water birds and non-target fish species has been significantly reduced with the aim to reach by-catch rates close to zero"*.

4.2.1 Status and trends

Ringed seals *(Phoca hispida)*

The ringed seal is an Arctic species, and its reproduction and moulting are tightly associated with the occurrence and quality of ice and snow. Pups are born in subnivean lairs, whereas the annual moult mainly occurs on ice. The Baltic ringed seal (*P. h. botnica*) is therefore mainly distributed in the Bothnian Bay, the Gulf of Finland, the Archipelago Sea, and the Gulf of Riga, as well as in Estonian coastal waters, where suitable ice and snow cover is formed annually. The main breeding season also coincides with the maximum ice coverage in February and March.

The current Baltic ringed seal population is distributed in the Bothnian Bay (70%), the Archipelago Sea (<5%), the Gulf of Finland (<5%) and in Estonian coastal waters including the Gulf of Riga (20%). Data from the bounty hunting in the 20th century suggest that the population size 100 years ago was 180 000 to 200 000 (Harding & Härkönen 1999). The hunting caused a major decline to about 25 000 ringed seals in the 1940s, and this level remained relatively constant until the 1960s, when a further decline to about 5 000 animals was caused by organochlorine pollution (Harding & Härkönen 1999). In the mid-1970s, only 15% of investigated females showed normal fertility (Helle 1980), which likely drove the population decline. Since then, the situation in the Bothnian Bay has improved, but still about 20% of adult ringed seal females suffer from uterine occlusion (Helle et al. 2005). The reproductive situation is mainly unknown for ringed seals in the Gulf of Finland and Estonian coastal waters.

Surveys of ringed seals in the Bothnian Bay started in the 1980s, suggesting approximately 2 000–3 000 seals (Helle 1986). Regular annual surveys have been carried out since 1988, and the trend of 4.3%

annual increase up to 2007 (Figure 4.2.1) is about half of what can be expected in a depleted healthy ringed seal population. The number counted on ice in the Bothnian Bay was 4 800 in 2007.

Data from the Gulf of Finland and Estonia are scarce because only three full surveys from the air have been carried out in these areas. However, the data suggest a growth rate close to zero in both regions at least since 1996. Counted numbers in the Gulf of Finland are about 300 animals, whereas about 1 500 are estimated to haul out during moult in Estonia (Härkönen et al. 1998, Ivar Jüssi pers. comm.). About 150 ringed seals have been counted in the Archipelago Sea (Antti Halkka pers. comm.), which totals to a counted population size of close to 7 000 ringed seals.

Grey seals *(Halichoerus grypus)*

The main concentrations of grey seals are found in the northern part of the Baltic Proper, although single individuals or scattered groups can be seen throughout the Baltic. In wintertime, the northern distribution is limited to areas with open waters. Baltic grey seals give birth in February–March and alternate between breeding on land sites and on open ice. However, when available, ice is preferred because pup mortality is higher and quality is much poorer when pups are born on land (Jüssi et al. 2008).

Grey seals were hunted heavily in the beginning of the 20th century and the previously abundant grey seals in the Kattegat and the southern Baltic were extirpated by hunting in the 1930s. The estimated total population of greys seals dropped from 90 000 to about 20 000 before 1940. A further decline occurred in the 1960s, as for ringed seals, and perhaps only 2 500–3 000 remained at the end of the 1970s (Harding & Härkönen 1999). Several lines of evidence indicate that environmental pollution also severely affected this population. Uterine disorders (occlusions or stenosis), probably as a result of fetal death, uterine tumours (leiomyomas), hormonal disturbances (adrenocortical hyperplasia), arteriosclerosis, and the occurrence of skull, renal, intestinal and integumental lesions were suggested to be caused by organochlorines (Bergman & Olsson 1986, Bergman et al. 1992, Bergman 1999, Bäcklin et al. 2003, Bredhult et al. 2008).

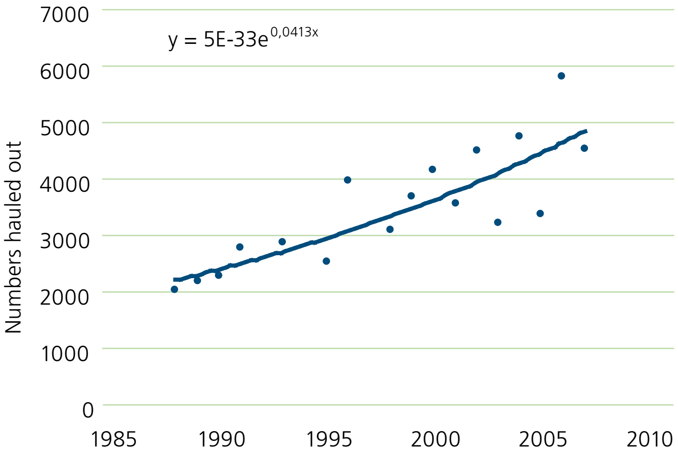

Figure 4.2.1. Numbers of ringed seals counted on ice in the Bothnian Bay, 1988–2007. The mean annual rate of increase was 4.3% for the study period.

The prevalence of uterine disorders has dropped considerably during the past two decades and other lesions have also decreased somewhat, but the prevalence of colonic ulcers has increased since the mid-1980s and the nutritional condition of grey seals appears to have diminished recently (e.g., Bergman 1999, Bäcklin et al. 2007, Routti et al. 2008).

There have been no fully compatible surveys of grey seals until very recently. Survey methods have changed over time and gradually improved, which precludes an overall assessment of the population growth rate of the entire Baltic grey seal population. The only longer time series providing compat-

Grey seal (*Halichoerus grypus*)

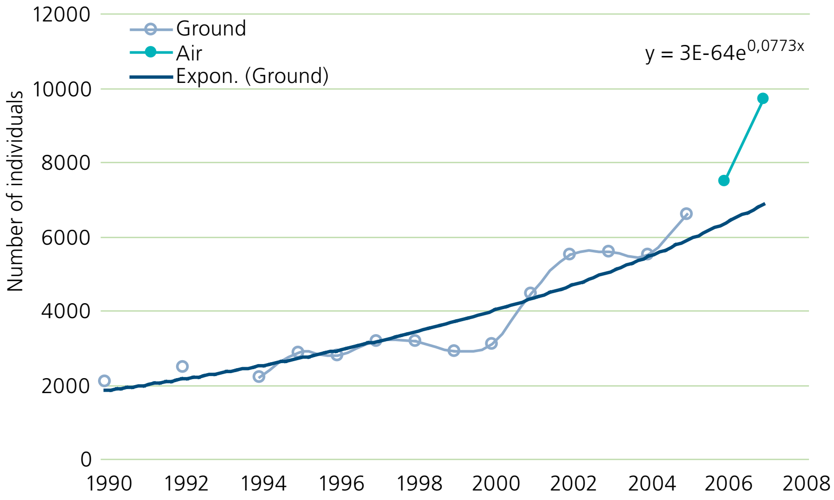

Figure 4.2.2. Numbers of grey seals counted from ground level along the Swedish coast. The annual rate of increase was 8% up to 2005. Surveys from air, started in 2006, give higher point estimates. Equation given for exponential (Expon.) curve fit.

ible data is for the Swedish coastal waters. The mean annual rate of increase in the period 1990–2005 was about 8% (Figure 4.2.2), which is somewhat less than the theoretical maximum growth rate of 10% for the species (Harding et al. 2007). Surveys from air carried out in 2006 and 2007 in Sweden give higher estimates of abundance, but it will take at least six years until such data can provide useful information for trend analyses (Harding et al. 2007).

The recovery of grey seals south of 59° N, where they had been regularly present before they were hunted to extinction in the beginning of the 20th century, is very slow (Herrmann et al. 2007). Although grey seals are observed more often than 10 years ago, no resident colonies have been reported on the southern Baltic coast (from Germany to Latvia).

Harbour seals *(Phoca vitulina)*

Harbour seals occur only in the southern part of the Baltic and there are no historical records of harbour seals north of a line from Västervik (Sweden) to Hiiumaa in Estonia. The harbour seals in the Kalmarsund region are genetically distinct from adjacent populations, with gene sequences present in only this population. The current harbour seal population in the southwestern Baltic (Scania and Denmark) seems to have colonized the area after the grey seals were severely depleted in the 1750s. Harbour seals reproduce in June, mate in July, and moult in July–August.

Harbour seals in the Kalmarsund region were close to extinction in the 1970s. Hunting, possibly in combination with effects of contaminants, resulted in a severe population bottle-neck and only some tens of pups were observed in the beginning of the 1970s (Härkönen et al. 2005). After protective measures were taken and seal sanctuaries were established in the 1980s and 1990s, the population increased by 7% per year up to 2007, when 630 seals were counted during moult. The pup production also showed a similar positive trend and close to 100 pups were born in 2007. Because harbour seals in this area spend about 65% of their time on land, the true population size is close to 1 000 seals. There is virtually no information on the health status of this population.

Harbour seals in the southern Baltic, the Kattegat, and the Skagerrak also declined steeply in the beginning of the 20th century as a consequence of the coordinated Nordic extermination effort. Bounty statistics suggest that more than 17 000 harbour seals were present in the area in 1890, but only about 2 000 seals remained at the end of the 1930s (Heide-Jørgensen & Härkönen 1988). Heavy hunting pressure kept the population at this level until the beginning of the 1970s, when hunting was prohibited and seal conservation areas were established. Annual surveys of the population started in 1979 and the population increased at 12% per year until 1988 when it was hit by a phocine distemper virus (PDV) epidemic that killed about half the population. Subsequently, the population increased exponentially at 13% per year until a new PDV epidemic in 2002 killed 66% of the seals in the Skagerrak and 30% in the Kattegat (Härkönen et al. 2006). A third epidemic caused by an unknown pathogen appeared in 2007 and killed some thousands of seals, but the total impact cannot be evaluated until survey results from 2008 become available. The total 'true' population size was about 10 100 in 2007, but this number should be regarded as uncertain because seals may have died in great numbers after the surveys in 2007 were conducted.

The reproductive status of this population appears to be normal because 95% of mature

Table 4.2.1. Population estimates and threats to the conservation of seals in the Baltic Sea.

	Population beginning 20th century	Estimated hauled-out population/trend	International protection	Conflict seal/ fishery	Major threats
Harbour seal	5 000 (Baltic Proper)	Baltic Proper: Currently: 630 1970s: 100 Trend +7.9% per yr	Bern/Bonn Conventions	Minor	Contaminants/diseases Entanglement in fishing nets Human disturbances Food limitation
		Kattegat and S. Baltic: Currently:10 100 1976: 2 200 Trend:+3% per yr	Habitats Directive	Moderate	
Grey seal	90 000	North of latitude 59°: Currently: 22 000 1970s: 2 500 Trend: +8.5% per yr	Bern Convention, Habitats Directive	Severe	Entanglement in fishing nets Contaminants/diseases Human disturbances
		South of latitude: 59° Currently: 640 Trend: slightly increasing			
Ringed seal	180 000	Gulf of Bothnia: Currently: 4 800 Trend: +4.3% per yr	Bern Convention	Increasing	Global warming Contaminants/diseases By-catches
		Gulf of Riga: Currently: 1 500 Trend: Zero		Minor	
		Gulf of Finland: Currently: 300 Trend: Zero Archipelago Sea: Currently: 150		Minor	

females reproduce, and the population growth rate is close to maximum levels for the species. However, the material collected in 1988 showed high prevalences of bone lesions (parodontitis and alveolar exostosis) (Mortensen et al. 1992). Alveolar exostosis is not present in material collected before 1950. Furthermore, experimental studies have shown that harbour seals carrying PCB loads comparable to levels observed in the Kattegat exhibit impaired immune functions (DeSwart 1995).

4.2.2 Factors that influence the status of seals in the Baltic Sea

The current and future status of Baltic seals can be expected to be affected by a number of anthropogenic factors (Table 4.2.1).

Xenobiotic substances have had a severe impact on the health and abundance of ringed and grey seals, and also affect hormonal processes in harbour seals. The multitude of chemical substances produced poses a potential threat to the health of all top consumers in the Baltic biota (Bergman & Olsson 1986, Bergman et al. 1992, Bergman 1999, Bäcklin et al. 2003, Bredhult et al. 2008).

Unsustainable management of fish stocks can lead to the depletion of important food organisms for marine mammals in the Baltic. The currently decreasing blubber thickness in grey seals (Figure 4.2.3) and ringed seals (Britt-Marie Bäcklin pers. comm.) may be linked to such effects. Similar effects are suspected in the Kattegat, where the population growth rate declined during the years before the 2002 PDV epidemic.

By-catches in fisheries reduce the growth rate in populations of marine mammals, which increases the risk for rapid declines in most scenarios in ecological risk analyses (Hansson et al. in prep.). No systematic information is available on by-catches of marine mammals in the Baltic.

History shows that Baltic seals are very vulnerable to hunting especially during warmer periods with

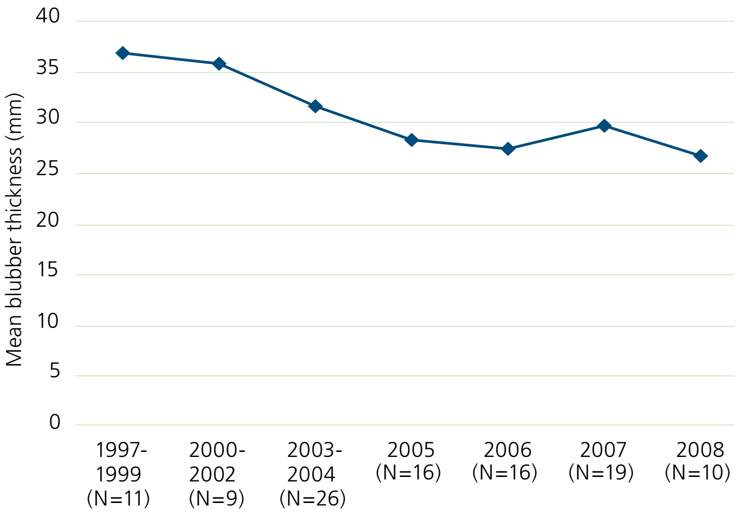

Figure 4.2.3. The mean blubber thickness in 1–3 year-old by-caught grey seals from 1997 to 2007 examined in Sweden. Note: The decrease in mean blubber thickness between these years is significant ($p<0.001$). Usually the blubber layer in the Baltic grey seal is thicker in the second half of the year compared to the first half. In 1997–1999, 54% of the animals examined were found in fishing gear in the second half of the year.

limited ice cover. The most important mechanisms are that warm winters lead to lower intrinsic population growth rates in both ringed seals and grey seals, and that both species are more easily hunted because they occur in more concentrated groups at suitable habitats.

A recolonization of former haul-out sites for grey (and harbour) seals south of 59° N is hampered by more frequent and intensified human activities along the coastline. It is therefore of utmost importance that potential haul-out sites become more strictly protected and regularly monitored (Herrmann et al. 2007).

Projections of future climate indicate that warming owing to greenhouse gas emissions will lead to decreasing ice and snow coverage. Decreasing ice coverage and, perhaps more importantly, decreased snow depth and a shorter season of ice cover will have strong negative effects on the reproductive output of ringed seals especially in the Gulf of Finland, the Archipelago Sea and Estonian coastal waters. Increasing frequencies of winters with no ice in these regions can lead to extirpation of the species in the south, and result in lowered reproductive output for ringed seals in the north, where they will reproduce in suboptimal habitats. In contrast, harbour seals will be favoured by decreasing ice.

4.2.3 Conclusions

The conservation status of Baltic ringed seals is still unfavourable because the population growth rate over the past decade appears to be close to zero in the Gulf of Finland and Estonian coastal waters. The stock in the Bothnian Bay has been increasing by 4.3% per year since 1988, which is less than half of the intrinsic capacity of increase. A future scenario with less ice and snow will not improve the situation for Baltic ringed seals. Management actions should therefore focus on reducing all kinds of mortality linked to human activities. The effects of decreasing ice coverage and shorter winters, in combination with the current low population growth rate in ringed seals, make it unlikely that this species will reach a favourable conservation status by 2015. On the contrary, the three southern stocks in the Archipelago Sea, Estonia and the Gulf of Finland risk extirpation. Based on these factors, the revised IUCN classification in 2008 will remain as ‘Vulnerable’.

Harbour seals in the Kalmarsund area are vulnerable owing to their low numbers and limited genetic variation, but the population is expected to continue to grow. Current actions with conservation areas and banned hunting are sufficient to ensure future expansion of the population, but it will not reach favourable population status by 2015. Harbour seals in the southern Baltic and the Kattegat-Skagerrak are expected to have favourable conservation status in 2015, but the current population is not expected to expand in the future because it appears to be close to the carrying capacity.

Although growing at a rate not far from the intrinsic rate of increase for the species (Harding et al. 2007), the Baltic grey seal is not established throughout its natural distribution area. The Baltic grey seal is projected to increase in abundance, but the current growth rate is expected to be hampered in a scenario with warmer winters. An expansion of the population south of 59° N will require dedicated efforts in the form of strictly protected areas designated for seals and a reduction of human impacts both landward and seaward of these sites.

4.2.4 Recommendations

Minimizing all human takes (hunting and by-catches) will improve the situation for Baltic ringed seals and harbour seals in the Kalmarsund area. However, by-catches of all Baltic marine mammal species will remain substantial and exceed 2% of their populations if the current structure of fisheries remains unchanged. The situation can be improved if fisheries with substantial by-catches change their methods. This is the single most important factor affecting mortality rates in Baltic seals.

The decreasing nutritional status of ringed seals and grey seals implies that food resources might be limiting. Actions should be taken to manage fish stocks in accordance with the principles of the ecosystem approach.

It has been suggested that the increasing prevalence of colonic ulcers is caused by harmful chemical substances. Further actions should be taken to reduce inputs of xenobiotic organohalogen compounds that affect Baltic biota.

The pristine distribution of harbour seals and grey seals encompassed also the German, Polish and Kaliningrad coasts of the Baltic. Measures in the form of protected areas and reduction of human impacts are required to achieve the main long-term objective 'Natural Distribution' of the 2006 HELCOM recommendation on seals.

4.3 Birds

One of the great achievements of nature conservation in the 20th century was the establishment of protected areas all around the Baltic Sea, including for the most important breeding and resting sites of seabirds. The unlimited persecution of species that for a long time had been considered as 'harmful', such as white-tailed eagle and great cormorant, was stopped by nature conservation legislation. Ultimately, with the EU Birds Directive, a comprehensive conservation regime for birds entered into force in 1979 and became effective for almost the entire Baltic, except Russia, when Poland, Lithuania, Latvia, and Estonia joined the European Union in 2004.

Despite these positive developments, anthropogenic factors such as pollution, habitat change and incidental killing still have a significant impact on bird populations in the Baltic Sea area.

Sandwich tern (*Sterna sandvicensis*)

There is no target in the biodiversity segment of the Baltic Sea Action Plan (BSAP) that addresses specific bird populations, but there are several targets that embrace birds, primarily the target to reach *"By 2015, improved conservation status of species included in the HELCOM lists of threatened and/or declining species and habitats of the Baltic Sea area, with the final target to reach and ensure favourable conservation status of all species"*. This list currently includes thirteen species of birds. Several targets in the biodiversity segment are also related to reducing the impacts of fisheries, an issue that is highly relevant for birds.

In addition, the Maritime Activity Segment of the BSAP includes the strategic goal *"To have maritime activities in the Baltic Sea carried out in an environmentally friendly way"*. Because maritime traffic causes oil spills and the release of hazardous substances and other wastes, this goal is also relevant for birds.

4.3.1 Status and trends

This section describes the status and population development of selected bird species. It aims to illustrate characteristic and representative developments. The population status of these species in Baltic basins is provided in Annex V.

Species that have indicative value for characteristic population developments of birds in the Baltic Sea region are:

- Cormorant (*Phalacrocorax carbo sinensis*): Representative of species that have recovered after being nearly extinct by persecution, and which benefit from eutrophication;
- White-tailed eagle (*Haliaeetus albicilla*): Representative of top-predators that have suffered from DDT and other chemical pollutants, and have a positive population trend after the ban on these substances;
- Dunlin (*Calidris alpina*): Representative of waders, which are declining in many regions of the Baltic Sea;
- Barnacle goose (*Branta leucopsis*): A new species which has recently occupied the Baltic Sea as a breeding area.

Typical marine and coastal species include:

- Sandwich tern (*Sterna sandvicensis*): A species that has expanded its range to the Baltic Sea during the 20th century; representative of the group of typical coastal birds;
- Eider (*Somateria mollissima*): A sea duck that has its main breeding sites at the coast;
- Razorbill (*Alca torda*): Representative of the auks; the Baltic Sea is a breeding area for the species, but also a wintering site for birds from the North Atlantic population.

Species of worldwide concern for which the Baltic is of special importance are:

- Steller's eider (*Polysticta stelleri*): Worldwide threatened species with globally important wintering populations in the Baltic Sea;
- Long-tailed duck (*Clangula hyemalis)*: The species has been the most numerous bird wintering in the Baltic Sea, but is now most likely rapidly decreasing in numbers. It is heavily affected by chronic oiling.

Great cormorant *(Phalacrocorax carbo sinensis)*

During the 19th century, the great cormorant was exterminated as a breeder in several Baltic countries. The persecution continued during the 20th century, and in the early 1960s the European breeding population of the continental subspecies *sinensis* had declined to 4 000 breeding pairs (bp), of which Germany and Poland hosted more than half.

The species was successful in recolonizing Denmark in 1938 and Sweden in 1948. As a result of protection measures, breeding pair numbers started to increase during the 1970s. By 1981, the number in the Baltic Sea area had reached approximately 6 500 bp, and in 1991 already about 51 000 bp.

Since about 1994, the population of the great cormorant has been fairly stable in the western part of the Baltic (Denmark and Germany, Figure 4.3.1), but breeding numbers have continued to increase in Poland (25 800 bp in 2006), Sweden (44 000 pairs in 2006), and the more recently colonized areas in the eastern Baltic.

The expansion to former breeding areas in the eastern Baltic took place during the 1980s and 1990s. The cormorant started to breed in Estonia in 1983, in Lithuania in 1985, and in Finland in 1996 (Žydelis et al. 2002, SYKE 2008a, V. Lilleleth, pers. comm.). In addition to the strong population growth in Finland and Estonia (Figure 4.3.2), numbers are also increasing in the Russian part

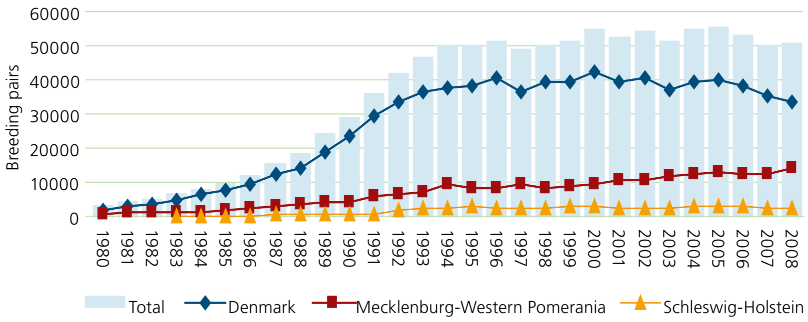

Figure 4.3.1. The population of the great cormorant in the western Baltic (Denmark and northern areas of Germany) has remained fairly stable since the mid-1990s.

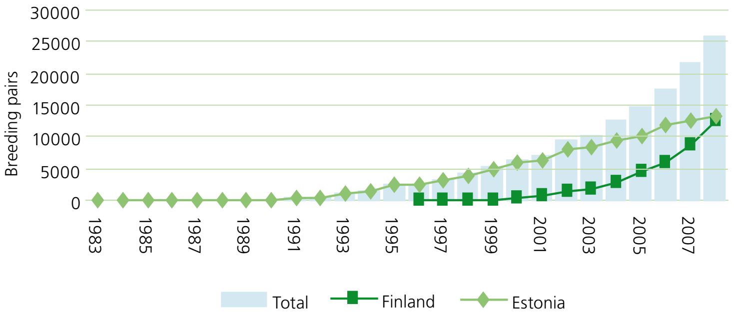

Figure 4.3.2. In the eastern Baltic, the cormorant population is still increasing (the total is the sum for Finland and Estonia). Data from SYKE 2008a and V. Lilleleth, pers. comm.

of the Gulf of Finland (from 1 400 bp in 1994 to 3 800 in 2006), in Lithuania (from 900 bp in 1995 to 3 700 in 2006), and in Kaliningrad (from 120 bp in 1991 to 8 500 in 2005). No increase has been recorded in Latvia, where only 200–300 bp have been nesting since the mid-1990s.

The total number of breeding pairs of great cormorants in the Baltic Sea littoral countries amounted to about 157 000 bp in 410 colonies in 2006, with almost 80% of the birds breeding in Denmark, Germany, Poland and Sweden[4]. All large colonies in the Baltic Sea area are located near to the coast. The largest colonies are found around the highly eutrophic estuaries of the large rivers: Vistula Lagoon (11 500 bp in 2006 in a colony on Vistula Spit, Poland), Odra lagoon (10 750 bp in 2006 in five colonies in Mecklenburg-Western Pomerania and Poland), and Curonian Lagoon (11 300 bp in 2006 in two colonies on the Lithuanian and the Kaliningrad side of the lagoon).

Some Baltic countries have initiated management actions to control breeding numbers in order to reduce conflicts with fisheries or to protect salmon smolts. These actions include oiling or pricking of eggs in ground-nesting colonies, scaring of birds attempting to found new colonies, and shooting of cormorants around fish ponds, lakes or fishing devices. Illegal persecution is also reported from several countries.

Barnacle goose *(Branta leucopsis)*

During past decades, the East Atlantic flyway population of barnacle geese, which consists of the Arctic Russian population, the temperate Baltic population and the temperate North Sea population, increased in numbers from about 20 000 birds in 1959/1960 to about 550 000 birds in 2005/2006 (Ganter et al. 1999, Eichhorn et al. 2009, Figure 4.3.3). Birds of the Russian population, which is by far the largest, use the Baltic Sea coast for foraging during spring and autumn migration. Birds belonging to the recently established Baltic population breed mainly in colonies along the coasts of Gotland and Öland in Sweden, Saaremaa in Estonia, and in southern Finland (Larsson et al. 1988, Black et al. 2007, Mikkola-Roos et al. 2008). Smaller breeding colonies are also found in mainland Sweden, Denmark, and Germany.

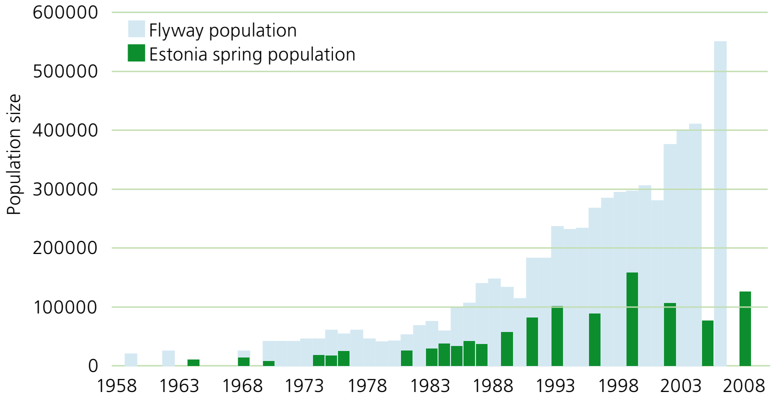

Figure 4.3.3. Development of the flyway population and Estonian spring population of the barnacle goose 1959–2008 (Eichhorn et al. 2009).

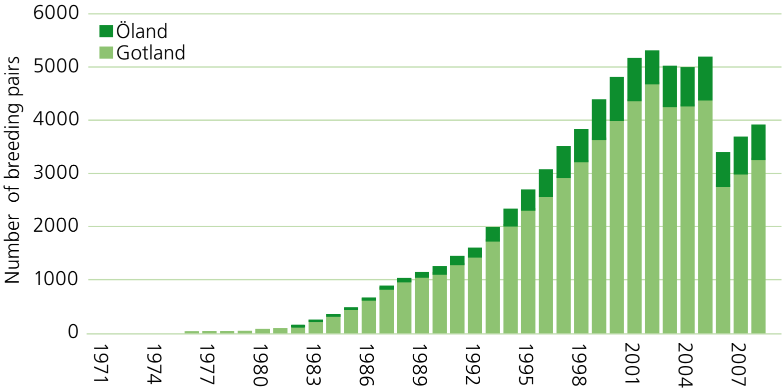

Figure 4.3.4. Number of breeding pairs of barnacle goose in the main Baltic colonies on Gotland and Öland, Sweden. The first breeding pair in the Baltic Sea was recorded in 1971. Reductions in the number of breeding pairs in 2003 and 2006 are due to the presence of foxes on major breeding islands.

The Baltic breeding population was established naturally in 1971 on Laus holmar off the eastern coast of Gotland. During the 1970s, the colony increased in numbers and consisted of 125 bp in 1982. In 1981, the first breeding pair was observed at the coast of Saaremaa, and in 1982 the first breeding was recorded on Öland. During the 1990s, the number of colonies increased considerably along the coasts of Gotland, Öland, Saaremaa and southern Finland. In 2002, about 5 300 pairs bred on more than 20 different small islands off Gotland and Öland. Since then the overall number of breeding pairs has decreased owing to the presence of red foxes on some of the breeding islands in some years (Figure 4.3.4). In addition to fox

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[4] Numbers include inland colonies; for Germany, only the Baltic Federal States Mecklenburg-Western Pomerania and Schleswig Holstein are considered, for Russia the St. Petersburg and Kaliningrad regions.

predation on nests and nesting adults, predation by white-tailed eagles on nesting adults may affect the number of breeding pairs in some colonies. The total number of barnacle geese in the Baltic is currently estimated at about 25 000 individuals.

Reproductive success, measured as the number of fledged young per pair, has been shown to be density-dependent and variable among years (Larsson & Forslund 1994). The amount of high-quality grass available around the colonies for newly hatched chicks in May and June, as well as predation by gulls, determines the production of fledged young. Annual survival rates of adults and fledged young are high. Only limited hunting is permitted in the Baltic region.

Many, but not all, large colonies of barnacle geese on Gotland and Öland are situated within protected areas. The colonies in Finland, Estonia, mainland Sweden, Denmark, and Germany range in size from a few pairs to several hundred pairs (Leito 1996, Mortensen & Hansen 1999, SOF 2006, Koop 1998, Mikkola-Roos et al. 2008). Some of the latter colonies have probably been founded by birds of captive origin. However, birds from such colonies usually cannot be distinguished from other birds.

Eider *(Somateria mollissima)*

The main breeding areas of the eider in the Baltic Sea are Sweden (270 000–360 000 breeding females, bf, in 1999/2000), Finland (80 000–100 000 bf in 2007), Denmark (25 000 bf 1990–2000), and Estonia (15 000 bf in 1995) (BirdLife International 2004, Desholm et al. 2002, Hario & Rintala 2008). The species also occurs in small numbers in the Russian part of the Gulf of Finland (70–80 bf) and at the German Baltic coast (80–100 bf in 2008). The eider does not breed, or breeds only exceptionally, in Poland, Lithuania, Latvia, and the Kaliningrad region of Russia.

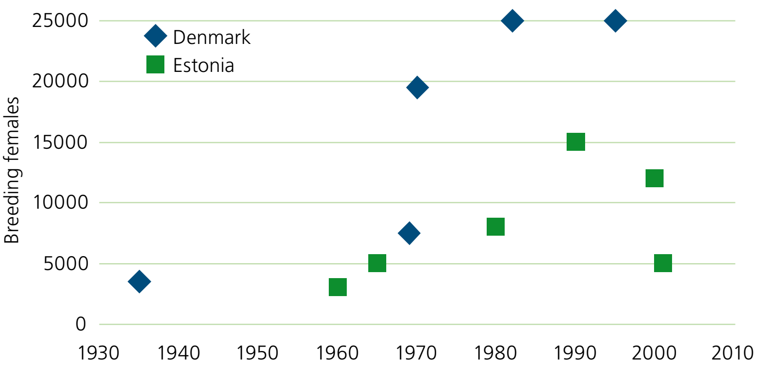

Figure 4.3.5. Development of the eider population in Denmark and Estonia during the 20th century. Data from Desholm et al. (2002), Lyngs (2000 and unpublished), and Elts et al. (2008).

The eider population showed a strong long-term increase throughout the 20th century. Simultaneously, it extended its breeding range southwards to the German Baltic coast, where the first breeding was recorded in 1985. However, since the late 1990s, stagnant or even strongly declining population trends have been observed in several countries (Denmark, Sweden, Finland, Estonia; Desholm et al. 2002, Elts et al. 2008, Figure 4.3.5). In Finland, the eider is currently the most rapidly declining seabird species, dropping down from 150 000–180 000 bf in 2001 to only 80 000–100 000 bf in 2007 (Hario & Rintala 2008).

This decline is true not only for the Baltic breeding population, but also for the Baltic/Wadden Sea flyway population as a whole. Mid-winter counts suggest that the total population may have fallen from 1.2 million birds in 1991 to 760 000 in 2000, which is a reduction of 36% (Desholm et al. 2002)[5]. Although reductions are evident for several breeding areas, the decline of the breeding population along the flyway seems to be less pronounced compared to the winter population. Shortcomings in the monitoring of breeding and wintering numbers, as well as an unknown buffering effect of non-breeders, are probably the reasons for the difference (Desholm at al. 2002).

The recent population development may be influenced by several factors, among them hunting, predation by mink and white-tailed eagle, bacterial and viral infections, parasite infestations, drowning in fishing gear, and oiling. Low reproductive success and high mortality of ducklings have been reported from several breeding areas in the most recent years. However, several of the factors mentioned above affected the population already in

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[5] These population numbers are probably underestimates because they reflect the counted numbers without any attempt to correct for birds that have not been seen. Noer et al. (1995) estimated a population size of 1.5–2.0 million birds in 1990. However, the estimated decrease of approximately 30%, giving a total population of about 1.0–1.2 million birds in 2000, seems to be realistic (Noer, pers. comm.).

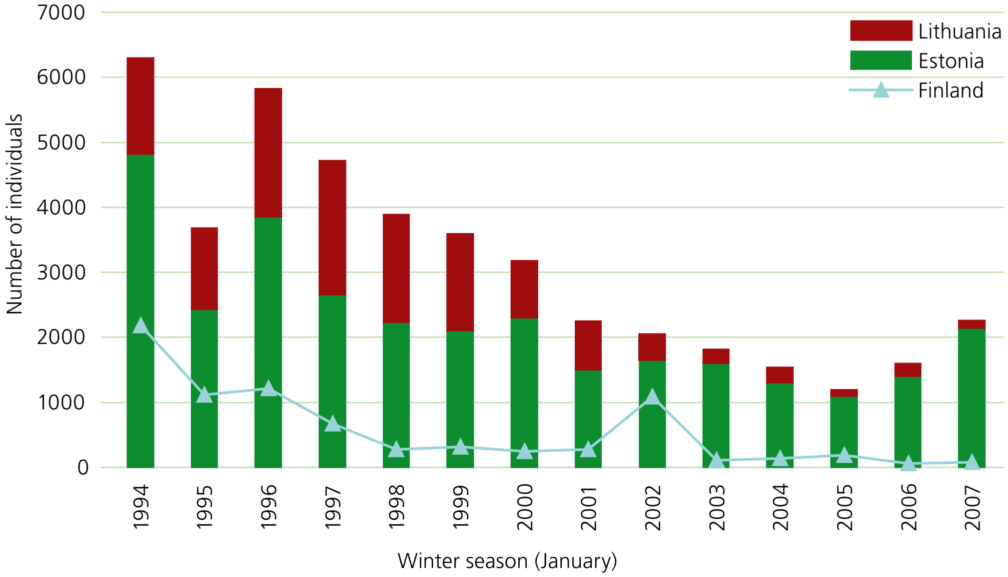

Figure 4.3.6. Numbers of wintering Steller's eiders in Estonia and Lithuania, and migrating birds at Hanko-Helsinki, Finland.

the past, when the number of eiders in the Baltic was still increasing, and some impacts, such as hunting, used to be even higher than today.

The eider is still hunted in several Baltic countries, e.g., Denmark, Sweden, and Finland (see Chapter 6, Hunting). The presence of American minks has caused substantial decreases of breeding bird numbers in those areas where minks reach high densities (e.g., Stockholm archipelago). Furthermore, minks force the eiders to change their nesting habitats, moving from bushy islets to gull colonies or solitary nesting gulls. In 1996 and 2001, outbreaks of avian cholera (caused by the bacteria *Pasteurella multocida*) affected the population. In Finland in 1996 and 1999, viral infections caused mass mortality among ducklings within the first weeks after hatch. Intestinal acanthocephalan parasite infestation is high among eiders and may have an impact in association with other predisposing factors, such as impaired feeding ability or virus infections (Desholm et al. 2002). Drowning in stationary fishing gear is also an important mortality factor, at least in some wintering areas (I.L.N. & IfAÖ 2005).

Steller's eider *(Polysticta stelleri)*

Steller's eider is one of the rarest sea duck species, identified as 'vulnerable' by the IUCN Red List of Threatened Species. The species nests in Arctic tundra, with the bulk of the Western Palearctic population wintering along the Kola Peninsula and in Varangerfjord in the Barents Sea. A significant proportion of the regional population (10–20%) also winters regularly in the Baltic Sea.

Winter distribution in the Baltic is restricted to very few areas: around Saaremaa and Hiiumaa Islands in Estonia, Lithuanian coastal waters off Palanga, and Lågskär Archipelago in Finland. Sightings of Steller's eiders are also regularly reported from Swedish and Latvian coastal waters.

Steller's eiders were very rare in the Baltic Sea from the beginning of the 20th century until the early 1960s. Then, numbers of Steller's eiders wintering in the Baltic increased steadily until the mid-1990s (Nygård et al. 1995). This period was followed by a rapid decline of bird abundance across all wintering sites (Žydelis et al. 2006). Peak numbers reaching 5 000 wintering individuals in Estonia and 2 000 in Lithuania dropped to lows of 1 500 and 90, respectively. The number of migrating birds counted in Finland generally also followed the same declining trend (Lehikoinen 2007). The number of wintering birds in Estonia, however, showed signs of increase during the most recent winters (Figure 4.3.6).

The reasons for the recent decline of the Baltic wintering population of Steller's eider are not clear. Most likely, a combination of different factors is in play, including a shift to wintering sites outside the Baltic, decreased reproductive success, and threats affecting bird survival.

Conservation concerns for Steller's eider in the Baltic Sea include accidental bird mortality in fishing nets, the threat of oil pollution, and the possibility of habitat degradation. The species is extremely site-faithful and regularly occurs on very few sites. Therefore, Steller's eiders are highly sensitive to factors affecting their wintering habitats.

Long-tailed duck *(Clangula hyemalis)*

The Baltic Sea is a globally important wintering area for the long-tailed duck. Surveys in 1992 and 1993 showed that approximately 4.3 million birds from the Fenno-Scandinavian and Russian breeding populations were wintering on offshore banks or in coastal areas of the Baltic Sea. About 66% of the wintering birds were found at four geographically limited offshore areas: Hoburgs Bank south of Gotland, Irbe Strait, the Gulf of Riga, and Pomeranian Bay (Durinck et al. 1994). However, spring migration counts in Finland and Estonia as well as regional winter surveys indicate that the total wintering population of long-tailed ducks has decreased dramatically in numbers in recent years (Kauppinen 2008, J. Bellebaum pers. comm.). Updated trends from offshore areas covered during the coordinated mid-winter census 2007–2008 will be published by the SOWBAS project in 2009 (http://sowbas.dhigroup.com/).

Because the majority of the birds winter on a few offshore sites, the population may be severely affected by oil spills from ships, fishery by-catch, and habitat changes. An important shipping route from the southern Baltic Sea to the Gulf of Finland with approximately 22 000 ship passages per year passes through the Natura 2000 site Hoburgs Bank. A large number of smaller oils spills, most of them less than one tonne, are registered along the route each year. Weekly winter surveys of oiled birds at southern Gotland between 1996/1997 and 2006/2007 have shown that several tens of thousands of long-tailed ducks are killed annually by oil in the central Baltic Sea (Larsson & Tydén 2005, Larsson 2007). Furthermore, analyses of 998 long-tailed ducks drowned in fishing gear at Hoburgs Bank showed


Long-tailed duck (*Clangula hyemalis*)

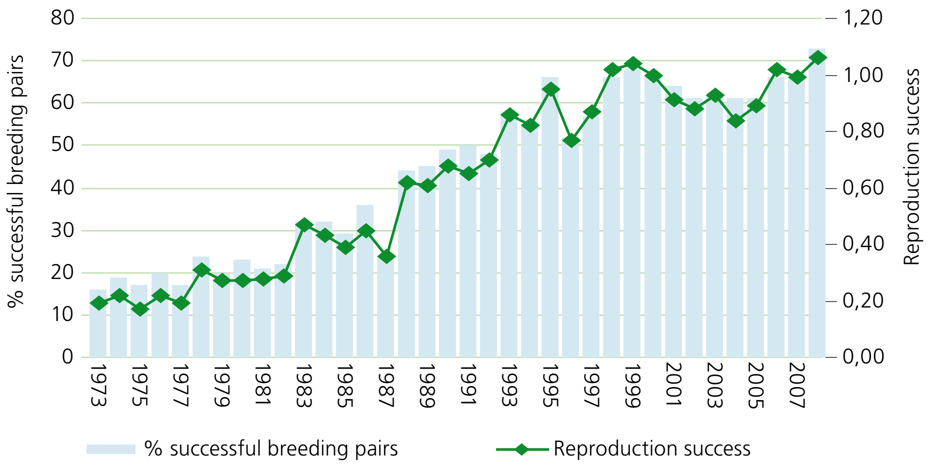

Figure 4.3.7. The development of reproductive parameters of the white-tailed eagle in Mecklenburg-Western Pomerania, 1973–2008.

that a large proportion, about 12% of the birds, had oil in the plumage (Larsson & Tydén 2005). Although any kind of oil discharge from ships is strictly prohibited in the Baltic Sea, chronic oiling is most likely an important reason for the decline of the European wintering population of the long-tailed duck.

White-tailed eagle *(Haliaeetus albicilla)*

The white-tailed eagle breeds in coastal and inland lake areas of all Baltic countries. These countries, together with Norway, host the major part of the European population, which currently probably accounts for more than 50% of the global population.

Although the white-tailed eagle is not a 'true' coastal species, it reaches remarkably high concentrations in some coastal areas. The Odra lagoon area, for example, has been known as one of the last density centres during the first half of the 20th century (Mizera 2002), and currently still shows the highest density of breeding pairs in Central Europe (Hauff et al. 2007). In Lithuania, a concentration of breeding sites in the Nemunas delta and around the Curonian Lagoon is obvious (Dementavičius 2007). In Sweden also, the major part of the population is found along the coast (Tjernberg & Svensson 2007). In Finland, the species is concentrated in the southwestern coastal areas, but also occurs along the whole coastline and around large inland lakes in Lapland (SYKE 2008b).

At the beginning of the 20th century, as a consequence of severe persecution, the white-tailed eagle was close to extinction all around the Baltic Sea. In Denmark, the species disappeared after 1911, in 1913 in Mecklenburg-Western Pomerania, only 23 bp were known, and the Polish population of that time was estimated at about 20 bp (Hauff & Wölfel 2002, Mizera 1999). In Lithuania and the Kaliningrad region of Russia, the white-tailed eagle also disappeared for a long time.

Owing to protection measures against persecution, the population started to recover during the 1920s, but the positive trend was reversed from the mid-1950s to the early 1980s by the harmful effects of chemical pollutants (DDT and PCBs) on fertility and reproductive success. The proportion of successful breeding pairs dropped down to only 20–30%, and the reproductive success to 0.2–0.4 fledglings per breeding pair. As a consequence, the population remained stagnant or even decreased. Owing to the ban on DDT and other pesticides in the early 1970s, the reproduction parameters started to improve at the beginning of the 1980s, and returned to normal levels in the mid-1990s (Figure 4.3.7).

Currently, the white-tailed eagle population is increasing in all Baltic countries (Table 4.3.1, Figure 4.3.8). The species has also returned to territories abandoned in the past (e.g., Lithuania in 1987, Denmark in 1995). In recent years, a range expansion to the west (western and southwestern parts of Germany) has been observed, and in 2006 the first breeding pair was recorded in the Netherlands.

Table 4.3.1. Development of the population of the white-tailed eagle in Baltic Sea littoral countries.

Country	Territorial pairs			Current population trend
	1991	1998	2007	
Denmark	0	5	17	++
Estonia	40	60	150–170	++
Finland	77	158	294	++
Germany, Schleswig-Holstein	8	20	53	++
Germany, Mecklenburg-Western Pomerania	102	153	242	++
Latvia	5–8	11	25	++
Lithuania	7	25–30	90	++
Poland	300	500	700–800	++
Russia, Kaliningrad region	1–4	5–6	>20	++
Russia, St. Petersburg region	15	20	25–30	+
Sweden	127	227	496	++
Total, Baltic Sea littoral countries	660– 670	1 170–1 180	2 100–2 250	++

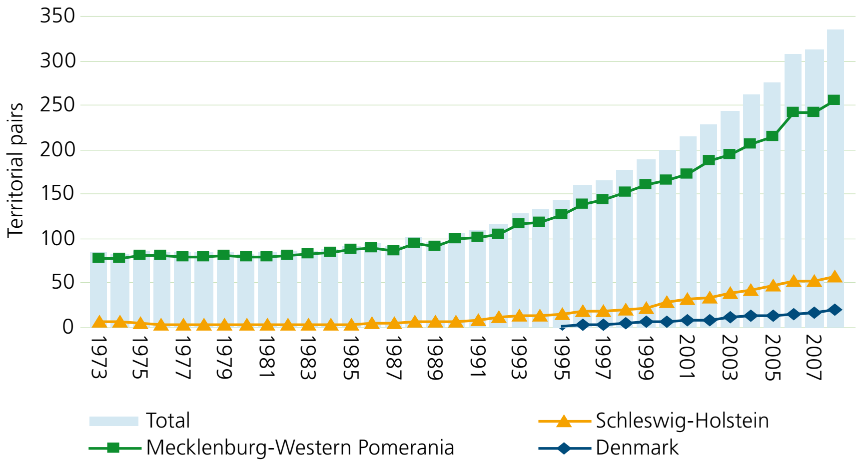

Figure 4.3.8. The population development of the white-tailed eagle in the western Baltic (Denmark, Schleswig-Holstein, and Mecklenburg-Western Pomerania), 1973–2008.

Dunlin (*Calidris alpina schinzii*)

The southern sub-species of the dunlin (*Calidris alpina schinzii*) colonizes southeastern Greenland, Iceland, the Faroe Islands, Great Britain and Ireland, southern Norway, and the Baltic Sea. In the past, the dunlin bred in the southern North Sea (Belgium, Netherlands and Germany), but in recent times breeding records are few and irregular.

At the beginning of the 20th century, the dunlin was still a very common bird around the Baltic. The Danish breeding population at that time is estimated at 50 000–100 000 bp (Thorup 1997), and the species was also widespread and common in Sweden, Germany, Poland and Estonia. Since then, the Baltic dunlin suffered a continuous, dramatic decline. The Danish population declined to about 600 bp in 1970 (Ferdinand 1980), 450 bp in the mid-1990s (Grell 1998), and 350 bp in 2002 (Thorup 2003). The breeding pair numbers in Sweden and Estonia declined to currently around 100 and 200–250 bp, respectively. Along the southern and eastern coasts of the Baltic Sea (Germany, Poland, Lithuania, Latvia, and the Kaliningrad and St. Petersburg regions of Russia), the dunlin has already disappeared or is close to extinction (Table 4.3.2). In Finland, the southern dunlin has never been numerous. During recent years

(2003–2007), the number of breeding pairs was between 50 and 60. The total Baltic population was estimated at about 1 110–1 360 bp in 2002 (Thorup 2006), and not more than 700–800 bp in 2007 (Table 4.3.2).

Habitat loss by drainage and land reclamation have been considered as reasons for the population decline in the past (Holz 1986). An increase in predators and management problems for coastal meadows seem to be other important factors affecting the population. However, the dramatic long-term decline from probably far more than 100 000 bp at the beginning of the 20th century to less than 1 000 one hundred years later cannot be explained only by habitat loss and predation. Even in areas where suitable habitats have been conserved and properly managed, the dunlin is declining or has even disappeared. In Germany, Denmark, Sweden and Lithuania, restoration projects for breeding habitats of dunlin, ruff (*Philomachus pugnax*) and other waders have recently been implemented or are currently under implementation. Specific programmes and projects aiming to restore breeding habitats are also being implemented in Finland and Poland. However, these efforts do not yet show positive effects for the dunlin population. It is very likely that the rapid decline of the dunlin in the Baltic Sea area is not a consequence of habitat loss, but rather is driven by large-scale factors such as climate change.

Sandwich tern *(Sterna sandvicensis)*

At the beginning of the 20th century, the Baltic Sea was not part of the breeding range of the sandwich tern. However, during the first half of the century, the species expanded its range gradually to the northeast, colonizing Skåne in 1911 and the Swedish east coast during the 1930s. Starting with the formation of a colony on the island Heuwiese (Germany, Mecklenburg-Western Pomerania) in 1957, the sandwich tern continued its range expansion to the southern coasts of the western and central Baltic, becoming a permanent breeding bird first at the German Baltic coast and shortly after, in 1962, in Estonia. It bred in Poland from 1977–1991 and again since 2006.

The range expansion and positive population development in the Baltic Sea area during the 1950s/1960s occurred at a time when the North Sea population declined dramatically. This indicates that the colonization of the Baltic Sea could have

Table 4.3.2. The dunlin population in the Baltic littoral countries.

Country	Current breeding population	Remarks	Source of information
Denmark	350	2002	Thorup (2003)
Sweden	85–120	2006	M. Larsson, pers. com.
Estonia	200–250	2007	Elts et al. (2008)
Finland	50–60	2003–2007	Finnish working group on Southern Dunlin, Ministry of Environment Finland
Germany, Mecklenburg-Western Pomerania	9	2007	Working Group for Coastal Bird Protection Meckl.- W. Pomerania
Germany, Schleswig-Holstein	0	at the west coast (North Sea) probably still 0–5 bp	W. Knief, pers. comm.
Latvia	1–5	1989–1997	Thorup (2006)
Lithuania	25–30	1996–1998	Thorup (2006)
Poland	0–5	no breeding record in 2007, but observation of some individuals during the breeding season	Sikora et al. (2008)
Russia, St. Petersburg Region	1–5	sporadic breeder at the Gulf of Finland, one nest found in 2008	V. Fedorov, pers. comm.
Russia, Kaliningrad Region	2	2001, no breeding record after 2001	Grishanov & Lykov (2008)
Total, Baltic Sea littoral countries	700–800		

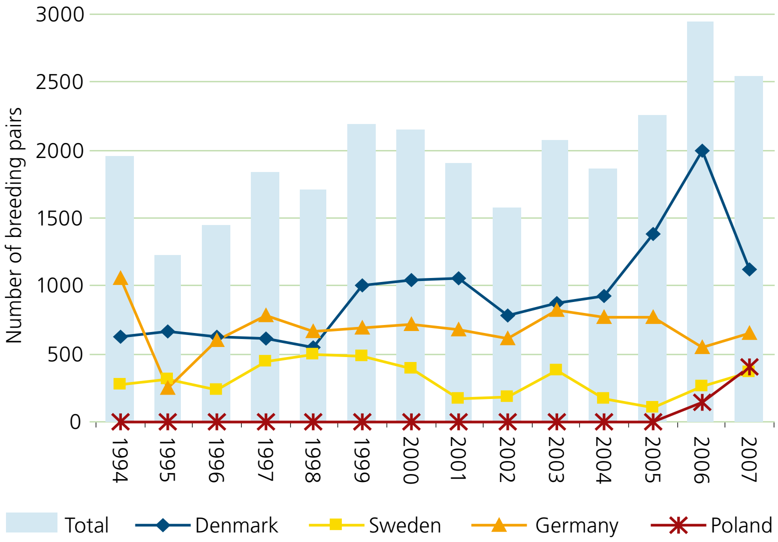

Figure 4.3.9. The breeding population of the sandwich tern in Denmark[1], Sweden[2], Germany, and Poland, 1994–2007. No detailed data was available for the Estonian population, which is estimated at about 600–900 bp (Herrmann et al. 2008).

been in response to a deterioration of the environmental conditions in the North Sea.

The Baltic breeding population grew constantly and reached about 2 500 bp by the end of the 1970s. Since then, despite some fluctuations and frequent shifts of breeding sites, it can be considered as more or less stable. More detailed surveillance data from the mid-1990s until now reveal a population size fluctuating between 2 000 and 3 500 bp (Figure 4.3.9).

The main conservation measure for the sandwich tern is the protection of suitable breeding sites. These are especially breeding colonies of black-headed gulls (*Larus ridibundus*) on small islands covered by low grass vegetation, without human disturbances or the presence of predatory mammals (Herrmann et al. 2008).

Razorbill *(Alca torda)*

The razorbill is a widespread breeder in coastal areas of northwestern Europe. Its European breeding population is large (430 000–770 000 bp, BirdLife International 2004), with Iceland hosting more than 50%. In the Baltic Sea area, the razorbill breeds in Sweden (9 000–11 000 bp in 1999–2000), Finland (6 000–8 000 bp in 1998–2002), Russia (St. Petersburg Region, 150 bp), Denmark (maximum 965 bp in 2006), and recently also with a few (1–10) pairs in Estonia. The Baltic population increased during the 1990s (Birdlife International 2004, Elts et al. 2003).

The only Danish breeding colonies are found on Bornholm and Græsholm (a small rocky island of the Ertholmene archipelago east of Bornholm). This site was colonized by the species during the 1920s. From 1983–2000, the population increased from about 280 bp to 745 (Lyngs 2001), and reached 965 bp in 2006 (Christiansø Feltstation).

Ringing recoveries show that razorbills from the Baltic breeding population usually stay all year round in the Baltic Sea. For example, out of 269 ringing recoveries of birds ringed in Denmark (Græsholm and Bornholm), 265 derived from the Baltic Sea and Kattegat, three from the Skagerrak, and only one from the North Sea, close to the entrance of the Skagerrak (Bonlokke et al. 2006).

Most birds of the Baltic breeding population winter in the central part of the Baltic Sea, including Irbe Strait and the Gulf of Riga (Durinck et al. 1994). However, ringing recoveries of razorbills from Bornholm/Ertholmene show that the inner Danish waters are also used as wintering sites (Bonlokke et al. 2006).

Razorbills of the North Atlantic breeding population winter in large numbers in the central and northern Kattegat. Danish ringing recoveries give evidence that outside the breeding season birds from the British Isles (mainly Scotland), Norway, and Russia visit the Kattegat and inner Danish waters (Bonlokke et al. 2006). The number of birds wintering in this area shows large fluctuations. From 1988–1993, on average 13% of the North Atlantic population was wintering in the Kattegat/inner Danish waters, but in some years the numbers were much higher (Durinck et al. 1994).

Ringing recovery data as well as by-catch studies show that the gillnet fishery is an important mortality factor for the species (Hario 1998, I.L.N. & IfAÖ 2005).

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[1] Only Baltic breeding sites, i.e., colonies in the central and southern Kattegat, Belt Sea and the Sound are considered, but not the breeding population of the northern Kattegat and the North Sea.

[2] Monitoring of the sandwich tern in Sweden was not complete in all years.

4.3.2 Conclusions

Long-term data on the population development of bird species in the Baltic Sea show that a more or less stable status quo never has existed. Dynamic changes in terms of the range and size of populations are characteristic. Some of the observed long-term changes can clearly be attributed to persecution or impacts on the reproductive success caused by hazardous substances. Other anthropogenic factors, such as loss of habitats, introduction of non-native predatory mammals, oil spills and by-catch in fishing gear, may also affect bird populations. On the other hand, human land-use management may promote certain species: high nutrient inflows from the catchment area have resulted in an increased biomass production in the Baltic and improved the feeding conditions for some species (e.g., cormorant). Last but not least even fishery practices may have advantageous effects for birds: the good status of auks is, at least partly, attributed to the growth of the sprat stocks owing to overfishing of cod.

However, not all population developments of bird species in the Baltic Sea can be solely attributed to anthropogenic factors. The decline of dunlin and ruff, the fluctuations of wintering populations of Steller's eider, and the range expansion into the Baltic of sandwich tern, herring gull (*Larus argentatus*) and barnacle goose are examples of population developments that are obviously not, or at least not primarily, driven by human activities. Global factors such as climate change or environmental changes in breeding areas outside the Baltic Sea certainly also exert a strong impact on the range and population size of bird species.

Strategic approaches to the conservation of birds in the Baltic Sea need to acknowledge the dynamics of their populations with respect to range and size. They should focus on anthropogenic factors that are known to have adverse impacts on bird populations or that are considered as potential threats. It must be recognized that the decline of some species (e.g., dunlin, ruff in the southern and western Baltic) must be attributed to reasons other than direct anthropogenic impacts such as habitat destruction or contamination. It will probably not be possible to reverse the negative population trend of these species by nature conservation measures.


White-tailed eagle (*Haliaeetus albicilla*)

4.3.3 Recommendations

Conservation measures should focus on those species that are negatively affected by anthropogenic factors such as habitat loss, deliberate or incidental killing, or hazardous substances.

In order to reach a 'favourable conservation status of Baltic Sea biodiversity', the protection of important bird habitats, including breeding, resting and wintering sites, is necessary. The establishment of an ecologically coherent network of Baltic Sea Protected Areas (BSPA), Natura 2000 areas and Emerald sites in the Baltic Sea by 2010 is an important step towards the protection of these sites.

Restoration and adequate management of degraded areas, especially coastal meadows and wetlands, are also important measures to improve habitat conditions for birds.

The BSAP target *"By 2012 spatial/temporal and permanent closures of fisheries of sufficient size/ duration are established throughout the Baltic Sea area"* should consider the serious impact of the gillnet fishery in wintering areas of seabirds; seasonal closures of gillnet fisheries in areas with high seabird concentrations are required to achieve the target *"by-catch rates of water birds close to zero by 2015"*.

The strategic goal of the BSAP to have *"maritime activities in the Baltic Sea carried out in an environmentally friendly way"* requires actions to reduce bird mortality related to illegal or accidental discharges of oil, hazardous substances, and other wastes. In order to reduce killing of birds by oil spills, the routing of ships must be improved, i.e., major resting and wintering sites of seabirds should be declared by the International Maritime Organization (IMO) as 'areas to be avoided'.

Conflicts between birds and offshore installations (e.g., wind parks) should be minimized by adequate spatial planning. Furthermore, more research is needed in order to improve the knowledge about bird behaviour at sea and possible interactions between birds and offshore installations.

The assessment of the conservation status and population development of birds in the Baltic Sea area needs continuous monitoring of: i) the range and size of breeding populations of bird species, ii) the distribution and numbers of wintering populations of birds, iii) the conservation and management status of breeding sites and areas, iv) anthropogenic mortality (hunting, oil spills, fishery by-catch), and v) reproductive parameters of indicator species for the impact of hazardous substances.

Since 2002, HELCOM has been preparing for the official launch of a 'HELCOM Baltic waterbird monitoring programme'. After finalization of the pilot project in 2003 and 2004, the plan for the design of the Waterbird Monitoring Programme was produced in 2005 and 2006 followed by coordinated censuses, trend analyses and indicator development within the framework of the SOWBAS (Status of wintering Waterbird populations in the Baltic Sea) project in 2007–2008. The results from SOWBAS, due for publication in 2009, will form a basis for a Baltic-wide compilation and assessment of the waterbird data. Therefore, it is recommended to launch the 'HELCOM Baltic waterbird monitoring programme'.

Great cormorant (*Phalacrocorax carbo sinensis*)

5 TOWARDS AN INDICATOR-BASED ASSESSMENT OF THE BALTIC SEA BIODIVERSITY

This chapter presents the results of testing an indicator-based approach to assessing Baltic marine biodiversity based on a set of 22 national case studies and an overall assessment of the Baltic Proper sub-basin.

According to the new HELCOM Monitoring and Assessment Strategy (HELCOM 2005a), the entire HELCOM system of assessments will be based on indicators, compiled in regular thematic assessments, such as this one on biodiversity, and eventually in overall regional holistic assessments covering the whole Baltic Sea and all relevant topics.

It is clear that to be measurable, the HELCOM goals and especially the three objectives for biodiversity (HELCOM 2007a, Backer & Leppänen 2008) must be further defined in quantitative terms. The status of a selection of indicators can be evaluated by comparing the desired, or historically observed, situations with the present status (Andersen & Backer 2008). This allows, at least in principle, a more exact definition of goals such as 'favourable conservation status' and a better possibility to monitor the progress towards these goals (Backer 2008). Another advantage of such quantitative approaches is that they enable explicit links to ecosystem models for estimating, for example, the distribution of habitats (see Chapter 3.2) and in some cases even exploring available policy options (e.g., Wulff et al. 2007). This kind of explicit indicator-based approach is already in use in the recently published assessment of eutrophication status in the Baltic Sea (HELCOM 2009a).

Compared to the well-defined topic of eutrophication, 'marine biodiversity' is a complex concept covering a wide range of issues and ecosystem components. The selection of concrete indicators required to represent biodiversity involves some inevitably arbitrary choices. Another complicating factor is the fact that many of the characteristic features commonly associated with marine biodiversity, such as habitats or marine mammals, are difficult and costly to monitor. Overall, this has resulted in fewer data available to produce indicators for the topic, both for defining a desired or target level, but also for assessing current status. In the case of economically exploited or hunted species, for example, fish and marine mammals, data certainly exist but there are other difficulties. Exact definitions of the status and targets of these issues are particularly politically sensitive.

Owing to such challenges, the overall aim of this chapter is mainly to provide a case study of, and with it initiate further discussion on, the role and functions of indicators in HELCOM marine biodiversity assessments. The aim is not to conclude on an established method, indicators or a definite assessment of the areas covered. Hopefully, the material presented will serve not only to develop HELCOM biodiversity assessments and indicators but also as a source of inspiration for other organizations and regions that are working with similar issues.

Macrophyte meadows and beds (shallow *Fucus*, red algae reef)

5.1 Assessing the status of biodiversity with indicators

Using the terminology of Pressure, State, Response (PSR; OECD 1993) or Driver, Pressure, State, Impact, Response (DPSIR), mainly *status* indicators have been assessed in this trial. Assessing the status of marine biodiversity within a given area requires that a number of challenges be addressed. The first is to gather data for a sufficient number of indicators, describing a sufficiently broad array of biodiversity components for a given site or area. The second is to define a desirable state for the selected indicators. In the approach used here, this includes both a quantitative reference ('pristine' or Reference Condition/RefCon) status, as well as an acceptable deviation (AcDev) from this reference. If a reference status cannot be defined, a tentative target value can be specified and later revised according to the adaptive management approach. Using the information from these two steps, the status of the single indicator from the site can be defined.

The third and final challenge, from the status assessment perspective, is to assess the overall status of the biodiversity. This can be accomplished by using the indicators, and their reference levels and acceptable deviations, as components in an overall assessment matrix. Such a matrix can be constructed in a number of ways, including weighting and grouping of the different indicators. In this assessment, a matrix tool termed BEAT (the HELCOM Biodiversity Assessment Tool) was used to assess the overall status of biodiversity divided into the three categories of 'Landscapes', 'Communities', and 'Species', according to the biodiversity segment of the HELCOM Baltic Sea Action Plan (BSAP).

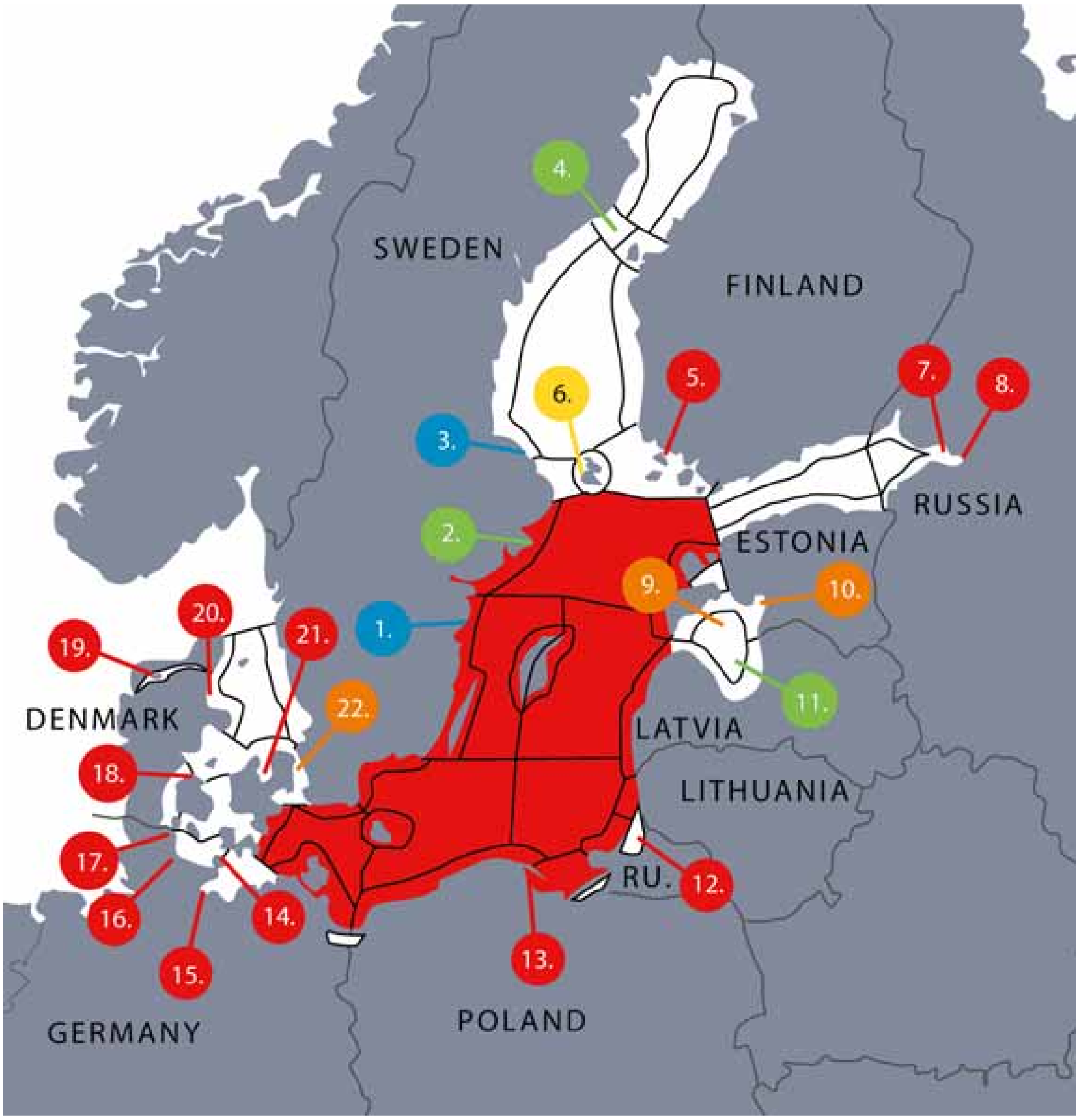

Figure 5.1. **Approximate location of national case studies. Colours of the pointers refer to assessment results (see Table 5.3). The Baltic Proper sub-basin was assessed as a whole as indicated with red colour on the map (see Table 5.4).**

Table 5.1. Overview of national case study sites with a reference to the data source.

Case study number	Country	Name	Description	Data source (unpublished)
1	Sweden	Kvädöfjärden (inner)	Rocky archipelago area ca. 25 km²	Olsson et. al. 2008
2	Sweden	Askö-Landsort area	400 km² area, University research station. Based on WFD data only.	Blomqvist 2007
3	Sweden	Forsmark (inner)	32 km² of relatively unexploited coastline	Olsson et al. 2008
4	Sweden	Holmöarna	Ca. 15 km² archipelago area	Olsson et al. 2008
5	Finland	Archipelago Sea (inner)	Area close to the Finnish mainland	Ekebom et al. 2007
6	Finland	Finbo	Archipelago area in Åland	Ådjers & Lappalainen 2008
7	Russia	Eastern Gulf of Finland	Russian waters off the St. Petersburg barrier	Golubkov 2007
8	Russia	Neva Bay	400 km² area inside the St. Petersburg barrier	Golubkov 2007
9	Estonia	Gulf of Riga, northern	Ca 8 000 km² area of open and coastal waters	Ojaveer & Martin 2007
10	Estonia	Pärnu Bay	Ca. 700 km² bay with strong riverine input	Ojaveer & Martin 2007
11	Latvia	Gulf of Riga, south	Single Latvian offshore monitoring station	Ikauniece et al. 2007
12	Lithuania	Curonian lagoon	Large lagoon	(national EUTRO-PRO)
13	Poland	Puck Bay	360 km² inner part of Bay of Gdansk	Andrulewicz & Weslawski 2008
14	Germany	Fehmarn Belt	69 km² area surrounding Fehmarn island	Karez et al. 2008
15	Germany	Neustadt Bay	46 km² area, inner parts of Lübeck Bight	Karez et al. 2008
16	Germany	Bülk (outer Kiel Fjord)	15 km² area outside Kiel Fjord	Karez et al. 2008
17	Germany	Gelting Bight	44 km² area of relatively exposed coastline	Karez et al. 2008
18	Denmark	Odense Fjord	62 km² shallow, eutrophic estuary	HELCOM, 2006
19	Denmark	Limfjorden	1 468 km² long semi-enclosed waterbody	Andersen & Kaas 2008
20	Denmark	Randers Fjord	27 km long, shallow estuary	HELCOM 2006
21	Denmark	Isefjorden-Roskilde Fjord	Two connected fjords	Andersen & Kaas 2008
22	Denmark	The Sound	118 km strait with a distinct halocline	Henriksen et al. 2008

Twenty-two national case studies from all nine HELCOM Member Countries were made available for testing the indicator-based biodiversity assessment tool BEAT. The location of the study sites is shown in Figure 5.1. Table 5.1 lists the sites and data sources (unpublished case study reports). In addition, the Baltic Proper as a whole was assessed using a compilation of available indicators to test and illustrate a geographically wider, sub-basin approach.

In the instructions for providing the case studies, no specific time period for defining the reference status was given and, according to the background information provided for each case study, the reference period varied substantially, essentially depending on the length of the data series. Furthermore, owing to the shortage in available data, no pre-defined indicators or indicator topics were given and the case study providers were free to select which indicators to report.

For the national case studies, the levels of acceptable deviation, i.e., a moderate (or larger) deviation from the indicated reference condition/state, were chosen by the authors of the case studies according to their expert judgement. However, the highest possible value of the acceptable deviation


Mussel bed reef community, Jasmund, Germany

was fixed at 50% from the reference value, which also was used if no other acceptable deviation was specified by the case study authors.

The BEAT matrix divides the range of possible values into five classes: high, good, moderate, poor, and bad. In this system, 'high' and 'good' are essentially equivalent to 'favourable conservation status' (~ 'good environmental status') and 'moderate', 'poor', and 'bad' are equivalent to 'unfavourable conservation status' (~ impaired status). For technical details of the assessment approach and definitions used for these five classes, see Box 5.1.

In order to create an overall assessment of the site, the reported indicators were regrouped in the following categories: Category I - Landscapes, Category II – Communities, and Category III – Species, following the structure agreed in the HELCOM BSAP. In addition to these three categories, an additional Category IV for supportive features was included to cover other parameters of interest (e.g., nutrient concentrations, physical variables). The topics covered under each of these categories are presented in Table 5.2. Within the Categories I–IV, weighted averages of the ratios between pristine and present status, or Ecological Quality Ratios (EQRs), as well as the acceptable deviations of the individual indicators were calculated. If not specified otherwise, the weighting was kept neutral by giving each of the indicators an equal weight. On the basis of the EQR and AcDev values, the Categories I–IV were each given a quantitative assessment according to the principles described above for a single indicator (ranging from high to bad status).

The overall assessment of the site or geographic unit, combining the results of the four categories, is conducted by applying the so-called 'One out - All out' principle to the Categories I–III. This implies that the worst-performing category of these three defines the overall status of the site.

Category IV, covering supporting features, was not included in the "One out - All out" principle.

5.2 Compatibility with approaches of European Directives

The emerging process of setting quantitative target values for various biodiversity topics is also occurring to fulfil the requirements of European legislation. For EU Member States, this is being carried out in EC Directives such as the Habitats Directive (43/92/EEC), the Water Framework Directive (WFD, 2000/60/EC) and the recent European Marine Strategy Framework Directive (MSFD, 2008/56/EC).

The approach used here is based largely on the EQR approach *sensu* the WFD, especially regarding the emphasis on defining reference conditions and acceptable deviations. However, quantitative approaches are also found in other relevant European Directives. As an example, the aim of the Habitats and Birds Directives is to achieve and maintain favourable conservation status for all habitats and species of Community interest in addition to the overall objective of maintaining biodiversity. According to available reporting guidelines (European Commission 2006), in national reporting on the Habitats Directive, favourable conservation status should be assessed in the form of clear, measurable reference values or Favourable Reference Values. Three types of such values are to be defined: Favourable Reference Areas for habitats, Favourable Reference Populations for species, and finally Favourable Reference Ranges for both species and habitats. The Habitats Directive reporting guidelines acknowledge that, in many cases, delineating reference values is quite difficult, but in these cases expert judgement must be used as a starting point, e.g., by using 'greater than present day value'.

The recently adopted EU MSFD also indicates an approach that includes quantitative targets and associated indicators. A number of qualitative descriptors listed in Annex I of the MSFD will be used to define specific characteristics and ultimately targets and indicators of Good Environmental Status in European marine waters by 2012. According to Annex III of this Directive, a large proportion of the topics to be taken into account are clearly biodiversity related, e.g., population sizes, community structures and habitat information. All of these Directives aim for national assessments/reports to be coherent on a bioregional scale, e.g., the Baltic Sea marine region in the MSFD. This highlights the importance of regional processes such as the HELCOM assessment work.

5.3 Results

Seventeen of the 22 national case study areas are classified overall as having a 'moderate', 'poor', or 'bad' biodiversity status, meaning that these areas are in an unfavourable condition in terms of the indicators reported (Table 5.3, Figure 5.1). The exceptions are sites 1 (High), 2 (Good), 3 (High), 4 (Good) and 11 (Good) in the northern Baltic, but it should be noted that these five sites are limited in terms of the topics covered.

Overall, the indicator selection available in the case studies is, not surprisingly, dominated by a few topics recently developed for WFD purposes, e.g., zoobenthos community indices and mac-

Table 5.2. Grouping of indicators associated with each category.

Categories (Ecological Objectives on biodiversity and supporting features)	Indicator topics included within category
Category I: Marine Landscapes	Area-based habitat indicators (all types) and large geographic features
Category II: Communities	Community indicators on structure and function of phytoplankton, zooplankton, zoobenthos, macrophytes, fish community, bird community, endangered habitats and biotopes
Category III: Species	Single-species indicators of high profile species mainly fish, birds and mammals as well as indicators on endangered and alien species
Category IV: Supporting features	Indicators of environmental parameters including e.g., water clarity, water temperature, oxygen concentrations, nutrients

Table 5.3. Assessment results of the national case studies expressed as quality classes. The overall status is based on the use of the 'one out, all out'-principle, i.e., the worst performing category except for the Supporting features (SF) category. Key: ML = marine landscapes, CO = communities, SP = species, and SF = 'supporting features', F = Fish, Z = Zoobenthos, M = Macrophytes, P = Phytoplankton, Zp = Zooplankton, B = Birds, S = Seals, E = Endangered species, C = water Clarity, T = water Temperature, N = Nutrients, O = Oxygen, Sa = Salinity.

Case study areas	Indicator topics covered within category (see separate background document for details)				Category Status				Over-all
	ML	CO	SP	SF	ML	CO	SP	SF	
1. Kvädöfjärden	-	F(4)	F(2)	C(1), T(1)	-	High	High	Mod.	High
2. Askö-Landsort	-	Z(1), M(1), P(2)	-	C(1), N(6)	-	Good	-	Bad	Good
3. Forsmark (inner)	-	F(4)	F(2)	T(1), C(1)	-	High	High	High	High
4. Holmöarna	-	F(4)	F(2)	T(1), C(1)	-	High	Good	High	Good
5. Archipelago Sea	1	B(1), Z(2), P(2)	-	C(2)	Bad	Mod.	-	Mod.	Bad
6. Finbo	-	F(3)	F(3)	T(1),C(1), Sa(1)	-	Mod.	High	High	Mod.
7. Easten Gulf of Finland	-	Z(2), F(1)	S(1), E(2)	-	-	Bad	Bad	-	Bad
8. Neva Bay (inner)	2	Z(2), F(1)	-	-	Mod.	Bad	-	-	Bad
9. Gulf of Riga, N	1	M(2), Z(1), F(1), P(1)	F(6)	C(1), N(2)	High	Good	Poor	Bad	Poor
10. Pärnu Bay	-	M(2), Zp(3), P(1)	F(4)	C(1)	-	Mod.	Poor	Poor	Poor
11. Gulf of Riga, S	-	P (2), Z(2)	-	C(1), O(1)	-	Good	-	Mod.	Good
12. Curonian lagoon	-	M(2), Z(2), P(2)	-	N(4)	-	Bad	-	Bad	Bad
13. Puck Bay	5	M(3), F(1)	F(2)	-	Poor	Bad	Bad	-	Bad
14. Fehmarn Belt	2	M(6), Z(1), P(1)	-	N(2)	Bad	Poor	-	Bad	Bad
15. Neustadt Bay	2	M(6), Z(1), P(1)	-	N(2)	Bad	Bad	-	Poor	Bad
16. Bülk	2	M(6), Z(1), P(1)	-	N(2)	Good	Bad	-	Mod.	Bad
17. Gelting Bight	2	M(6), Z(1), P(1)	-	N(2)	Bad	Bad	-	Mod.	Bad
18. Odense Fjord	2	M(2), P(3)	-	N(7)	Poor	Bad	-	Bad	Bad
19. Limfjorden	-	Z(12), M(4)	-	C(2), N(2)	-	Bad	-	Mod.	Bad
20. Randers Fjord	-	M(2),Z(3), P(2)	-	N(4)	-	Bad	-	Poor	Bad
21. Ise-Roskilde fj.	-	M(2), Z(2)	-	N(1)	-	Bad	-	Bad	Bad
22. The Sound	1	Z(1), M(1), P(2)	-	C(1)	Poor	Mod.	-	Good	Poor

rophyte depth distribution. Areal coverage and status of habitats (Landscape category) as well as distribution and status of bird, fish and mammal populations (Species and Community categories) were lacking from a majority of sites, likely reflecting an overall lack of information, or consensus, on these issues. A separate background document with complete assessment sheets, including more information on the indicators used at the sites, is available at the HELCOM website (www.helcom.fi)[6].

The result of a sub-basin-wide Baltic Proper test assessment is presented in Table 5.4. As with the national case studies, the indicator selection available for the sub-basin trial is heavily dominated by a few well-studied topics, e.g., zoobenthos, for which indicators with both reference values and status information are available. The Baltic Proper was assessed to have a bad status in terms of biodiversity.

5.4 Conclusions

The HELCOM BSAP identified the need for continuous monitoring of the conservation status of biodiversity and for regular assessments on the issue using a harmonized, indicator-based approach. Biodiversity has been considered as the 'controlling element' of the BSAP. The development of an indicator-based assessment of biodiversity is thus important for assessing the implementation of the measures agreed in the BSAP. It also clarifies the implementation status of other existing international legal regimes focusing on biodiversity issues, such as the Convention on Biological Diversity (1992). Even though biodiversity is a concept that is both complex and often difficult to link to specific human activities, it undeniably reflects the desirable things we want to protect in our environment. By a pragmatic selection of indicators, the concept can be tied to concrete phenomena and an indicator-based assessment becomes possible, as has been shown here.

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[6] http://www.helcom.fi/publications/en_GB/publications/

Many of the parameters reported in the 22 case studies (Table 5.1), e.g., zoobenthos community structure and distribution of submerged aquatic vegetation, originate from EU WFD-related research, which has been an intensive field during the past decade. As many of these parameters are also relevant indicators of marine biodiversity, this in itself is reasonable. However, information on other topics is also needed. Specifically, area-based and species-specific indicators are lacking (Table 5.3). The species and indicators used in the national cases and in Chapters 2–4 of this assessment provide a starting point for widening the spectrum of available Baltic marine biodiversity indicators for HELCOM and other fora.

In most parts of the Baltic Sea, many of the components commonly associated with marine biodiversity (e.g., hard-bottom community structure, porpoises, coastal fish) have not been covered by operational monitoring systems until recently, if at all. The lack of a coordinated monitoring effort is also evident; for example, it is difficult to find data on macroalgae and fish from the same area. Interestingly, this applies to the protected areas as well. Not a single Baltic Marine Protected Area was among the test sites reported for this assessment. This is somewhat surprising as it would be reasonable to assume that they would be monitored over a relatively wide range of biodiversity topics.

It is evident that the selection, or limitation, of indicator topics as well as the way indicator groupings/categories are constructed have an impact on the outcome of an assessment approach such as the one tested here. For this reason, it would be pref-

Table 5.4. Baltic Proper sub-basin scale test of the indicator approach to biodiversity assessments. Note that similar calculations were done for all the case studies 1–22, although Table 5.3 shows only the results of the category and overall assessments, N=number, R= indicator response to degradation, i.e. if increasing (+) or decreasing (-), SSB=Spawning Stock Biomass, BSAP=HELCOM Baltic Sea Action Plan, ZB= Zoobenthos, EQR=Ecological Quality Ratio, RefCon= Reference condition.

Category	RefCon	Unit	R	Acceptable deviation	Present Status	EQR-Indicator	Indicator or Assessment	Weight	Category Status (EQR)
I.Landscapes									Moderate (0.41)
Anoxic seabed area [8]	18.50	10 000 km3	+	50%	44.40	0.417	Poor	50%	
Wild salmon rivers [9]	22.00	N rivers	-	50%	9.00	0.409	Moderate	50%	
II.Communities									Bad (0.22)
Threatened biotopes[10]	0.00	N biotopes	+	15%	12.00	0.000	Bad	16.6%	
ZB (SE Baltic Proper)[11]	8.00	ave. N species	-	40%	1.83	0.229	Bad	16.6%	
ZB (E. Gotland basin) [11]	5.30	ave. N species	-	39%	0.62	0.117	Bad	16.6%	
ZB (Bornholm Sea) [11]	12.40	ave. N species	-	40%	2.96	0.239	Bad	16.6%	
ZB (N. Baltic Proper) [11]	4.70	ave. N species	-	33%	0.00	0.000	Bad	16.6%	
ZB (Arkona Sea) [11]	18.33	ave. N species	-	27%	14.00	0.764	Good	16.6%	
III.Species									Bad (0.50)
White-tailed eagle (Baltic)	200.00	N	-	50%	2 250.00	1.000	Good	20%	
Established Alien Species 1950-[12]	6.00	Established species	+	15%	14.00	0.429	Bad	20%	
E. Baltic Cod SSB [13]	270.00	1 000 t	-	15%	160.00	0.593	Bad	20%	
Threatened and declining species [14]	0.00	N species	+	15%	53.00	0.000	Bad	20%	
Common Seal (Kalmarsund)	0.12	Rate of increase	-	25%	0.80	1.000	Good	20%	
IV.Supporting Features									Moderate (0.68)
Secchi depth (Baltic Proper, BSAP)	9.3	m	-	25%	6.3	0.68	Moderate	100%	
Overall status of Biodiversity using worst performing category of I, II and III = Bad									

[8] Savchuk et al. 2008

[9] Ranke et al. 1999 Baltic Salmon Rivers

[10] HELCOM 2008a

[11] Basin average from HELCOM 2009a, see also chapter 3.4

[12] Baltic Sea Alien Database

[13] RefCon=ICES long termn average, acceptable deviation=ICES Bpa (ICES 2006 b)

[14] HELCOM 2008a

Aerial photo of harbours seals (*Phoca vitulina*) in Roedsand, Denmark

erable to agree upon and use common guidelines for the indicators to be included and the way they are grouped.

One of the clear strengths of the approach tested here is the flexibility of the size of assessment units as well as the potential to compare ecologically widely different areas with each other through the assessed status (e.g., ’good’ vs. ’bad’). A possible weakness lies in the assumption that the overall status of biodiversity can be defined by fixed values of a set of indicators (see, e.g., Moss 2007). Owing to the inherent natural stochasticity in many of the parameters, this can be questioned. However, by a rigorous selection of topics and the way they are evaluated, even this can be overcome (Moss 2007). Many indicators, such as those developed for zoobenthos (see, e.g., Chapter 3.4), explicitly try to circumvent such problems.

For future implementation of this approach, more focus should be given to the reasoning and ecological validity behind defined acceptable deviations and the reference values. This is necessary in order to estimate the range of natural variation as well as threshold values that are linked to a risk of population collapse and regime shifts. In most of the case studies presented here, only general references to various literature sources were given.

The possibility to rate the confidence in the reference, present and acceptable deviation values of a given indicator is one important aspect for future consideration. This option, used in the HELCOM Eutrophication Assessment Tool (HEAT, see HELCOM 2009a), was not available during the time the national case studies presented here were collected but would likely increase the overall confidence in the results of an indicator-based assessment. The sub-basin approach illustrated by Table 5.4 should also be utilized more extensively.

Finally, the case studies presented assessed the *status* of the marine biodiversity. They did not focus on the human *pressures* affecting the status. However, pressure indicators are important as a means of linking biodiversity status to management actions. Owing to the inherent complexity of the concept, an assessment of the overall status of marine biodiversity is currently difficult to translate into a targeted management response unless it is directly related to, e.g., pollution (inputs of nutrients and hazardous substances) or resource extraction (fisheries and hunting). This must be done separately for each subtopic or even each species (see Chapters 2, 3 & 4).

5.5 Recommendations

The majority of biodiversity issues require assessments on a regional scale owing to the population dynamics or ecology of the species, communities and habitats in question. This requires further development of Baltic marine biodiversity indicators and target levels beyond what is currently available.

The implementation and use of indicators require a flow of information and data from continued and expanded marine monitoring programmes to cover all central components of Baltic marine biodiversity. Monitoring could be combined with activities such as habitat modelling (see, e.g., Chapter 3.2) to provide a knowledge base for indicator-based biodiversity assessments. Some improvement can likely be achieved with enhanced coordination of the present monitoring activities, as information on, e.g., fish populations and habitat status is available but not from the same sites. Baltic Sea Protected Areas could possibly serve as pilot areas for a more integrated and coordinated monitoring and assessment approach based on indicators.

Box 5.1. Defining conservation status using indicators

The approach used in this assessment is based on Ecological Quality Ratios (EQR) where EQR is the ratio (0 to 1) between the present status and the reference condition (RefCon)i.e., RefCon/Present if degradation increases indicator value, otherwise the inverse.

Calculation of the status is possible if a reference condition, acceptable deviation (AcDev), and present status of a given indicator are available.

For indicators that have a numerically positive response to a given pressure factor, for example, the share of opportunist species, the border between Good and Moderate, i.e. between Favourable and Unfavourable, conservation status is calculated as:

Equation 1: *If* Present status ≤ RefCon x (1+AcDev in decimal form), i.e. if EQR > 1/(1+AcDev in decimal form), *then* favourable status is fulfilled for the indicator in question.

For indicators that have a numerically negative response to degradation (e.g., population sizes of endangered species or distribution/area of endangered habitats), the status is calculated as:

Equation 2: *If* Present status ≥ RefCon x (1 – AcDev in decimal form), i.e. if EQR> (1 – AcDev in decimal form), *then* favourable status is fulfilled.


Sea trout (*Salmo trutta*) jumping, Gotland, Sweden

Assessment to classes other than by using the good-moderate boundary shown above (i.e., to High, Good, Moderate, Poor and Bad) is derived as follows: in terms of EQR, *the lower boundary of reference condition is set to 0.95*. The boundary between Good and High is *midway between the Good/Moderate boundary and 0.95*. The same class width is used to define Moderate/Poor, while the Poor/Bad boundary is same distance as that from the Good/Moderate boundary to 0.95.

The categories in the BEAT matrix (e.g. Communities, Species) are assessed following the same method; the EQR and the acceptable deviation used are simply weighted averages (weight can be neutral) of the indicator EQRs and AcDevs.

6 HUMAN PRESSURES ON BIODIVERSITY

A human population of approximately 85 million people lives in the catchment or drainage area of the Baltic Sea. A great number of different types of human activities taking place in the catchment area, coastal zone, and open sea exert pressures on Baltic Sea biodiversity.

Some pressures act on a local scale, while others act at basin-wide scales. For example, dredging may have a local and short-term impact, while eutrophication affects vast areas and is long lasting. Similarly, certain pressures act at the level of species, while others have an impact at the greater landscape level of biodiversity (Figure 6.1). Many of the pressures also cause synergistic effects, whereby the negative impact of one pressure is exacerbated by another.

This chapter addresses the magnitude and impact of different pressures originating from various economic sectors. It mainly covers human activities that are directly associated with the Baltic Sea and that exert multiple pressures on biodiversity, namely, fisheries, maritime traffic, technical installations, and recreational activities. In addition, the chapter provides an overview of the magnitude and known impact of eutrophication, hazardous substances, alien species, noise, and hunting. Projected changes in climate caused by anthropogenic factors are also presented as a case of anticipated future pressure.

Pressures addressed in this chapter include the predominant pressures and impacts on Baltic Sea biodiversity. They also largely cover the pressures and impacts listed in Annex III, Table 2 of the EU Marine Strategy Framework Directive (MSFD).

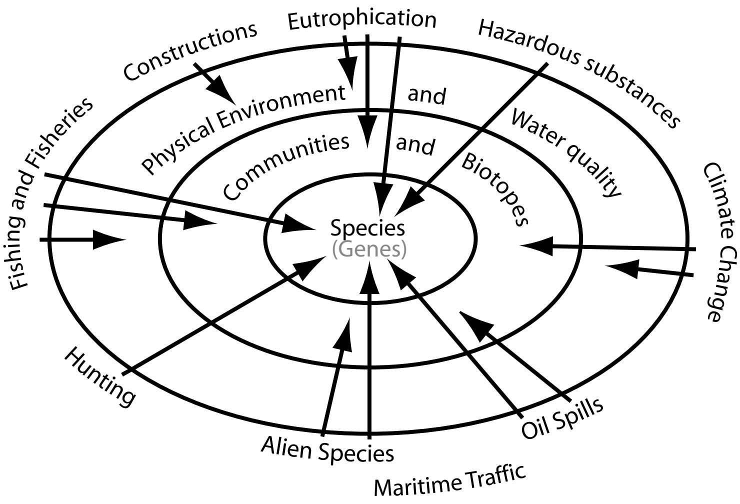


Figure 6.1. Human pressures in the Baltic Sea region act on different levels and scales of biodiversity.

6.1 Fisheries

Fisheries have been an important source of livelihood for people of the Baltic countries for centuries. There is archaeological evidence suggesting that fishing was conducted along the Baltic coasts already since before the Middle Ages (e.g., Makowiecki & van Neer 1996). However, the magnitude of landings and fishing effort is mostly documented for the 20th century, while information on the stock status of the eastern Baltic cod population dates back to the 1920s (Eero 2008) and for herring and sprat only to the 1970s (ICES 2008b).

There is increasing evidence that fisheries have a substantial impact on the biodiversity and function of the entire Baltic ecosystem. This extends from key abiotic parameters to the upper trophic levels of the food web. The biodiversity segment of the Baltic Sea Action Plan (BSAP) includes a large number of actions targeted to fisheries; in fact, the number of measures related to fisheries in the biodiversity segment is larger than that related to any other human activity. Moreover, the BSAP specifically includes a recommendation to implement the ecosystem approach to fisheries management in the Baltic Sea.

6.1.1 Description of fisheries

Cod (*Gadus morhua callarias*), herring (*Clupea harengus membras*), sprat (*Sprattus sprattus*) and salmon (*Salmo salar*) are the most important internationally assessed and managed fish stocks in the Baltic Sea. Most other fish species are mainly of local importance and are therefore managed nationally and/or locally. The assessment and management units of the internationally assessed species are provided in Figure 6.1.1.

Pelagic trawls dominate in the herring and sprat fishery. Usually the catch consists of a mixture of these two species, while their proportion in the catch varies by area and season. Herring is also caught by trapnets/pound-nets and gillnets in coastal areas as well as with bottom trawls. In addition to clupeids, vendace (*Coregonus albula*) is caught by pelagic trawls in the northern part of the Bothnian Bay. Cod is mostly caught by demersal trawls, pelagic trawls and gillnets. The importance of longlines has increased recently in cod fisheries at the expense of the gillnet fishery (ICES 2008b). While feeding in the sea, salmon are caught by longlines; during the spawning migration they are caught along the coast, mainly in trapnets and fixed gillnets. The use of drift nets was very important in the salmon fishery up to 2008. In river mouths, set gillnets and trapnets are used (ICES 2008b). A detailed description of the current fisheries by country, sub-basin, and stock is given in ICES (2008b,c).

The list of other, mostly locally important, commercial fish includes species such as pikeperch (*Sander lucioperca*), pike (*Esox lucius*), perch (*Perca fluviatilis*), vendace, whitefish (*Coregonus lavaretus*), burbot (*Lota lota*) and eel (*Anguilla anguilla*). Coastal fishing activities take place along the entire coastline of the Baltic Sea. The coastal fishery is usually a mixed fishery. As trawling is prohibited in the coastal zone (shallower than 20 m) in most of the countries, gears used in coastal fisheries include fixed gears (e.g., gill-, pound- and trapnets, and weirs) and Danish seines. The selection of gear depends on the target fish and also on coastal morphology. Although all Baltic countries keep their own national statistics, there are only estimates available on the total coastal fish landings in the Baltic Sea; these amount to about 50 000 tonnes (Lindquist 2001).

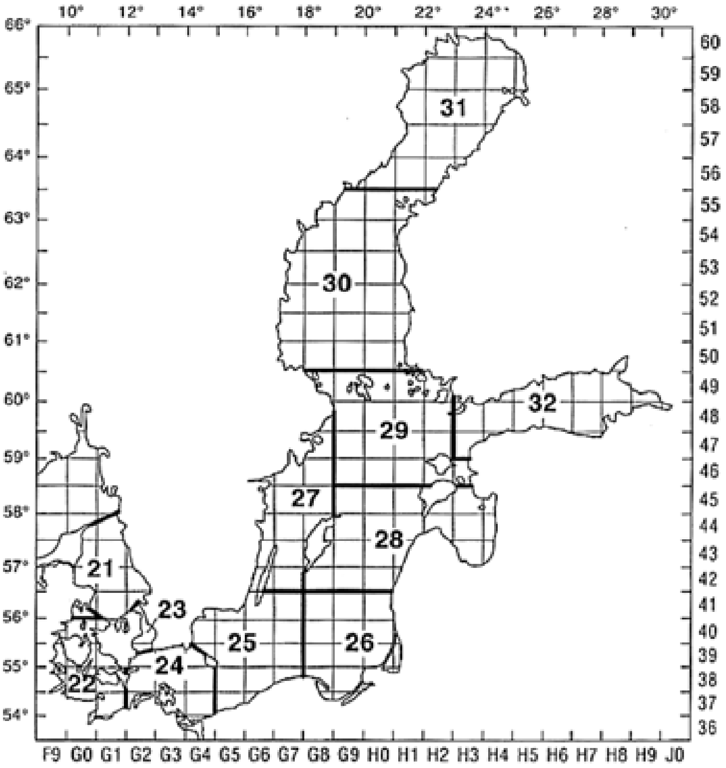


Figure 6.1.1. Baltic Sea subdivisions of the International Council for the Exploration of the Sea (ICES). Assessment and management units of the main fish species are: Herring: the main Basin (including Gulf of Finland; ICES subdivisions 25–29 and 32; excluding Gulf of Riga); Bothnian Bay (SD 31), Bothnian Sea (SD 30) and Gulf of Riga (SD 28.1); Cod: eastern (SD 25–32) and western (SD 22–24) stocks; Sprat: one single stock (SD 22–32); and Salmon: Main Basin and Gulf of Bothnia stocks (including the following separate assessment units: Northeastern Bothnian Bay; Western Bothnian Bay; Bothnian Sea, Western Main Basin, Eastern Main Basin) (SD 22–31) and Gulf of Finland (SD 32).

Trends in landings

Of the major commercial fish stocks, the eastern Baltic cod landings peaked in the 1980s (over 300 000 tonnes annually); they subsequently declined and have remained at very low levels during the past 15 years (the last 5-year mean was ca. 65 000 tonnes). Landings of the western cod exceeded 50 000 tonnes annually from the 1960s until the early 1980s, but have amounted on average to only half of this during the past five years. At the same time, sprat landings substantially increased from less than 50 000 tonnes during the mid-1980s to over 350 000 tonnes recently. The stock of herring in the main basin (including the Gulf of Finland) has steadily decreased from 300 000 tonnes in the late 1970s

Baltic herring trawling, Bothnian Bay.

Table 6.1.1. Catch range during the past five years and the current state of selected major Baltic commercial fish stocks (ICES 2008b,d). SSB: Spawning stock biomass; F: Fishing mortality.

Stock	Catch range in past 5 years (2003–2007, 10^3 tonnes)	SSB in relation to precautionary limits	F in relation to precautionary limits	F in relation to high long-term yield
Western cod	20–24	Increased risk	Undefined	Overfished
Eastern cod	50–71	Undefined	Harvested sustainably	Overfished
Herring in SD 25–29 (excl. GoR) and 32	91–116	Undefined	Harvested sustainably	Underfished
Gulf of Riga herring	31–40	Undefined	Harvested sustainably	Overfished
Sprat	308–405	Unknown	Increased risk	Overfished
Flounder	15–19	Unknown	Unknown	Unknown

to about 100 000 tonnes recently. In contrast, the stock of Gulf of Riga herring has more than doubled during the past two decades. Flounder catches have increased since the early 1990s and are currently over 15 000 tonnes annually. The dynamics in the landings of eleven marine fish species over time are shown in Figure 6.1.2 (ICES 2008b). Landings of the major Baltic fish stocks are shown in Table 6.1.1.

6.1.2 Ecosystem effects of fishing activities

The major impact of fishing is undoubtedly on exploited fish stocks, but there are also impacts on benthic invertebrate and fish communities, marine mammals, seabirds and the abiotic environment. The effect of fishing on various ecosystem components other than fish is different in the open sea from that in coastal areas mainly owing to the different fishing gears employed, which depends on the species composition of exploitable resources and the different habitat characteristics.

Fish stocks

The main ecological impact of fisheries is the removal of large quantities of fish, in particular target species. The major effects include, amongst others, a decrease in fish abundance and/or spawning stock biomass, a decrease in the size of individual fish at sea, and changed predator-prey interactions. A dramatic reduction in a piscivorous marine fish population may initiate a multi-level trophic cascade and indirectly also affect zooplankton and phytoplankton populations (Casini et al. 2008). Although the effect of fisheries on non-target species is of great importance from an ecosystem perspective, there is only very little known on this topic. Effects of fishing on fish stocks and fish communities are also discussed in Chapter 3 of this report.

An important impact on the ecosystem is also caused by by-catches and discards. Except in the cod fishery, the extent of fish by-catch is unknown in the Baltic Sea. Discard estimates for the two Baltic cod stocks are available since 1996 when sampling began. The western and eastern cod discards have fluctuated during the period of data availability (i.e., 1996–2007) from 5.0–26.6 million and 3.7–23.3 million individuals, respectively. However, the discard estimates are relatively uncertain (ICES 2008b). Calculations show that the amount of cod offal discarded in the entire Baltic Sea (i.e., sub-divisions 22–32) reached a peak in the early 1980s (average ca. 58 000 tonnes annually) and was relatively low in the 1990s, with an annual mean of about 19 000 tonnes (ICES 1997).

Demersal communities

In general, bottom trawls have an impact on marine biota in several ways including (i) a reduction in structural biota; (ii) a reduction in the geographic range of species; (iii) a decrease in populations that have low rates of turnover; (iv) fragmentation of populations; (v) alteration of the relative abundance of species; (vi) sub-lethal effects on individuals; (vii) an increase in populations that have high rates of turnover; and (viii) favouring populations of scavenging species (ICES 2000).

There are only a few studies available in the Baltic region on bottom trawling impacts on the marine ecosystem. It has been documented that

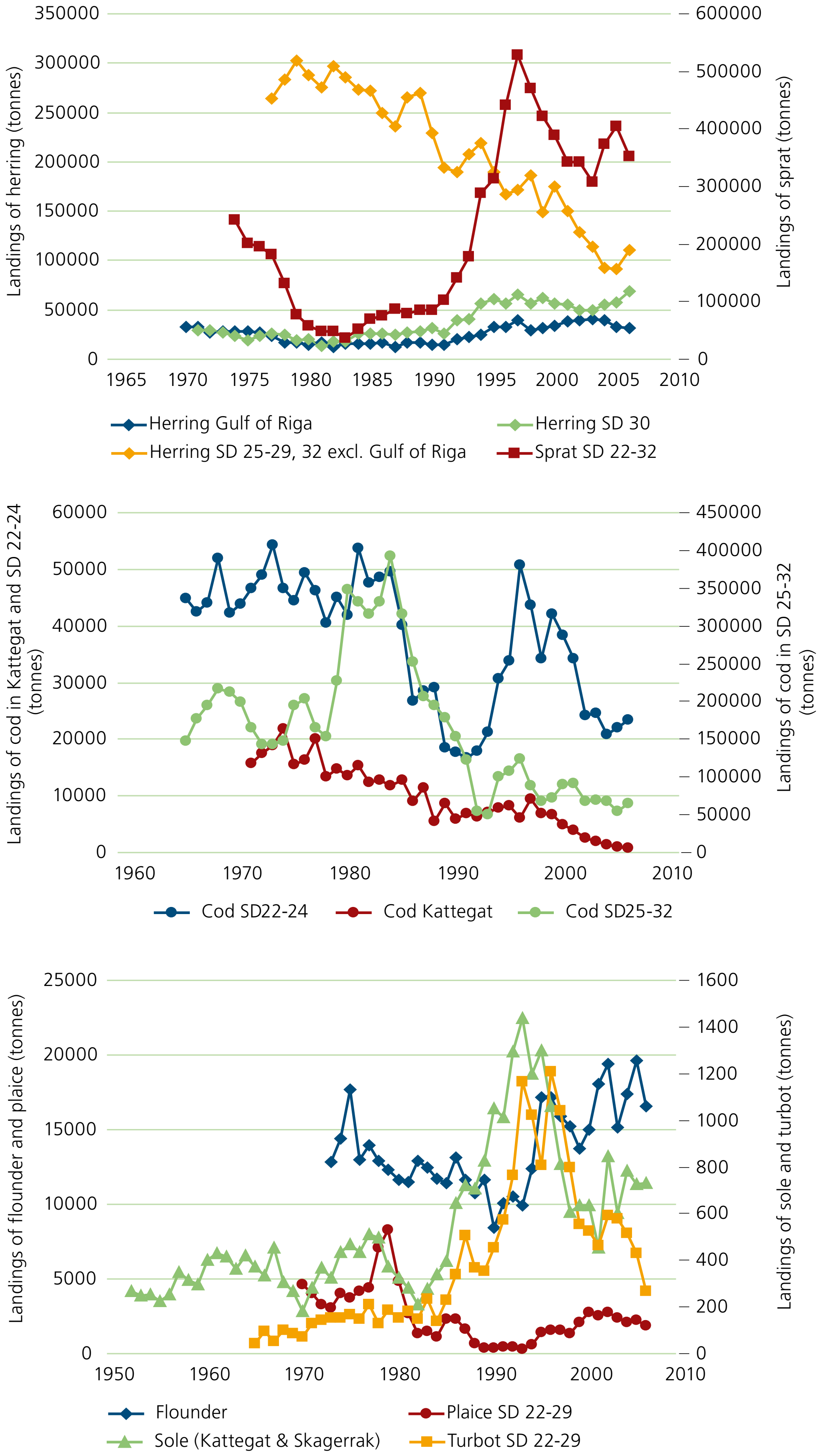


Figure 6.1.2. Dynamics of landings of eleven major fish stocks/species in the Baltic Sea from 1952–2006 (ICES 2008b).

Baltic herring trawling, Bothnian Bay.

bottom trawling may cause heavy damage to several species of thin-shelled bivalves and starfish, whereas thick-shelled bivalves seem to be more resistant. An increased proportion of damage with increasing body size was found for the mussels *Macoma calcarea*, *M. balthica*, *Arctica islandica* and *Musculus niger* owing to an unfavourable shell surface/thickness relationship amongst larger specimens (Rumohr & Krost 1991). The same study indicates a considerable impact on benthic communities, specifically for *A. islandica*. Trawling activities do not necessarily lead to a total destruction of benthic communities, but rather to the resuspension of sediments and dislocation of living organisms, mainly epibenthic organisms. This leads to an increase in predatory and scavenging species (Krost 1990, Rumohr & Krost 1991 and references therein). However, the effect is relatively regional, being confined to the southern Baltic Sea.

Marine mammals

The adverse effects of fisheries on seal populations can be summarized as: (i) the direct killing of seals as competitors to the fishery; (ii) accidental drowning of seals in fishing gear; (iii) entanglement of seals in discarded netting; and (iv) a decrease in food resources for seals (Pilats 1989). As seals are generalists in terms of feeding and their main prey is therefore the most abundant fish in the system (Lunneryd 2001), open-sea fisheries can affect seal populations via a reduction in their food resource. In contrast, coastal fisheries directly impact the survival of seals as they can become entangled in the static gears (such as trapnets and gillnets) employed by the coastal fishery. It has been estimated that at least 300 grey seals, 80 ringed seals and 7–8 harbour seals are captured as by-catch annually in the Baltic Sea (ICES 1995). More recent estimates are available for the Swedish Baltic Sea coastal fisheries, where in total over 400 grey seals and 50 ringed seals were by-caught in 2001 (Lunneryd et al. 2004, 2005).

In 2001, a survey estimated the annual by-catch rate of harbour porpoises to be 25 porpoises caught in bottom trawls and 89 porpoises in gillnets, trammel nets and pelagic trawls in the Swedish part of the Skagerrak and Kattegat (ASCOBANS 2008). In the German part of the

Baltic Sea, most of the 105 recorded by-caught porpoises in the years 1990 to 2001 were reported from bottom-set gillnet fisheries or were stranded with characteristic net-marks (Siebert et al. 2006). While these numbers are considered to be minimum figures, Rubsch & Kock (2004) estimated the annual by-catch in the German set-net fishery to be 57 individuals in the western Baltic Sea and 25 in the German part of the Baltic Proper. A total of 45 by-caught animals were reported from Polish waters between 1990 and 1999 (Skóra & Kuklik 2003). In Latvia, two porpoises were found entangled in fishing nets in the Gulf of Riga in October 2003 and in January 2004, respectively (ASCOBANS 2004). A modelling study by Berggren et al. (2002) estimated the potential limits to anthropogenic mortality for harbour porpoises. To achieve the goal of a population recovery to more than 80% of carrying capacity, by-catch limits of two individuals per year in the Baltic Proper and three individuals per year in the Kiel Bight–Mecklenburg Bight area should not be exceeded.

Seabirds

Several studies from different parts of the Baltic Sea have shown that set-net (gillnet) fisheries in the Baltic Sea cause the death of tens of thousands of birds every year. The by-catch problem is of special relevance where gillnet fisheries are practiced in areas with high concentrations of resting, moulting or wintering seabirds. The conflicts are usually seasonal.

Piscivorous birds (divers, grebes, mergansers, auks, cormorants) and benthophagic ducks may become entangled and die in fishing gear. At the southern coast of the Baltic Sea, the long-tailed duck (*Clangula hyemalis*) is the most numerous species caught in gillnets, followed by black scoter (*Melanitta nigra*), common scoter (*Melanitta fusca)* and red-throated diver (*Gavia stellata*), while in some areas*,* eider (*Somateria mollissima*), greater scaup (*Aythya marila*), guillemot (*Uria alge*) and cormorant (*Phalacrocorax carbo*) are also found in large numbers (I.L.N. & IfAÖ 2005, Schirmeister 2003, Stempniewicz 1994, Kirchoff 1982, Kowalski & Manikowski 1982). In the coastal waters of Lithuania, losses of Steller's eiders are of concern owing to the rareness of this species (Dagys & Žydelis 2002). In Finland, especially eider, black guillemot (*Cepphus grylle)*, razorbill (*Alca torda*) and red-throated and black-throated divers (*G. stellata* and *G. arctica*) are the species most affected (Hario 1998). The most recent Swedish by-catch study covering the Swedish fishery as a whole (Lunneryd et al. 2004) showed that the cormorant was the species predominantly affected, followed by eider, guillemot, merganser, and long-tailed duck. The threat of drowning in fishing gear is larger for piscivorous species than for benthophagic ducks, although in most areas the total number of piscivorous birds drowned is lower owing to their smaller populations. The studies available mainly investigated bird by-catches in near-coastal waters. Information about the by-catch on fishing grounds further offshore is scarce, although it is known that high densities of birds and high fishing intensity may overlap seasonally in these areas also.

Another effect of fisheries on birds is related to the discarding of unwanted catch and offal at sea. Gulls especially benefit from this food source. Furthermore, the increase in sprat stocks as a consequence of cod overfishing is expected to have a positive effect on piscivorous birds, especially auks.

Abiotic environment

In general, the effects of bottom-towed gears on abiotic habitats are primarily (i) removal of physical features, (ii) reduction in complexity, and (iii) alteration of the physical structure of the seafloor (ICES 2005b).

Towed demersal fishing gear can also substantially affect the abiotic environment in the Baltic Sea area, where this fishing practice is applied. For example, in the intensely fished Kiel Bight, the total area disturbed was estimated at 630 km^2 per year causing a mobilization of nutrients estimated to be 0.6–2.5 tonnes silicate, 0.3–1.3 tonnes nitrogen and 0.1–0.5 tonnes phosphorus per km^2 and year (Krost 1990). The increase in nutrient concentrations was followed by an increase in oxygen consumption of 1.5–7.8 tonnes per km^2 and year. This points to a considerable impact of fishing activities on the marine environment (Krost 1990). There is no documented evidence that traditional coastal fisheries (e.g., by means of trapnets and gillnets) have affected the abiotic environment.

6.1.3 Major international frameworks that regulate fisheries in the Baltic Sea

Before 2006, coordination of the management of the living resources in the Baltic Sea and the Belts occurred under the Gdansk Convention (signed in 1973) and the preparation of science-based recommendations for consideration of the Contracting Parties was a duty of the International Baltic Sea Fisheries Commission (IBSFC). Amongst others, IBSFC adopted the Salmon Action Plan in 1997, which is one of the first long-term management plans adopted by an international fisheries organization. Major Baltic fish stocks are currently managed by a system developed under the EU Common Fisheries Policy (CFP). The objective of the CFP is sustainable exploitation and equitable distribution of a resource which is under constant change. The scientific advice for fisheries management is obtained from the International Council for the Exploration of the Sea (ICES). However, fisheries management in the European Union is under change. There have been moves towards greater involvement of stakeholders in fisheries management as well as towards management on a more regional scale. As a result of this change, Regional Advisory Councils (RACs) were recently established for a number of seas and fisheries to bring a wide range of interest groups together to discuss and deliver management advice on fisheries. The Baltic Sea RAC (BS RAC) was set up in 2006 to prepare and provide advice on the management of the Baltic Sea fisheries. The BS RAC consists of representatives from both the fishing sector as well as the other interest groups affected by the CFP. The BS RAC has three working groups: pelagic fisheries, demersal fisheries, and fisheries for salmon and sea trout.

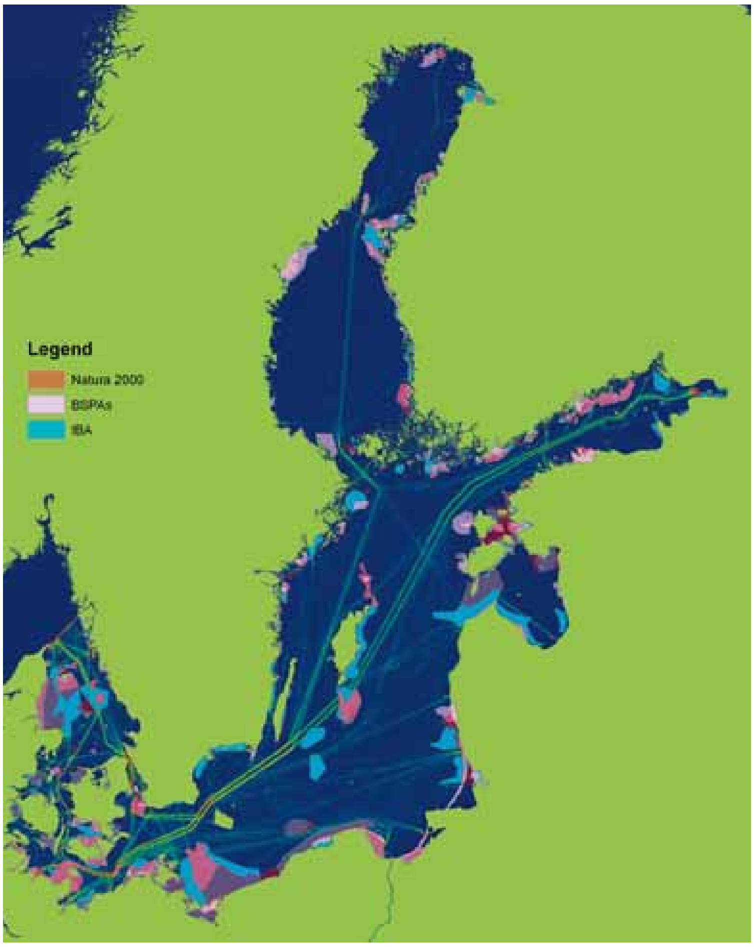


Figure 6.2.1. Shipping density based on data in the HELCOM Automatic Identification System (AIS) in February 2007, shown together with Natura 2000 areas, Baltic Sea Protected Areas (BSPA), and Important Bird Areas (IBA). The three different types of protected areas often overlap and are shown in the order indicated in the figure legend, from the top down.

6.1.4 Conclusions

Fisheries have substantial impacts on the Baltic ecosystem, extending from the abiotic environment to the upper trophic levels of the marine food web, including mammals and seabirds. Evidence of these impacts is accumulating continuously and the effects strongly indicate an urgent need for effective implementation of an Ecosystem Approach to Fisheries Management (EAFM). A critical evaluation of the related targets listed in the BSAP indicates that while they are very ambitious, they are also in need of immediate implementation to mitigate the impacts of fisheries on the Baltic Sea ecosystem, and by doing so to guarantee a stable and sustainable fishery in future times. There is no doubt that there are many activities that need to be undertaken by the various competent authorities individually and jointly to solve potential problems in relation to legal authority, finances and human resources.

6.2 Maritime activities

Roughly 15% of the world's commercial fleet sails in the Baltic Sea. More than one tanker per hour passes in the intensely trafficked areas, totalling over 10 000 passages annually. Furthermore, maritime transport in the Baltic is expected to increase by 64% between 2003 and 2020 (Anonymous 2006a).

Maritime traffic inflicts multiple pressures on the Baltic Sea biodiversity, including the release of nutrients, underwater noise, oil spills, and the spreading of alien species. Many of the marine protected areas (MPAs), which have been established to protect the unique marine nature of the Baltic Sea from human impact, are close to heavily trafficked areas (Figure 6.2.1).

Maritime traffic is addressed by one of the four main segments of the Baltic Sea Action Plan (BSAP). A number of management objectives have been established to indicate the main areas of concern including, e.g., 'Safe maritime traffic without accidental pollution', 'Minimum sewage pollution from ships', 'No introductions of alien species from ships', and 'Minimum air pollution from ships'.

6.2.1 Impacts of maritime traffic on biodiversity

Nutrient inputs

Shipping activity contributes to the eutrophication of the Baltic Sea through emissions of nitrogen oxides (NOx) and discharges of nitrogen and phosphorus contained in sewage (for impacts on biodiversity, see Chapter 6.5, Eutrophication). NOx emitted to air is deposited both directly onto the sea surface and in the catchment area, from where part of the nitrogen drains into the sea via rivers. NOx deposited onto the Baltic Sea is particularly effective in causing eutrophication because it is directly available for use by primary producers.

According to the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe, EMEP (Bartnicki 2007), shipping in the Baltic Sea contributed 9% of the total airborne nitrogen deposition directly to the sea in 2005. The major share of nutrients to the Baltic enters as waterborne input from the catchment area (Knuuttila 2007) and shipping contributes only about 2% of the total nitrogen inputs to the Baltic Sea (Table 6.2.1). A recent study, however, suggests that, based on NOx emissions from ships, nitrogen deposition may be somewhat higher than previously estimated (Stipa et al. 2007). With a projected 2.6% annual increase in shipping traffic in the Baltic, and assuming no abatement measures, the estimated annual input of NOx from maritime traffic alone has been estimated to increase by roughly 50% until 2030 (Stipa et al. 2007, IMO document MEPC 57/INF14).

Nitrogen loads to the Baltic Sea originating from ships' sewage discharges have been estimated to represent about 0.05% of the total waterborne nitrogen load and up to 0.5% of the total phosphorus load to the Baltic Sea (Table 6.2.1) (Huhta et al. 2007). These figures have been calculated based on the assumption that there is no sewage treatment onboard ships (cargo ships, cruise ships and passenger/car ferries) and that all sewage is discharged into the sea, i.e., the theoretical worst-case scenario. The proportion of nutrients originating from ships' sewage water is thus relatively small compared to the total nutrient load to the Baltic Sea. Nutrients in sewage discharge may nevertheless have considerable effects on the growth of pelagic phytoplankton because the nutrients are discharged directly to the open sea ecosystem. The amount of total nitrogen discharges from commercial ship traffic is comparable to the 500 tonnes of annual nitrogen load from the city of Helsinki sewage treatment plant, which purifies the sewage of approximately 1 million people (Huuska & Miinalainen 2007).

Table 6.2.1. Magnitude of nitrogen (N) and phosphorus (P) inputs from shipping, including nitrogen deposition from airborne emissions and sewage, and total waterborne and airborne loading of nitrogen and phosphorus to the Baltic Sea. Note that the estimates concern either the year 2000 or 2005.

Nitrogen	Total N in 10^3 tonnes	NOx in 10^3 tonnes
Airborne N deposition from Baltic shipping in 2005[1]	19	14
Total deposition of airborne N to the Baltic Sea in 2005[1]	208	86
Sewage N from Baltic shipping in 2000[2]	0.47	-
Waterborne loading of N to the Baltic Sea in 2005[3]	620	300

Phosphorus	Total P in 10^3 tonnes	
Sewage P from Baltic shipping in 2000[2]	0.16	-
Waterborne loading of P to the Baltic Sea in 2005[3]	29	-

1) Bartnicki 2007; 2) Huhta et al. 2007; 3) Knuuttila 2007.

Oil spills

The turnover in oil terminals around the Baltic Sea has increased steadily during recent years (Figure 6.2.2). Together with the expected increase in maritime traffic, this means that the risk of a major oil accident in the area is on the rise. Despite an increasing preparedness of HELCOM Contracting Parties, any major oil spill would have severe impacts in both offshore as well as coastal areas. The major oil accident of the ship "Prestige" on the Atlantic coast of Spain in 2002 caused significant short-term reduction in phytoplankton and zooplankton biomass (Mendes et al. 2005), reduced abundance and species richness of littoral invertebrates (ICES 2007b), and decreased fish reproduction (Dominguez & Saborido-Rey 2005). It killed or harmed about 200 000 birds (Zuberogoitia et al. 2006), caused strandings of marine mammals and turtles (López et al. 2005) and significant egg and adult mortality of peregrine falcons (Zuberogoitia et al. 2006). In the Baltic, cascading ecosystem effects of oil, from phytoplankton to higher trophic levels, are poorly known, but expected to be harmful owing to decreased food availability and increased bioaccumulation of toxic chemicals.

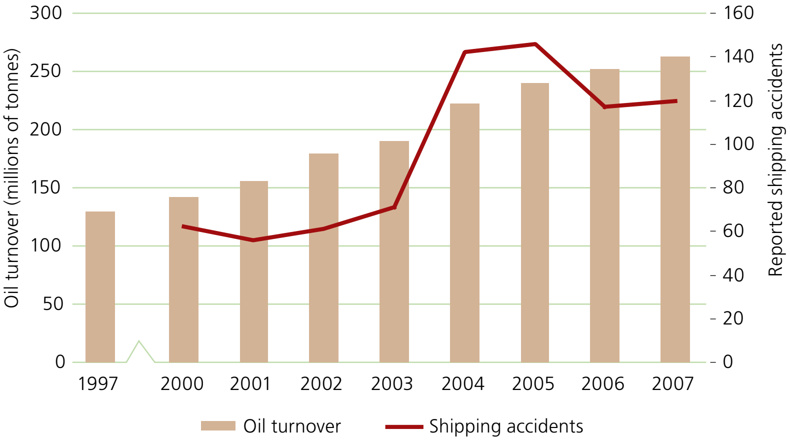


Figure 6.2.2. Total oil turnover in major Baltic terminals handling >3 million tonnes (Mt) per year. The line represents the number of reported accidents for the same time period.

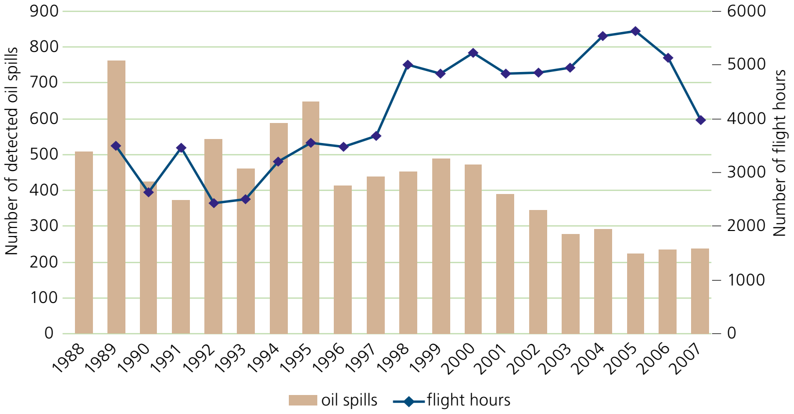


Figure 6.2.3. Number of illegal oil spills detected by airborne monitoring 1988–2007. The number of flight hours is shown by the black line. Based on HELCOM aerial surveillance data.

In spite of the dramatically increasing oil transportation, most oil spills detected in the Baltic are small illegal or accidental spills (HELCOM 2008b). However, the cumulative effects of such smaller spills also have direct harmful impacts. Oiled birds and mammals suffer from hypothermia or intoxication, which are particularly lethal to the avian fauna. Annually, an estimated 100 000–500 000 ducks, guillemots and other bird species die owing to small oil spills in the Baltic Sea (BirdLife International 2007). Encouragingly, such smaller oil spills seem to have decreased during recent years, possibly due to better enforcement (Figure 6.2.3).

Other effects of shipping, including physical impacts

In addition to oil and nutrient pollution, heavy shipping has a number of other negative impacts on marine biodiversity, especially in shallow areas. Ship-generated water movements reform the coastal zone (Soomere 2005), circulate nutrients in the water column thus enhancing eutrophication (Lindholm et al. 2001), and change species composition in rock pools (Östman & Rönnberg 1991). Even structural changes and declines in coastal fish communities may be linked to increased shipping through coastal erosion, increased sedimentation and eutrophication (Rajasilta et al. 1999).

Maritime traffic is also a significant producer of marine litter, even though the amount of litter is smaller in the Baltic Sea than in some other parts of the world (HELCOM 2007e). Ship hulls, as well as ballast water and sediments, transport alien organisms to the Baltic Sea (see Chapter 6.7, Alien species) and anti-fouling chemicals used on ship hulls cause acute effects on organisms, especially at lower trophic levels of the food web (see Chapter 6.6, Hazardous substances).

Although maritime traffic considerably increases noise both underwater and above the surface, it has not been found to cause acute harm to marine animals, but may potentially disturb harbour porpoises (see Chapter 6.8, Noise pollution).

6.2.2 Major international frameworks regulating maritime traffic

The International Convention on the Prevention of Pollution from Ships (MARPOL 73/78, amended in 1997) is the major environmental regulatory tool used by the International Maritime Organization (IMO). Its provisions are used to implement, e.g., the 2005 Baltic Sea Particularly Sensitive Sea Area (PSSA), which presently imposes restrictions on shipping in the Baltic Sea. Restrictions are imposed via a number of routeing measures, including traffic separation schemes, deep-sea routeing, areas to be avoided, and by regulating the allowable level of sulphur in fuel oil in the Baltic Sulphur Emission Control Areas (SECA).


Shipyard, Stralsund, Germany

MARPOL Annex VI specifically includes limits for the emissions of NOx, sulphur oxides (SOx), and particulate matter and prohibits emissions of ozone-depleting substances. In 2008, IMO adopted a revised MARPOL Annex VI and an associated NOx Technical Code. The new Annex VI aims, *inter alia*, at establishing Nitrogen Emission Control Areas (NECAs) in addition to the existing Sulphur Emission Control Areas, such as the Baltic SECA in force since 2006. According to the revised Annex VI, NOx emissions from certain types of ships are to be reduced by 15% compared to current levels, starting from 1 January 2011, followed by an 80% reduction in NECAs starting from 1 January 2016. Work has started within HELCOM to designate the Baltic Sea as a NECA. This is important because future scenarios (IMO document BLG 11/16, Stipa et al. 2007) indicate that in the Baltic, only the 80% reduction of NOx emissions from marine diesel engines installed in ships on or after 1 January 2015 would counteract the effect of increasing traffic volumes. The fuel sulphur limit applicable in SECAs will also be reduced to 1.00% (from the current 1.50%) beginning on 1 July 2010, and further reduced to 0.10% effective from 1 January 2015.

To eliminate discharges of oily wastes, which are the main source of oil in minor spills, sewage and garbage, HELCOM has established a 'no-special-fee' system providing incentives to ships to deliver their ship-generated waste to port reception facilities. In order to reduce the risk of major oil accidents, the BSAP commits the Baltic Sea countries to encouraging shipping companies to use crew trained for winter navigation and to use pilots. HELCOM is also developing a joint proposal of the Baltic Sea countries for new regulations containing restrictions on the discharge of sewage water from passenger ships into the Baltic Sea, to be submitted to IMO in 2010.

Other international instruments regulating shipping include the International Convention on the Control of Harmful Anti-fouling Systems on Ships, which entered into force in September 2008 and aims at reducing the amount of toxic chemicals in the marine environment. The Convention for the Control and Management of Ships' Ballast Water and Sediments has not yet been ratified, but will be one of the main international legal instruments addressing alien species introductions once it has entered into force.

6.2.3 Conclusions

The impact of maritime traffic on Baltic biodiversity is both direct, in the form of physical disturbance and nutrient and chemical pollution, and indirect, for example, through acting as a vector of non-indigenous species (Figure 6.2.4). The risk for a major accident releasing oil and hazardous substances is growing due to increas-

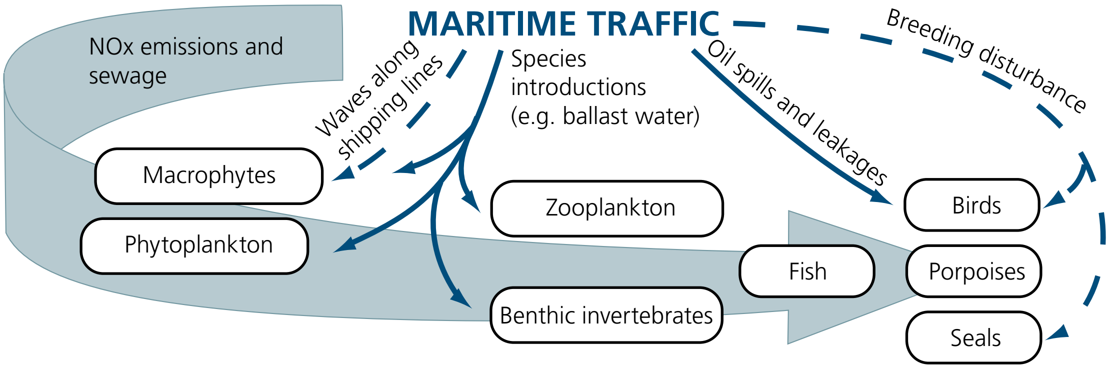


Figure 6.2.4. A conceptual model of the impacts of maritime traffic on components of Baltic biodiversity. Eutrophication resulting from NOx pollution is not covered as models exist elsewhere (see, e.g., HELCOM 2009a).

ing maritime transportation in the area, including tanker traffic. However, the smaller spills which are frequently observed also have considerable negative effects. Although most of the shipping in the Baltic Sea follows narrow routes through the sea area, nearly every corner in the Baltic Sea is to some extent used by shipping, as shown by the recent AIS (Automatic Identification System) data (Figure 6.2.1). To meet the challenges posed by the increasing maritime traffic, a comprehensive cross-sectoral approach should be established, implementing the principles of Marine Spatial Planning and including a Baltic-wide risk assessment (Formal Safety Assessment) of maritime traffic.

6.3 Physical damage and disturbance

Human activities discussed in this section can be classified into three major types: extraction of sand and gravel, dumping of dredged spoils, and effects of various types of construction works. The harmful effects of these activities are caused by largely similar processes: resuspension of nutrients and hazardous substances, increased turbidity, siltation and habitat loss. The operation of different installations is linked to diverse effects including disturbance from underwater noise, magnetic fields and also by the introduction of new habitats.

6.3.1 Extraction and disposal activities in the Baltic Sea

Extraction of bottom substrates

Extraction of sand and gravel from the seafloor has increased markedly in many HELCOM Contracting Parties during recent years. The marine areas considered suitable for mining resources from the seabed have until recently been restricted to areas less than 80 m deep, but currently depths down to 100 m can be exploited cost-effectively owing to more efficient and powerful dredgers (UNEP GPA 2008).

In 2006, the volume extracted in Denmark (HELCOM area) was 1.6 million m^3, in Finland 2.2 million m^3, and in Germany (HELCOM area) 1.4 million m^3. In Estonia, the volume in 2004 was 1.4 million m^3 and in Poland it was 0.5 million m^3 in 2002 (ICES 2003, 2005c, 2007a).

After the construction of the Öresund bridge between Sweden and Denmark, there has been no permitted marine sand extraction in Sweden. The amount extracted in that project in the Swedish EEZ was 2.5 million m^3. When the fairway to the Gothenburg harbour was deepened in 2003, 12 million m^3 was dredged (ICES 2006a). In general, port constructions and enlargements are among the largest dredging and landfill projects. For example, during the enlargement of the Århus port in Denmark, 8 million m^3 of sand was dredged from Århus Bight and in the new port of Helsinki, Finland, the volume was 4 million m^3. An overview of Baltic ports shows that there are enlargement plans for most of them (BPO 2007).

Disposal of dredged material at sea

It is difficult to obtain an overview of the current volume of disposal of dredged material at sea in the HELCOM area. HELCOM Contracting Parties have an obligation, based on Article 11 and Annex V of the Helsinki Convention and the associated

Guidelines (adopted in 2007), to report on the amount and contaminant levels of dredged spoil disposed at sea. Currently, there is information available only from Sweden (153 000 tonnes in 2006), Germany (450 000 and 50 000 tonnes in 2006 and 2007, respectively), and Lithuania (1.39 million tonnes in 2007). Obviously, the volume of disposed spoils varies annually depending on large construction projects, such as port enlargements. HELCOM Contracting Parties have agreed to use the Best Environmental Practice (BEP) approach to minimize both the quantity of material that has to be dredged and the impact of the dredging and disposal activities in the maritime area. Moreover, when evaluating disposal sites, comprehensive information on natural features and human activities should be obtained for environmental impact assessments (EIAs).

Ecosystem impacts of sand and gravel extraction, small-scale dredging and dumping of dredged spoils

The harmful impacts of sand and gravel extraction, dumping of dredged spoils, and dredging on the marine ecosystem are mainly caused by direct killing of benthic infauna and epifauna, increased turbidity, siltation, and resuspension of nutrients and hazardous substances (reviewed by HELCOM 1999). For example, the spill of sand from the dredging operation in the Århus harbour enlargement was estimated to be 3.7% and the resuspension of inorganic nitrogen and phosphorus was estimated to increase the nutrient concentrations in the water phase 3–100 fold (ICES 2003).

Extraction activities destroy, at least temporarily, the vegetation and benthic fauna of the dredged area. After minor sand extractions, benthic invertebrate communities are usually restored after 2–4 years, but after major sand extraction the recovery phase lasts much longer (e.g., Boyd et al. 2005). In the Baltic Sea, benthic species richness has been found to recover within a year after finishing the activities, whereas biomass and density remain low for several years (HELCOM 1999). However, water currents have been shown to spread the plume of fine sand up to 4 km away from the site of activity. Although the observed negative impact on benthos at that distance may be minor and short-lasting (Lisberg et al. 2002, Vatanen & Haikonen 2008), siltation and overflowing sand may drastically change the species composition of the benthic fauna. At an extraction site in the English Channel, this effect reduced the species diversity by half, and decreased the density and biomass down to 10% of that in nearby areas (Harlay et al. 2003).

Small-scale dredging in marinas, boat routes, and private shores have potentially a large local negative impact on biodiversity because they are often located in sheltered bays, coastal lagoons and estuaries, which support rich submerged vegetation and associated fauna (Dahlgren & Kautsky 2004; see also Chapter 6.4, Recreational activities). Some sensitive species, such as *Chara* spp., have disappeared from areas exposed to small-scale dredging (Appelgren & Mattila 2005).

An additional problem with dredging old ports is that the sediments often contain substances toxic to marine organisms (Smith et al. 1995).

6.3.2 Technical installations

There is a growing number of construction works and different types of installations on the Baltic coasts but also in offshore areas and on the seabed: traffic links, high voltage power cables (HVPC), oil platforms, oil and gas terminals, pipelines, wind farms, marinas and ports, and numerous coastal protection barriers. This section provides an overview of existing large installations and their known impact on the Baltic biodiversity.

Sediment extraction

Communication links

There are a number of communication links (mainly bridges) connecting cities and/or countries in the Baltic Sea. One of the major projects finalized during recent decades is the communication link between Denmark and Sweden (bridge combined with tunnel and an artificial island) (Figure 6.3.1, left). Other large-scale construction projects include the Öland Bridge, the Great Belt Fixed Link, and the St. Petersburg flood barrier and communication link (Figure 6.3.1, right). Currently, a plan to build the world's longest bridge from Germany to Denmark over the Fehrman Belt marine protected area has been adopted by the Danish and German governments.

Environmental concerns associated with the construction of communication links are usually related to mechanical damage of the sea bottom and the release of sediment plumes during the construction phase; i.e., they cause the same effects as dredging, as described above. After construction, bridges may affect the water exchange. The underwater parts of bridges also introduce a new habitat that provides good attachment sites for sessile organisms (Elsam Engineering & ENERGI E2 2005).

Power and communication cables

Power cables have a long history in the Baltic; one of the first cables in the world was the 'Gotland', which connects the island of Gotland with the Swedish mainland. The present cable network in the Baltic Sea consists of nine high-voltage direct current lines (HVDC) (Figure 6.3.2, left). The most recent cable connection is the 'SwePol Link' (230 km, 450 kV). In addition to power cables, there are several existing and planned communication cables across the southern sea basins.

The underwater power transmission lines cause mechanical damage to the seafloor (during cable laying), the release of toxic chlorine during electrolysis (in one cable solution), and are the source of an electromagnetic field that may possibly influence migrating fish. However, the relative impact of power cables on Baltic Sea biodiversity is probably low (Andrulewicz et al. 2003).

Oil and gas exploitation platforms

Oil in the Baltic Sea is extracted by two oil platforms: 'Petrobaltic' in the Polish Exclusive Economic Zone (EEZ), and 'D-6' in the Russian sector of Kaliningrad Oblast (started in 2006). The operation of these oil platforms has not been observed to cause any significant environmental problems. However, oil and gas extraction activities may increase in the Baltic Sea and therefore may be recognized as a potential environmental concern (for impact, see Chapter 6.2, Maritime activities).

Ports, oil terminals and piers

Ports, oil terminals and piers have been constructed in many places along the Baltic Sea coast. The annual throughput of the 51 member ports of the Baltic Ports Organization (BPO) is 400 million tonnes

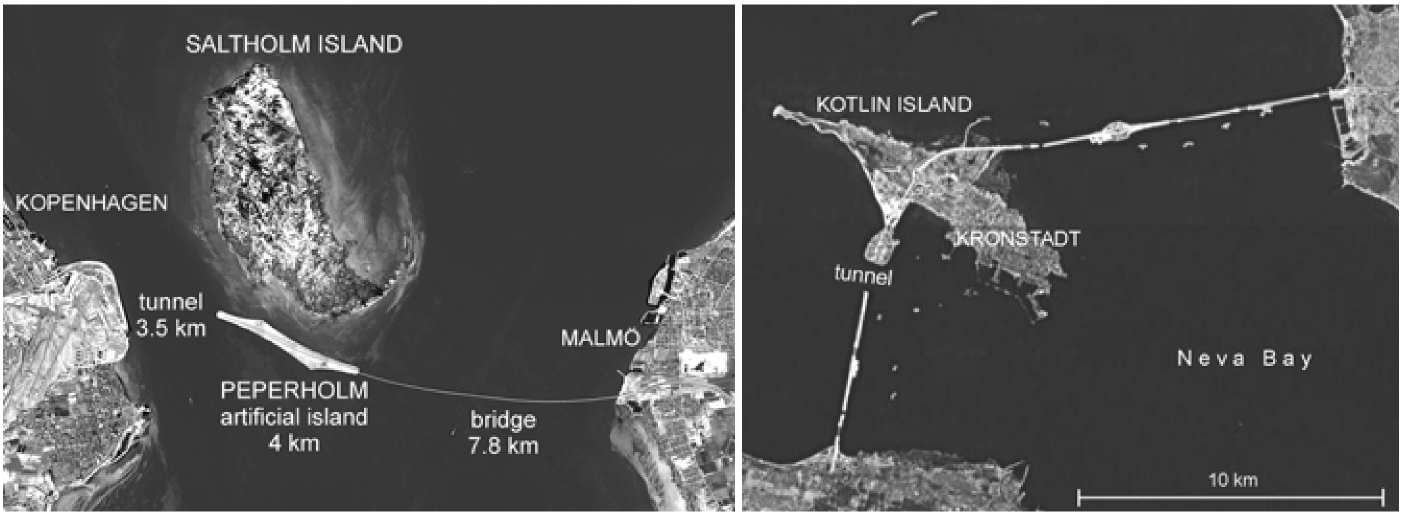


Figure 6.3.1. Left: 'Öresund Link' connecting Denmark and Sweden. Right: satellite image of the St. Petersburg flood barrier and a by-pass road off St. Petersburg (under construction) (picture based on the www portal http://maps.google.com).

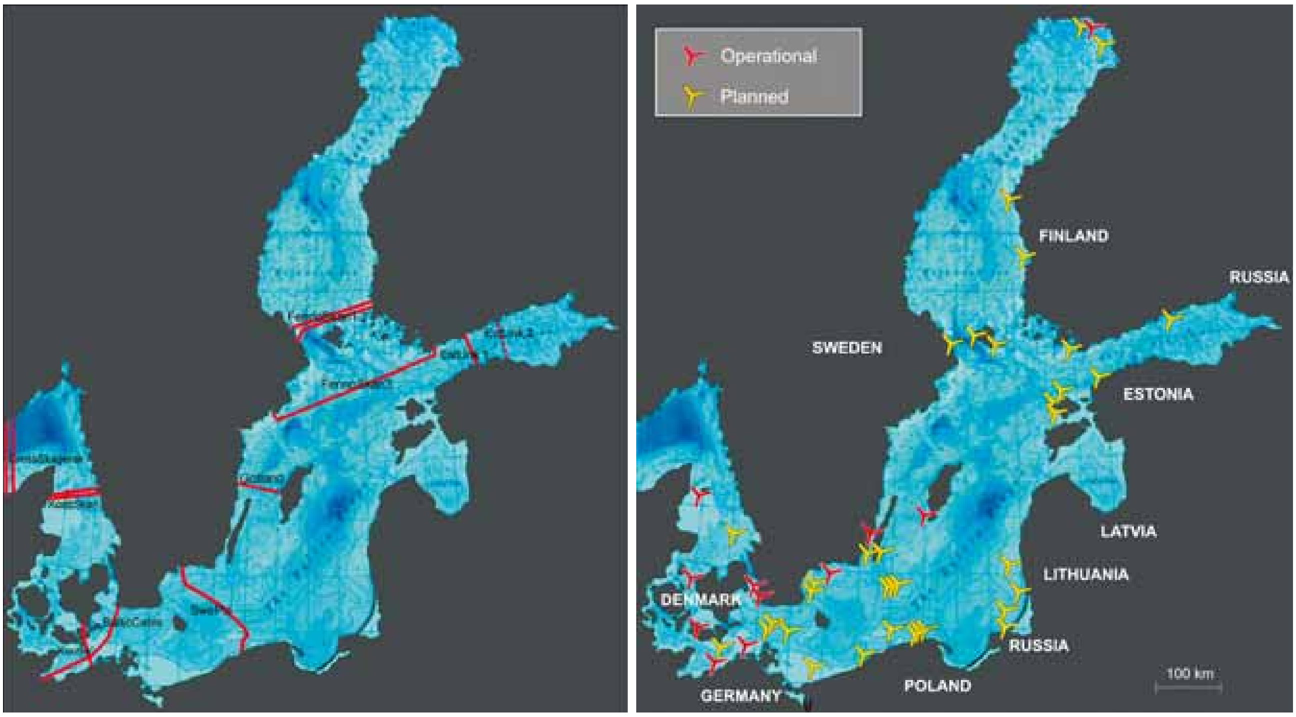


Figure 6.3.2. **Left: High-voltage electric power cables in the Baltic Sea. Right: Location and status of wind farms in the Baltic Sea (Compiled from: BSH - German Hydrographic Agency; EWEA - The European Wind Energy Association; Elsam Engineering A/S, 2004 – Denmark; Georg Martin – Estonia; Maritime Offices – Poland; Pasi Laihonen – Finland; Ulla Li Zweifel –Sweden; www.vattenfall.se).**

of cargo, 3.3 million containers, 60 million passengers and 200 000 port calls (BPO 2007). The capacity of Baltic ports is constantly increasing and almost all Baltic ports have new development projects. Large development projects have been planned for Primorsk, Ust-Luga and St. Petersburg in Russia; Ventspills, Riga and Liepaja in Latvia; Klaipeda in Lithuania; Tallinn and Sillamae in Estonia; and Gdańsk and Świnoujście in Poland.

Traditionally, ports have been constructed in estuaries, which are biotopes of high biological value. Ports are also places of increased risk of accidental pollution, emissions of contaminants to the atmosphere and sea, and introduction of alien species. Construction of ports generally leads to degradation of the seafloor and coastal habitats and alteration of coastal currents. For example, during the construction of the new port of Helsinki, extensive environmental monitoring showed an increase of TBT in bivalves, a deterioration in the spawning of herring and degraded macroalgal zonation (Vatanen & Haikonen 2008). However, impacts from increased turbidity on nearby areas remained smaller than expected and the construction work did not visibly affect marine or coastal bird populations (Yrjölä 2007).

Offshore wind power farms

Although there are currently only a few large wind farms in operation in the Baltic Sea, there are many that have been planned (Figure 6.3.2, right) or are already going through an EIA process. Despite the fact that wind farms are not a source of chemical or biological pollution, they remain controversial. They may have environmental effects such as: i) the possibility of bird collisions, ii) emission of noise and vibration, iii) possible disruption of fish migration, iv) loss of feeding and spawning grounds, v) creation of electromagnetic fields, vi) possible alterations of sea currents, and vii) changes in the natural landscape.

According to recent studies on wind farms, their construction phase causes more harmful effects on the environment than the operational phase (Prins et al. 2008). The reactions of fish and mammals to noise, vibrations and electromagnetic fields created by wind farms are still rather poorly known but there are several ongoing projects addressing the issue. At the Nystedt wind farm in the southern Baltic Sea, harbour porpoises clearly avoid the operating wind farm area, possibly owing to noise pollution (Elsam Engineering & ENERGI E2 2005). On the other hand, in the North Sea such behaviour has not been found

Figure 6.3.3. Left: concrete-stone coastal protection on some parts of the Hel Peninsula in Poland. Right: planned route of the Nord Stream pipeline (www.nord-stream.com).

and seals do not seem to avoid wind farms at all (see also Chapter 6.8, Noise pollution).

Power cables (132 kV) from wind farms may have a harmful effect on migration patterns of eel and other fish, but the results from existing studies are not clear and further studies are needed to assess possible effects (Elsam Enginreering & ENERGI E2 2005). Migrating birds avoid wind farms, showing similar or lower collision frequencies than to other objects (Desholm 2006). However, white-tailed eagles have been found to be vulnerable to wind mills. Wind power farms clearly also change the appearance of the original landscape/seascape (DONG Energy et al. 2006).

Wind farms affect biodiversity by introducing a hard substratum that facilitates the development of communities of sessile organisms through the so-called ‘reef effect’. As a result, wind power farms enhance local biodiversity (e.g., macroalgae, invertebrates and reef fish) (Elsam Engineering & ENERGI E2 2005, DONG Energy et al. 2006).

Coastal defense barriers

The construction of numerous coastal defense barriers (sea walls) and beach nourishment projects occurs in the southern part of the Baltic Sea, mainly in Denmark, Germany, Lithuania and Poland. These types of construction usually involve massive dredging, physically affecting benthic organisms, and landfill causing disruption of coastal dynamics and loss of coastal habitats (Figure 6.3.3, left). The scale of environmental effects of these structures depends on the type and size of construction and the construction area. Coastal habitats and wetlands, with associated species, currently show a decreasing trend in Europe (EEA 2006). Coastal defense measures under the conditions of HELCOM Recommendation 16/3, however, may be necessary in view of sea level rise and the associated increased risks of flooding of settlements.

Gas pipelines

Currently, there are at least three planned gas pipeline routes in the Baltic Sea: ‘Baltic Gas Interconnector’ from Germany to Sweden, ‘BalticPipe’ from Denmark to Poland and ‘Nord Stream’ from Russia to Germany. The largest of the three, the Nord Stream construction (Figure 6.3.3, right), will consist of two pipelines, both 1 200 km long, with a diameter of 122 cm and under a pressure of 220 atm. The size and length of the Nord Stream gas pipes pose a number of environmental safety concerns related to: i) effects of construction on bottom habitats and bottom organisms, ii) effects of possible contacts with chemical weapons dumped in the Baltic Sea, iii) effects of the mobilization of nutrients and hazardous substances deposited in sediments, iv) effects of discharged toxic test waters into the sea, and v) effects of a possible pipeline breakage.

6.3.3 Major international frameworks that regulate physical alterations

Exploitation of marine bottom substrates, the dumping of dredged spoils, and the construction of coastal and offshore installations cover such a wide array of actions that there are several international conventions, directives and recommendations regulating their conduct. The earliest international effort was the London Convention (1972, revised 1996), soon followed by the Helsinki Convention (1974, Article 9), both of which regulate, *inter alia*, the dumping of dredged spoils. In the Helsinki Convention, Article 11 on prevention of dumping (and Annex V and Guidelines adopted in 2007) requires that all dumping must be approved by national authorities and hazardous substances must not be allowed to be dumped at sea. Moreover, Recommendation 19/1 (adopted 1998) contains guidelines for marine sediment extraction, requires environmental impact assessments, limits extraction activities in sensitive areas, and prohibits such activity within marine protected areas. The Espoo Convention (1991), regarding transboundary environmental impact assessments (EIAs), has been ratified by eight of the nine Baltic Sea littoral countries.

To protect the Baltic Sea from negative effects of large-scale installations and construction works, HELCOM has developed and adopted a special recommendation on information and consultation with regard to the construction of new installations affecting the Baltic Sea (Recommendation 17/3). A number of other HELCOM recommendations are applicable to construction works, particularly Recommendation 15/1 regarding protection of the coastal strip, Recommendation 16/3 regarding preservation of natural coastal dynamics, Recommendation 19/17 regarding pollution from offshore units, and Recommendation 21/4 on protection of heavily endangered or immediately threatened marine and coastal biotopes in the Baltic Sea area.

Within the European Union, at least four directives deal directly with construction, extraction and dumping activities in the sea (EIA Directive, Habitats Directive, Birds Directive, Marine Strategy Framework Directive and Water Framework Directive). In addition, the EU Recommendation on Integrated Coastal Zone Management regulates the uses of coastal marine areas.

6.3.4 Conclusions

Altered water quality, habitat damage or loss, and underwater noise are the dominant factors reducing biodiversity in areas subject to marine sediment extraction, dumping and installation activities. Directives, recommendations and conventions provide several guidelines aiming to mitigate the negative effects on biodiversity, while the pressure to use marine areas and exploit sediments is steadily increasing.

In contrast to sediment extraction and dumping of dredged spoils, the various pressures from technical installations and construction works are often overlooked and rarely sufficiently understood. The growing number and scale of technical installations and construction works in the Baltic Sea generate new pressures on the marine ecosystem, interacting with all components of the ecosystem (Figure 6.3.4). There is clearly a need for better international information exchange on the extent as well as the environmental effects of the existing large-scale installations. Gaining a regional overview of the extent, effects and future developments of the activities presented here is an important component of Marine Spatial Planning (MSP), launched by the BSAP (Recommendation 28E/9). The process of Baltic regional marine spatial planning aims to improve integration of regional environmental and sectoral policies using, for example, Strategic Environmental Assessments (SEA) and a long-term development perspective.

There are a number of HELCOM recommendations which address these conflicts (28E/9; 24/10; 21/4; 19/1; 17/3; 16/3 and 15/1). A full national implementation and application of these

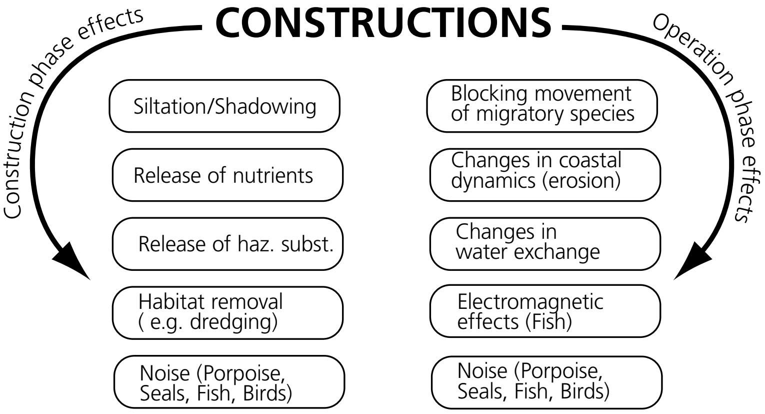


Figure 6.3.4. A conceptual approach to environmental effects of technical constructions.

recommendations would contribute to a sustainable performance of many human activities in the Baltic Sea area.

6.4 Recreational activities

Millions of people take part in boating, fishing and bathing in the Baltic Sea every year. The recreational value of the Baltic Sea area depends on a healthy ecosystem and pleasant environment, both with regard to individual appreciation and economic revenue for the tourism sector. At the same time, these activities have the potential to affect the Baltic Sea negatively through the release of nutrients, physical disturbance, and extraction of resources. A Baltic-wide assessment of the impact of recreational activities is not available, but information from some countries gives an indication of the extent of the pressure.

6.4.1 Recreational activities and their impact on the Baltic Sea

All coastal areas visited for recreational purposes are subject to littering and direct physical disturbance such as trampling, which may affect the submerged vegetation in beach areas. A more continuous impact stems from summerhouses, which contribute a disproportionately large nutrient release to the Baltic because many summerhouses are not connected to municipal sewage treatment plants. The construction of jetties in summerhouse areas also contributes to fragmentation of shallow-water habitats.

Tourism, Eckernförder Bay, Germany

In addition, boats and associated activities such as fishing are the cause of multiple impacts on the Baltic environment. An overwhelming majority of recreational boats in the Baltic Sea area belong to residents of Denmark, Finland and Sweden; in Denmark and Finland, the number of privately owned boats used along the Baltic Sea coast is around 400 000, and in Sweden the number is 450 000. These estimates include vessels ranging from rowboats to motor- and sailing boats with overnight capacity (DEPA 2002, SCB 2004). In Estonia and Latvia, the number of leisure boats is about 14 500 and 7 300, respectively.

Impacts of boating

In Finland, it has been forbidden to release toilet waste within territorial waters since 2005. Private boat owners are thus obliged to collect toilet waste onboard and deliver the waste to reception facilities in Finnish harbours. In many cases, however, toilet waste from recreational boats is released directly into the sea. This is the case for an estimated 60% of Swedish boats that have onboard toilets (SCB 2004). The toilet waste poses a hygienic risk when disposed in coastal areas and is also a source of nutrients (for impacts on biodiversity, see Chapter 6.5, Eutrophication). In the Stockholm archipelago, it is estimated that 4.5 tonnes of nitrogen and 1.1 tonnes of phosphorus are released to the water as toilet waste every summer (SEPA 2007). On a Baltic-wide scale, recreational boats have been estimated to contribute within the range of 30–190 tonnes of nitrogen and 4–28 tonnes of phosphorus per year (DEPA 2002).

High boating activity also affects the aquatic vegetation in the nearshore area. Shallow bays that are exposed to traffic by recreational boats and small ferryboats show a smaller area of vegetation coverage and lower species richness compared to reference areas (Eriksson et al. 2004). The fish communities also differ between these areas; fish dependent on aquatic vegetation during early life stages appear less common in the areas affected by boating (Sandström et al. 2005).

The adverse effects of antifouling paints containing zinc, copper and organic tin compounds on aquatic organisms are well known. Bans on the use of tributyltin (TBT) on small boats (<25 m) in the Baltic Sea area began twenty years ago. However, TBT is still found in high concentrations in sediments close to small guest and natural harbours along the Swedish coast of the central Baltic Proper and the entire Finnish coast (Nordfeldt 2007, Vahanne et al. 2007). Because there is no commercial vessel traffic in these areas, the results indicate that past use by recreational boats is still a significant contributor of TBT in the marine environment.

Gas emissions from motorized boats are an additional problem, in particular regarding carbon monoxide (CO) and hydrocarbon (HC) emissions. This is because a large fraction of recreational boats have two-stroke engines with inefficient fuel combustion. Along the Finnish coast, recreational boats accounted for more than 70% of CO and HC emissions from all boat and ship traffic in 2000 (Wahlström et al. 2006). As much as 20–30% of the gas is released directly into the water.

Motorized leisure boats also disturb marine mammals and waterfowl through generation of noise, and collisions between mammals and leisure boats occur occasionally.

Recreational boating activity is supported by a considerable number of marinas that contribute to fragmentation of the coastal zone and are associated with the negative impacts of dredging during construction. Along the German Baltic coast, there are 250 marinas and several more being planned (Fröhle 2008), while in Finland the number is about 530, including Åland. Along the Swedish coast, including the Kattegat area, the number of guest harbours alone is 290, i.e., harbours offering berths to visiting recreational boats. In Estonia and Latvia, the number of yacht harbours is around 50 and 20, respectively (Estonian Maritime Administration, Anonymous 2006b). With a rapidly developing tourism sector, the demand for yacht harbours is increasing in both countries: in Estonia, the number of incoming yachts doubled during the past ten years and in Latvia visiting yachts increased by 70% in the period 2001–2005 (Anonymous 2006b). Also in Poland, there are plans to enlarge existing marinas as well as to build new marinas to serve a growing number of tourists arriving by boat (E. Andrulewicz pers. comm.).

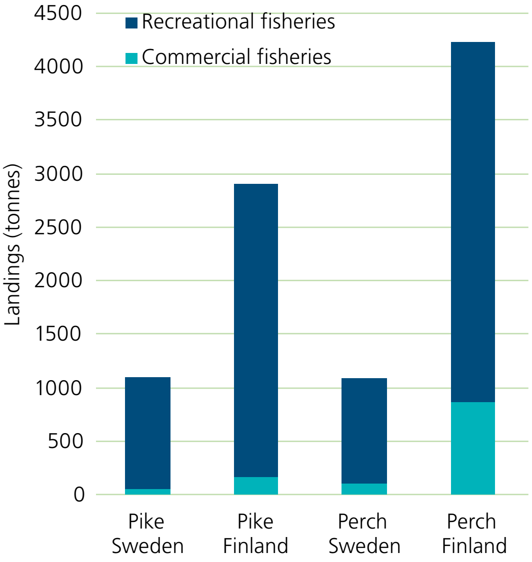


Figure 6.4.1. Recreational and commercial fisheries of pike and perch in Sweden and Finland in 2006. The estimated landings in recreational fisheries are based on questionnaires. Sources: Swedish Board of Fisheries (SNBF 2008), Official statistics on landings in the Swedish commercial fisheries (http://www.fiskeriverket.se), Finnish Game and Fisheries Research Institute (FGFRI 2007a,b).

Impacts of recreational fishing

In 2006, about 330 000 Swedes and 458 000 Finns were engaged in recreational fishing along the Baltic Sea coast and in archipelago areas (FGFRI 2007b, SNBF 2008). The same year, 225 000 fishing licenses were issued in Denmark. In Estonia, about 2 500 licenses allowing fishing by gillnet and longline were issued in 2007 to leisure fishermen operating in marine waters, while the number of persons involved in angling at sea was estimated at 7 000.

Estimates of landings in recreational fishing are available from a few countries. In Sweden and Finland, the total landing in recreational fishing is about 10% of that in the commercial fisheries. However, for specific species the share of recreational fishing is much higher. Pike and perch are the most common species caught in recreational fishing in both countries and in 2006 the estimated landings of pike and perch were many times higher than the relatively limited commer-

Tourist fishing

cial fishery for these species (Figure 6.4.1, FGFRI 2007b, SNBF 2008). The same year the recreational catch of cod along the Swedish coast of the Baltic Sea, including the Kattegat, comprised 6% (729 tonnes) of the commercial landings. In Estonia, the licensed fishing for the two most important target fish in 2007 was estimated at 43 tonnes of flounder and 11 tonnes of perch.

6.4.2 International frameworks addressing recreational activities

Recreational activities are almost exclusively regulated at the national level. Regarding recreational fishing, there is therefore considerable variation among the Baltic Sea countries in terms of access rights to coastal waters, license requirements, as well as the definition of recreational fishing (Lawson et al. 2008).

There are, however, several international regulations and directives that are linked to boating activities. Since 2003, the application of TBT antifouling paint is forbidden for all vessels in all EU countries (EC No 782/2003). However, the use of antifouling paints containing TBT was banned for small boats (<25 m) in several countries in the Baltic Sea area already in the late 1980s/early 1990s.

Two EU directives are directly related to recreational boats: Directive 94/25/EC which covers design and construction aspects and Directive 2003/44/EC which amends the former directive by including limit values for exhaust and sound emissions from motor boats. The limit values apply to engines and craft built after 2005 and 2006 depending on motor type.

HELCOM has two recommendations that link directly to recreational activities. Recommendation 22/1 stipulates that all vessels that have a toilet, including pleasure craft, should have a toilet waste retention system that can be emptied into port reception facilities. In the principles outlined for sustainable tourism in Recommendation 21/3, the guidelines stipulate that *"Leisure activities should be managed, particularly in* *the protected areas, in a way that they fulfil the requirements of biological and landscape diversity and soil conservation"*.

6.4.3 Conclusions

Compared to other pressures such as land-based nutrient inputs and commercial fisheries, recreational activities are still minor contributors to the negative impact on Baltic biodiversity. This is not to say that the contribution is insignificant. Locally, boating and other leisure activities such as surfing or kite surfing can have a negative impact on important habitats and cause considerable disturbances for birds and marine mammals, particularly in the near-coastal zone. Recreational fishing may have an impact on declining stocks, in particular on local coastal stocks.

The increasing standard of living in the Baltic region will likely be followed by an increasing number of privately owned boats. In Estonia and Latvia, there is also a rapid increase in the tourism sector (Anonymous 2006b). As the number of recreational boats increases, so does the demand for marinas and space in the coastal zone. All indications point to recreational activities as an increasing pressure in the Baltic Sea area.

6.5 Eutrophication

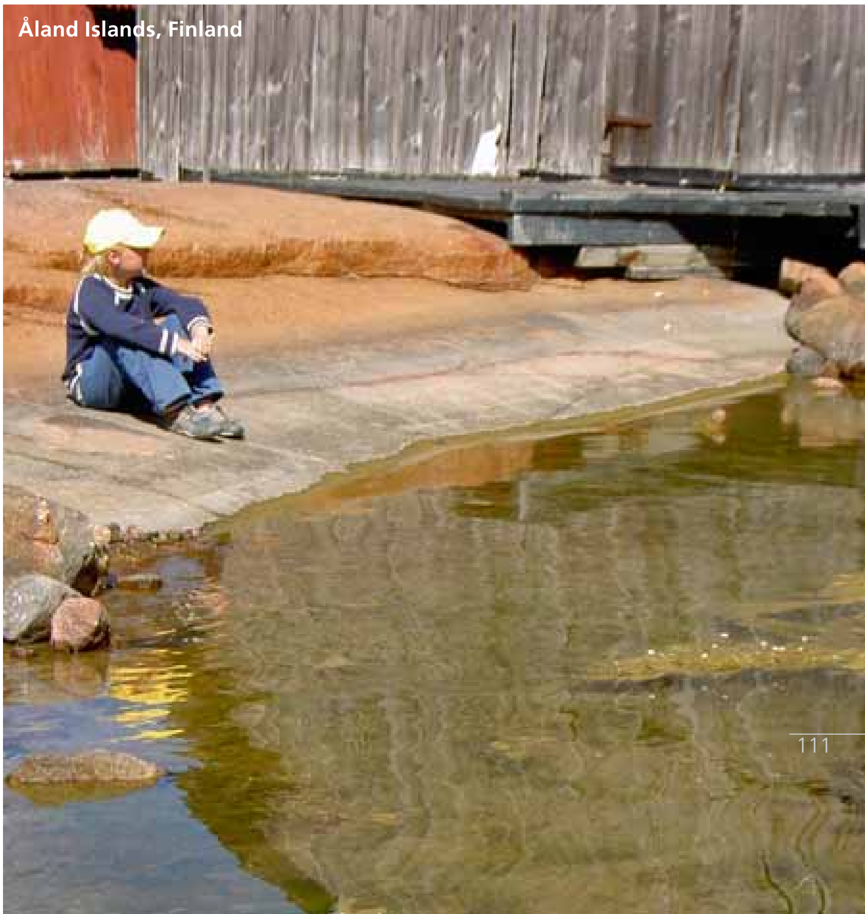
The effects of nutrient enrichment, also known as eutrophication, are perhaps the most significant threat to the marine environment of the Baltic Sea. Briefly, eutrophication means 'well nourished', but for more than three decades it has been acknowledged that very large amounts of nutrients, e.g., nitrogen (N), phosphorus (P), and sometimes organic matter, can result in a series of undesirable effects on ecosystem structure and functioning.

The Baltic Sea Action Plan (BSAP) identified eutrophication as one of the four main issues to be addressed in order to improve the health of the Baltic Sea environment. The Action Plan set a strategic goal related to eutrophication: 'Baltic Sea unaffected by eutrophication'. The vision of good environmental status of the Baltic Sea has been divided into five eutrophication-related ecological objectives: 'Concentrations of nutrients close to natural levels', 'Clear water', 'Natural level of algal blooms', 'Natural distribution and occurrence of plants and animals', and 'Natural oxygen levels'. In addition, HELCOM countries agreed on provisional country-wise nutrient reduction targets and decided to take action to diminish nutrient inputs to the Baltic Sea not later than 2016.

HELCOM recently published an integrated thematic assessment of eutrophication in the Baltic Sea which gives an in-depth overview of the problem (HELCOM 2009a). Hence, the issue is only briefly covered here.

6.5.1 Causes of eutrophication

Owing to the shallow and strongly stratified basin and the long residence time of water, the Baltic Sea is highly sensitive to eutrophication. The external inputs of nutrients to the Baltic Sea flow in from the drainage basin or are deposited from the atmosphere, but internal inputs of phosphorus from the sediments and fixation of atmospheric nitrogen by cyanobacteria can also be substantial. Excess nutrients originate particularly from municipal and rural human sources, from agricultural activities, as well as from nitrogen emissions from transportation and combustion activities and subsequent deposition onto the Baltic Sea.


Åland Islands, Finland

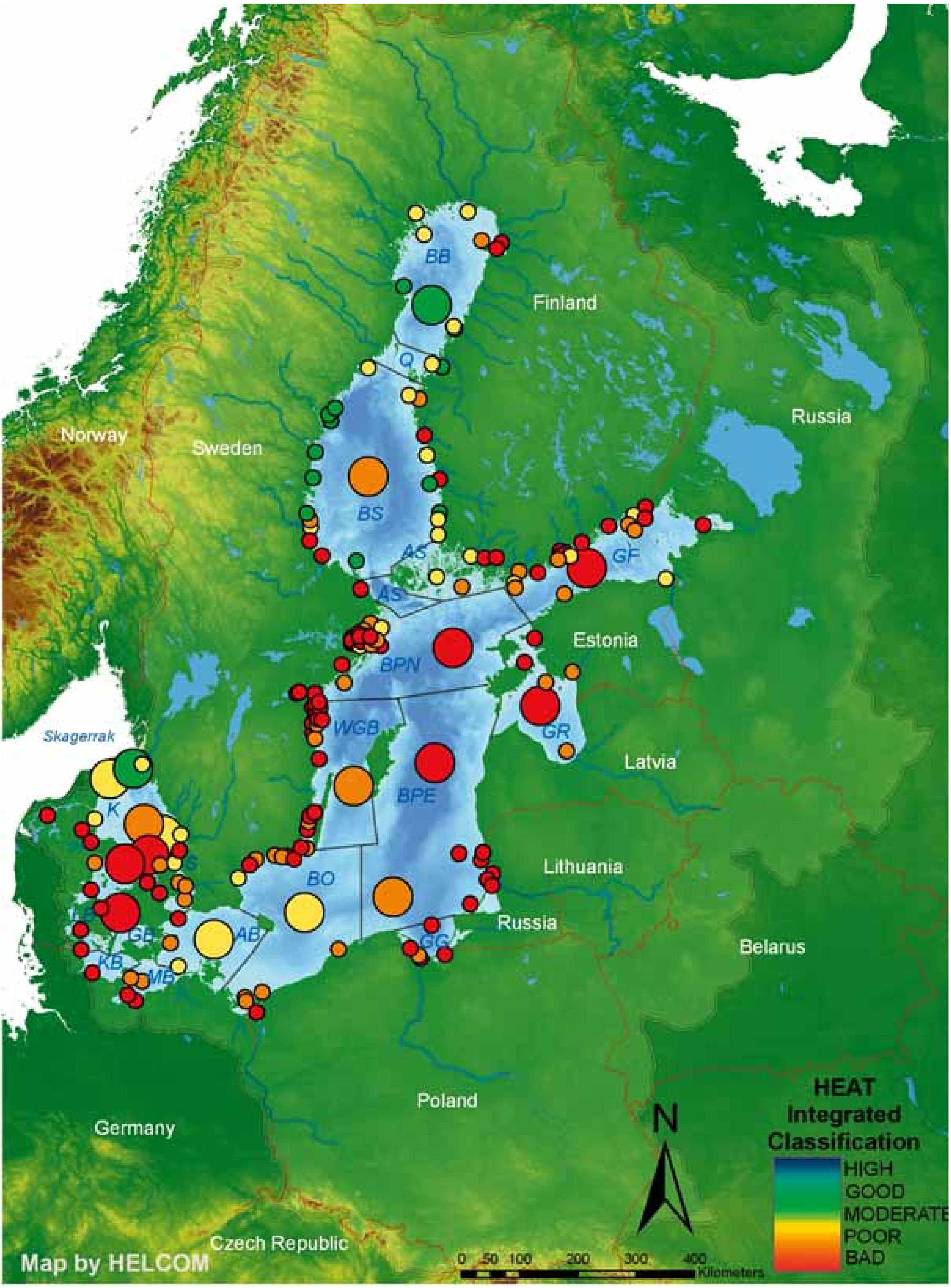


Figure 6.5.1. Integrated classification of eutrophication status based on 189 areas. Good status is equivalent to 'areas not affected by eutrophication', while moderate, poor and bad status are equivalent to 'areas affected by eutrophication'. Large circles represent open basins, while small circles represent coastal areas or stations. HEAT = HELCOM Eutrophication Assessment Tool. Abbreviations: BB=Bothnian Bay, Q=The Quark, BS=Bothnian Sea, AS=Archipelago Sea, ÅS=Åland Sea, BPN=Baltic Proper northern parts, GF=Gulf of Finland, BPE=Baltic Proper Eastern Gotland Basin, GR=Gulf of Riga, WGB=Western Gotland Basin, GG=Gulf of Gdańsk, BO=Bornholm Basin, AB=Arkona Basin, MB=Mecklenburg Bight, KB=Kiel Bight, GB=Great Belt, LB=Little Belt, S=The Sound, K=Kattegat.

Large nutrient inputs in combination with long residence times mean that nutrients discharged to the sea remain in the sea for a long time, even decades, before being flushed out of the Baltic Sea into the Skagerrak and North Sea surface waters or being buried into the sediments.

6.5.2 Eutrophication status of the Baltic Sea

The eutrophication status of the Baltic Sea in 2001–2006 was extensively assessed, analysed and evaluated in the HELCOM integrated thematic assessment of eutrophication (HELCOM 2009a). According to the report, the overall eutrophication status of the Baltic Sea is unacceptable. Only 13 of the areas assessed in the report were classified as being 'eutrophication non-problem areas', while 176 areas were classified as 'eutrophication problem areas'. The non-problem areas were found in the Gulf of Bothnia and in the Kattegat (Figure 6.5.1). The overall view, however, is not completely dark because nutrient inputs to the Baltic seem to have decreased slightly from 1995–2000 to 2001–2006. In most sub-basins, the highest surface concentrations of nutrients were observed in the 1980s and during the past two decades there have been encouraging signs of decreasing surface nutrient concentrations in many of the sub-basins.

6.5.3 Effects of eutrophication on biodiversity

Eutrophication has direct as well as indirect negative impacts on biodiversity. The manifestations of the large-scale eutrophication problem are well known in most parts of the Baltic Sea; these include turbid water caused by high quantities of planktonic algae and other planktonic organisms, mats of macroalgae stranded on shores, reduced distribution of benthic habitats such as eelgrass meadows, or oxygen depletion resulting in the death of benthic animals and fish.

The abundance of phytoplankton reflects the productivity of the planktonic ecosystem. Phytoplankton blooms in spring and summer are periods of naturally high production supplying energy to the ecosystem. However, excessive algal blooms and especially blooms of harmful algae, such as cyanobacteria or certain haptophytes, are a major problem in the Baltic Sea. Harmful algal blooms represent periods of reduced biodiversity and the toxins produced by algae are a threat to other organisms.

Extensive seagrass meadows and perennial macroalgal communities harbour the highest biodiversity found in coastal shallow-water areas. In the HELCOM Red List of Marine and Coastal Biotopes and Biotope Complexes, eutrophication was considered to be the main threat, along with general pollution, to the marine and coastal biotopes and biotope complexes of the Baltic Sea (HELCOM 1998).

Eutrophication has complex effects on the state of submerged aquatic vegetation: (1) reduced light penetration through the water column, caused by increased pelagic production, limits the depth penetration of submerged species such as eelgrass and bladder wrack; (2) increased sedimentation can prevent the settlement of new specimens on the seafloor and reduces the amount of suitable substrate to be colonized by perennial species on all types of substrates; and (3) the excess of nutrients during the whole vegetation period often favours opportunistic species with short life cycles and rapid development over the perennial species with lower productivity, causing a shift in community composition.

The composition of animal communities living on the seafloor of the Baltic Sea reflects the conditions of the environment. In the eutrophication process, broad-scale changes in the composition of the communities usually accompany the increasing organic enrichment of the sediments. At advanced stages of eutrophication, oxygen depletion becomes common. In many areas of the Baltic, the seafloor animals are exposed to widespread oxygen depletion or even complete anoxia. As a result, the biodiversity on the seafloor is reduced or animal communities are completely destroyed if anoxia is long lasting (see also Chapter 3.4, Benthic invertebrate communities). Permanent anoxia is common in deep, permanently stratified basins of the Baltic Sea, such as the Gotland Basin. In shallow areas, oxygen depletion mainly occurs seasonally.

The effects of eutrophication are also manifested in fish communities. In principle, eutrophication can be considered as having been a beneficial process to fisheries owing to increased fish production. However, it has affected fish stocks selectively; for example, increased turbidity of water has favoured percids and cyprinids and negatively affected salmonids, which prefer clear water. Eutrophication has affected fish communities in other ways also, such as through lost shelter or spawning ground function caused by reduced macro-vegetation coverage.

6.5.4 Conclusions

Eutrophication is a Baltic-wide problem of serious concern which has a negative effect on most components of biodiversity in the Baltic Sea. It reduces water quality and extends to nearly all areas of the Baltic Sea, including the marine protected areas. This implies that spatial protection measures cannot result in a favourable conservation status of biodiversity unless eutrophication is reduced to a level causing no disturbance.

For further conclusions and recommendations, see the integrated thematic assessment of eutrophication in the Baltic Sea (HELCOM 2009a).

Table 6.6.1. Substances or substance groups of specific concern to the Baltic Sea and included in the HELCOM BSAP.

1.	Dioxins (PCDD), furans (PCDF) & dioxin-like polychlorinated biphenyls
2.	a. Tributyltin compounds (TBT)
	b. Triphenyltin compounds (TPhT)
3.	a. Pentabromodiphenyl ether (pentaBDE)
	b. Octabromodiphenyl ether (octaBDE)
	c. Decabromodiphenyl ether (decaBDE)
4.	a. Perfluorooctane sulfonate (PFOS)
	b. Perfluorooctanoic acid (PFOA)
5.	Hexabromocyclododecane (HBCDD)
6.	a. Nonylphenols (NP)
	b. Nonylphenol ethoxylates (NPE)
7.	a. Octylphenols (OP)
	b. Octylphenol ethoxylates (OPE)
8.	a. Short-chain chlorinated paraffins (SCCP or chloroalkanes, C_{10-13})
	b. Medium-chain chlorinated paraffins (MCCP or chloroalkanes, C_{14-17})
9.	Endosulfan
10.	Mercury
11.	Cadmium

PCDD = polychlorinated dibenzo-*p*-dioxin; PCDF = polychlorinated dibenzofuran

6.6 Hazardous substances

The Baltic Sea is particularly sensitive to persistent, toxic and bioaccumulating substances because of its special abiotic characteristics and the fact that many of the resident species are not originally adapted to a brackish water environment.

Once released into the Baltic Sea, hazardous substances can remain in the marine environment for very long periods and can accumulate in the marine food web to levels which are toxic to marine organisms. Adverse effects on biodiversity caused by hazardous substances include impaired general health status of animals, impaired reproduction, and increased pollutant levels in fish consumed by humans. Effects on plants and invertebrates may be less pronounced because hazardous substances tend to accumulate over time and magnify through the food chain to species at higher trophic levels.

The loads of some hazardous substances to the Baltic Sea have decreased considerably over the past 20–30 years but problems still persist. With the increased use of chemicals and the development of new synthetic chemical compounds, concentrations of certain new substances have increased in the marine environment.

One of the four segments of the Baltic Sea Action Plan (BSAP) is devoted to hazardous substances (HELCOM 2007a). With the hazardous substances segment, the HELCOM Contracting Parties have committed themselves to numerous actions to diminish pollution. HELCOM has agreed to focus its work on two heavy metals, cadmium and mercury, and nine organic substances or substance groups (Table 6.6.1), which are specifically addressed in the BSAP.

6.6.1 Sources and inputs to the Baltic Sea

The main pathways of hazardous substances to the marine environment are atmospheric deposition and industrial and municipal wastewaters which are discharged directly to the Baltic or transported via rivers. In industrial processes, hazardous substances are emitted during all stages of the production chain.

Heavy metals

Heavy metals, such as mercury and cadmium which are specifically addressed by the BSAP, are widely used in industrial products and processes. As an example, mercury is extensively used in the chlor-alkali industry and cadmium in metal industries.

Significant amounts of atmospherically transported heavy metals originate from distant sources outside the Baltic Sea catchment area. For cadmium, lead and mercury, the proportion of distant sources located outside the HELCOM area was larger than half of the total emissions in 1996–2000 (HELCOM 2005b). A large part of the waterborne inputs of heavy metals also originates from non-HELCOM countries in the catchment area (HELCOM 2007f). For cadmium, lead and mercury, non-HELCOM countries accounted for 5% to 13% of total riverine transboundary inputs (HELCOM 2007f).

Annual emissions of heavy metals from HELCOM countries to air have decreased during the period from 1990 to 2006 by 47% for cadmium, 45% for mercury, and 86% for lead (Gusev 2008a) (Figure 6.6.1). Since the mid-1990s, riverine heavy metal loads, especially those of cadmium and lead, have also decreased in several countries (Knuuttila in prep.).

The total atmospheric deposition of heavy metals into the Baltic Sea during 2006 was 7.1 tonnes of cadmium, 3.4 tonnes of mercury and about 234 tonnes of lead (Gusev 2008b). The Belt Sea and Kattegat were the sub-basins receiving the highest amounts of heavy metal deposition. The reported waterborne loads to the Baltic Sea in 2006 amounted to 47.5 tonnes of cadmium, 10.8 tonnes of mercury and 274.2 tonnes of lead (Knuuttila in prep.).

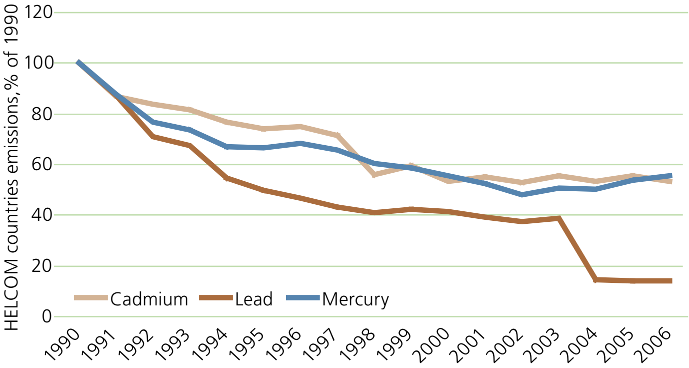


Figure 6.6.1. Total annual emissions (as % of 1990 emissions) of cadmium (Cd), mercury (Hg), and lead (Pb) to air from HELCOM countries in 1990–2006 (Gusev 2008a).

Organic pollutants

The main source or pathway to the Baltic marine environment of tributyltin (TBT) and triphenyltin (TPhT) is their use as anti-foulants on ship hulls and subsequent direct release to seawater. On the other hand, the main pathways of pentabromodiphenyl ether (pentaBDE), octabromodiphenyl ether (octaBDE) and decabromodiphenyl ether (decaBDE), hexabromocyclododecane (HBCDD), perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), short-chain chlorinated paraffins (SCCP), and medium-chain chlorinated paraffins (MCCP) to the Baltic Sea are via municipal and industrial wastewaters and the atmosphere. Municipal and industrial wastewaters are also the main sources of nonylphenols (NP), nonylphenol ethoxylates (NPE), octylphenols (OP), and octylphenol ethoxylates (OPE). The main pathways of endosulfan are via rivers receiving losses from agricultural land and from atmospheric deposition due to the application of agricultural pesticides containing endosulfan. Discharges from landfills and via storm water can be significant for some of the substances mentioned above (HELCOM 2007a, 2007g, HELCOM 2009b).

The net annual atmospheric deposition of polychlorinated dibenzo-*p*-dioxins/polychlorinated dibenzofurans (PCDD/Fs) to the surface of the Baltic Sea has decreased by 59% during the period 1990–2006. At the sub-basin level, the most significant decrease in PCDD/F deposition has been observed in the Belt Sea (73%) and Kattegat (65%). Currently, the highest levels of PCDD/F deposition over the Baltic Sea have been observed for the Belt Sea and the lowest deposition fluxes for the Gulf of Bothnia (Gusev 2008c).

6.6.2 Occurrence and impacts of hazardous substances on Baltic biodiversity

For many organic contaminants, a full assessment of their levels and effects in Baltic marine biota is not possible owing to the lack of monitoring and ecotoxicological data.

Although no direct, dramatic mass mortalities may occur after exposure to contaminants, reduced fitness of organisms owing to physiological disturbances and increased energy costs, e.g., related to detoxification processes, synthesis of chaperone proteins and maintenance of other energy-consuming protective functions to cope with chemical stress, may have significant long-term structuring effects on population and community scales.

PCBs and DDTs

Amongst the most well-known success stories for nature conservation in the Baltic Sea are the recoveries of seal and predatory bird populations from the declines caused by hazardous chemicals. During the 1970s, the reproductive health of seals and predatory birds was observed to be severely impacted as a result of pollution by PCBs (polychlorinated biphenyls) and DDT (dichloro diphenyl trichloroethane). Uterine damage is now less common in grey seals (Bäcklin et al. 2008) and for ringed seals the situation has also improved simultaneously with decreasing concentrations of contaminants (Helle 1981, Ministry of Agriculture and Forestry 2007). Intestinal ulcers, on the other hand, are now common, even in young grey seal individuals (HELCOM 2007g).

Decreasing reproductive success of top predators is an indicator of detrimental effects of accumulating hazardous substances. The shell thickness of the eggs of common guillemot (*Uria aalge*) from Stora Karlsö in the central Baltic Proper has been monitored in Sweden since the end of the 1960s. The thin eggshells observed during the 1960s were attributed to the severe DDT pollution during that period. Guillemot eggshell thickness increased in the 1990s and the shell thickness is now back to levels recorded prior to the 1940s. Similar impacts and recovery from DDT and other substances have been observed for white-tailed eagle (*Haliaeetus albicilla*) brood size and nesting success (Figure 6.6.2).

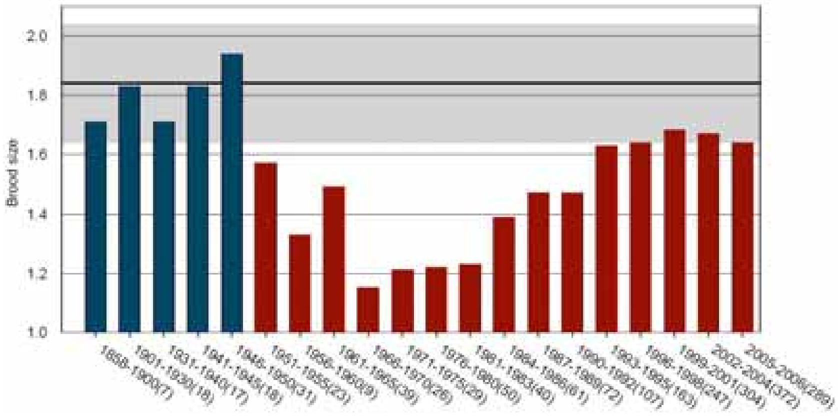


Figure 6.6.2. Mean brood size of white-tailed sea eagle on the Swedish Baltic coast over time. Sample size for each time period is given in brackets. Reference level based on 1858-1950 is given with 95 % confidence limits according to Helander & Bignert (2008).

PCB levels in the muscle of herring in Swedish coastal areas from the Kattegat to the Bothnian Bay decreased significantly during the time period 1978/1980–2005. The levels are still significantly higher in the Baltic Proper and in the southern Bothnian Sea compared to the Kattegat and the Skagerrak. Two cod liver time-series (1980–2004/2005) from the southeast of Gotland and the Kattegat also show significant decreasing trends of PCBs (Bignert et al. 2007a).

Heavy metals and dioxins

Decreasing trends, or no trend at all, have been observed for mercury concentrations in herring in Swedish and Finnish coastal waters. In recent years, cadmium levels in herring and cod have been decreasing in some Swedish coastal areas. However, the levels have not yet reached those of the beginning of the 1980s (Bignert et al. 2007b, ICES 2007c). Among the positive signs is the clear decrease in lead levels in biota (e.g., herring and perch liver) in most Baltic Sea areas (Bignert et al. 2007c, ICES 2007c).

Concentrations of dioxins in the Baltic marine ecosystem declined during the 1970s and 1980s but this decrease levelled off in the 1990s and fatty Baltic fish (e.g., herring and salmon) still have high levels of dioxin contamination (HELCOM 2004).

Organotin compounds

The occurrence of organotin compounds is widespread in the Baltic marine environment (water, biota and bottom sediment), particularly near harbours and shipyards (Table 6.6.2, HELCOM 2009b). Elevated levels also occur near ship routes and at disposal sites for dredged material. The current

Table 6.6.2. TBT and TPhT concentrations in Baltic Sea water. The Predicted No-Effect Concentration (PNEC) has been presented for comparison purposes (HELCOM 2009b).

Area	Seawater (ng l^{-1} as TBT or TPhT)
Denmark, Sound and Kattegat[1]	<2.4 TBT
Finland, Gulf of Finland, dredging sites[2]	<1–13.6 TBT / TPhT not detected (<1)
Lithuania, southern Baltic Proper, harbour area[3]	12 TBT / TPhT not detected (<1)
Sweden, Bothnian Sea[4]	mean 11 TBT / mean 12 TPhT
Sweden, northern Baltic Proper[4]	mean 2.2 TBT / TPhT not detected
Sweden, Kattegat[4]	0.24–2.2 TBT / 0.03–2.4 TPhT
Sweden, Kattegat[4]	year 2001: 0.24–1.5 TBT / max 0.68 TPhT year 1987: 29–634 TBT
PNEC	AA 0.2 TBT* / MAC 1.5 TBT* / 1.0 TPhT**

[1] One bay in the Sound and one 'fjord' in Kattegat; [2] Six sites in the vicinity of a harbour under construction (dredging), 8 samplings in 2005; [3] One harbour area sampled in 2006; [4] Sampled in 2001; * proposed EU Environmental Quality Standard (EQS) for chronic effects (AA-EQS, annual average value) and for short-term ecotoxic effects (MAC-EQS, maximum allowable concentration) in inland and other surface waters for TBT, ** Estimated PNEC for TPhT in marine waters.

levels of the most toxic triorganotin compounds, TBT and TPhT, pose a risk to the marine environment and especially to organisms at the lower trophic levels of the food web, such as sediment-dwelling organisms. Imposex and intersex reproductive and sexual disorders induced by TBT are widespread in organisms such as neogastropods in the Danish Straits and coastal areas (Strand & Jacobsen 2002, 2005, HELCOM 2003). High butyltin concentrations have also been found in sediments and biota from marinas, e.g., in the Gulf of Gdańsk (Albalat et al. 2002, Falandysz et al. 2002), with potentially similar effects on local populations and thus species distributions.

The most sensitive reaction of mammals to TBT is linked to effects on the immune system. It is supposed that TBT could increase the susceptibility of mammals to diseases such as microbial infection. It is possible that TBT acts in a synergistic way with other immune toxicants such as PCBs. The potential adverse effects of contaminants (e.g., PCBs and heavy metals) on the immune system and the health status of marine mammals are still under some debate (Beineke et al. 2005).

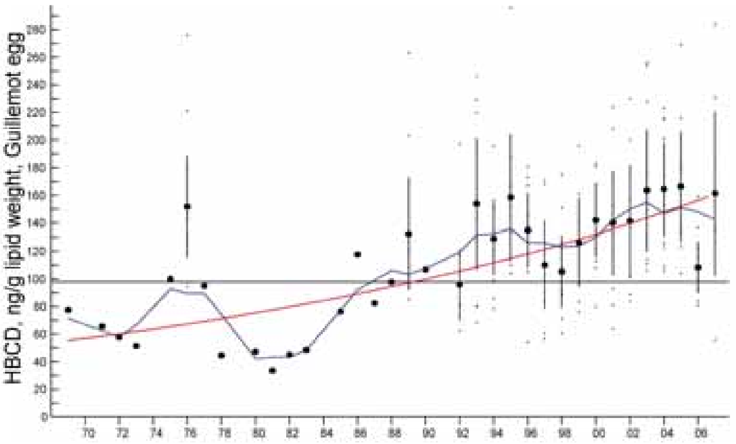


Figure 6.6.3. Temporal trends of HBCDD concentrations (ng g^{-1} lipid weight) in guillemot eggs in 1969–2005 (Bignert et al. 2007d).

PFOS and HBCDD

PFOS (perfluorooctane sulfonate) has various types of uses, e.g., in the semiconductor industry and as a dirt rejecter or a surface active agent in waxes, while HBCDD (hexabromocyclododecane) is widely used as a flame retardant.

There are indications that PFOS may be threatening Baltic Sea top predators such as seals and predatory birds via secondary poisoning (HELCOM 2009b). Moreover, the level of HBCDD in guillemot eggs shows a significant increase of about 3% per year (Figure 6.6.3). However, no trend has been detected for HBCDD in herring muscle during the time period monitored, 1999–2005, although HBCDD levels in fish of the Baltic Sea are in general low and always lower than the estimated Predicted No-Effect Concentration (PNEC) level (HELCOM 2009b).

6.6.3 Major international frameworks regulating hazardous substances

The two main global agreements on hazardous substances are the Stockholm Convention on Persistent Organic Pollutants and the Protocol on Persistent Organic Pollutants to the UNECE Convention on Long-Range Transboundary Air Pollution. The Anti-fouling Convention of IMO concerns the use of organotin compounds (e.g., TBT and TPhT); the application of TBT and TPhT has been banned in anti-fouling systems since 2003 and the removal of coatings containing TBT or TPhT on hulls or

Chinese mitten crab (*Eriocheir sinensis*), Bothnian Bay, Finland

other surfaces has been required since 2008 (see also Chapter 6.2, Maritime activities).

EU legislation concerning hazardous substances includes the Regulation 2006/1907/EC concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), the Integrated Pollution Prevention and Control Directive (96/61/EC) and the Water Framework Directive (60/2000/EC) complemented with a list of priority substances (2455/2001/EC and a proposal COM(2006)397). In addition, many HELCOM recommendations concern the limitation of chemical pollution, including HELCOM Recommendation 19/5 on the HELCOM Strategy for hazardous substances.

6.6.4 Conclusions

There are encouraging signs of decreasing concentrations and impacts on biota of certain hazardous substances for which there are long-term monitoring data. At the same time, there are increasing concerns about the occurrence and negative biological effects of substances such as TBT/TPhT, PFOS, dioxins, furans and dioxin-like PCBs. The effects of specific substances on Baltic biodiversity are difficult to estimate owing to a lack of ecotoxicological information or a lack of monitoring data concerning both the occurrence of substances and their biological effects in the Baltic marine environment.

Bearing in mind the complex hydrographic conditions, and the fact that most Baltic Sea organisms live at the edge of their physiological tolerance range, anthropogenic chemical pollution has to be seen as a further stress factor acting upon Baltic Sea biodiversity. Only during recent decades have we started to gain advanced understanding on how multiple stressors (e.g., salinity, temperature, hypoxia and chemical pollution) in combination may affect biota and, thus, biodiversity.

6.7 Alien species

The Baltic is a sea of invaders as most animal and plant species there are postglacial immigrants. In contrast to distribution by natural spreading mechanisms, alien species are defined as "*species or lower taxa occurring outside of their natural range (past or present) and dispersal potential...*" (IUCN 2002). Some alien species have become invasive, i.e., an alien whose population undergoes an exponential growth stage and rapidly extends its range (Occhipinti-Ambrogi & Galil 2004).

Alien species act as modifiers of biodiversity and biogeography. Owing to this, the characteristics and integrity of the Baltic developed since the last Ice Age are threatened, and the sea is subject to worldwide homogenization of the aquatic flora and fauna (Leppäkoski & Olenin 2001). Recent establishment of a number of alien species populations can be considered as biocontamination (Arbačiauskas et al. 2008) of the indigenous Baltic ecosystem because the invaders have caused alterations in the taxonomic structure of the invaded communities. In the Baltic, these changes have been restricted mainly to the family and genus level. For example, more than every second established alien species included in the Baltic Sea Alien Species Database (Olenin et al. 2008) belongs to genera that are not represented among the native flora and fauna of the Baltic Sea. In the inner Baltic, some newcomers contribute to taxonomic diversity at higher levels: the alien barnacle *Balanus improvisus* is the only representative of its order Thoracica. Similarly, the only species belonging to gambarid decapod crayfish (*Orconectes limosus* and *O. virilis*) and to mud crabs (Decapoda, Xanthidae (*Rhithropanopeus harrisii*)) as well as the Chinese mitten crab *Eriocheir sinensis* (family Grapsidae) are invaders in the Baltic. Only one native comb jelly species

(*Pleurobrachia pileus*) represents the phylum Ctenophora; in addition, an introduced species (*Mnemiopsis leidyi*) has become established since 2006. Furthermore, only one native cumacean crustacean (*Diastylis rathkei*) was present prior to the introduction of *Stenocuma graciloides*, first found in 2004.

One of the management objectives of the maritime segment of the Baltic Sea Action Plan (BSAP) is 'No introductions of alien species from ships'. In addition, the biodiversity segment of the BSAP includes the specific target: *"To prevent adverse alterations of the ecosystem by minimising, to the extent possible, new introductions of non-indigenous species"*.

6.7.1 Trends and impacts

Trends

Since the early 1800s, about 120 alien species have been recorded in the Baltic Sea including the Kattegat (Figure 6.7.1, Box 6.7.1). 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).

Since World War II, 81 new alien species have been recorded in the Baltic, 35 species of which have been ship-assisted. Eight new species have been observed during the past five years alone. Many of the past invaders are currently widespread and occur in high densities in the coastal areas of the Baltic Sea; for example, the barnacle *Balanus* improvisus and the bivalve *Dreissena polymorpha*, but also

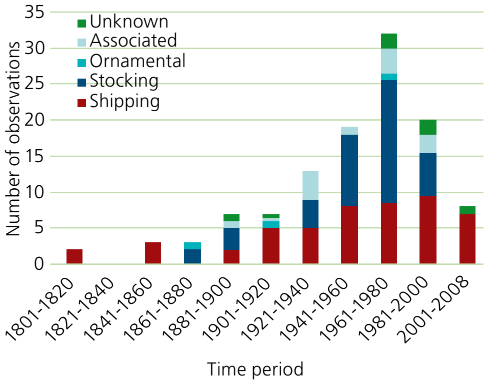


Figure 6.7.1. Number of new alien species observed since the early 1800s in the Baltic Sea (including the Kattegat) and likely vector of introduction (derived from the Baltic Sea Alien Species Database, update 10 April 2008). Note that the last bar only covers the past 8 years, while the other bars cover 20-year periods.

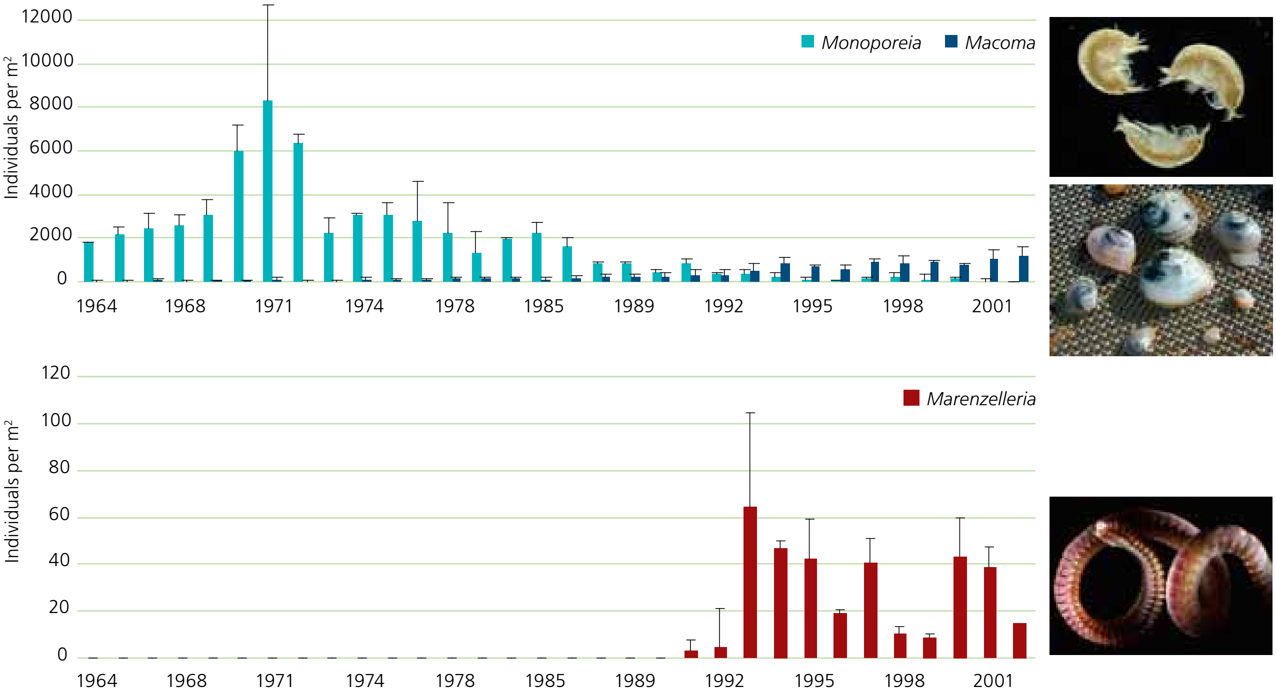


Figure 6.7.2. Long-term changes in the Tvärminne area, western Gulf of Finland, in the abundance of zoobenthos described as density (individuals per m^2 on y-axis) of the dominant native species (*Macoma balthica*, the Baltic clam, and *Monoporeia affinis*, an amphipod crustacean) and the invasive North American bristle worm *Marenzelleria* spp. Note the difference in abundance scales (Laine et al. 2001). Photos by Ari O. Laine (*Monoporeia* (top) and *Macoma* (middle)) and Johanna Stigzelius (*Marenzelleria* (bottom)).

Box 6.7.1. Invasion status of the Baltic Sea as of April 2008

Number of species[1]	
Number of alien species recorded	120
Number of established[2] species	77
– of which ship-mediated species	40

Cergopagis pengoi

Major groups[3]	
Crustaceans (shrimps, crabs, etc.)	23
Molluscs (snails, mussels, clams, etc.)	9
Fish	8
Oligochaetes	7
Polychaetes (bristle worms)	4

[1] Including the Kattegat.
[2] A few species with unknown status are to be added (in total 25 species).
[3] Only species known to be established were taken into account.

Source: Baltic Sea Alien Species Database (http://www.corpi.ku.lt/nemo; update: 10 April 2008)

some of the most recent invaders have shown a very rapid expansion. One of the best-documented invasions is that of the benthic bristle worm *Marenzelleria* spp. that currently occurs in the entire Baltic Sea and has become common in many soft-bottom habitats and is even a dominant species in some bottom communities; this has occurred in only the roughly ten years since its first appearance (Zettler 1996, Cederwall et al. 1999, Perus & Bonsdorff 2004, Figure 6.7.2). Recent genetic studies have also revealed that the invasion has been made by three different species (*M. viridis, M. neglecta* and *M. arctia*) that obviously are still expanding their range (Blank et al. 2008). Other recent alien species with a rapid invasion over large sea areas in the Baltic include pelagic species such as the fishhook water flea *Cercopagis pengoi* and the American comb jelly *Mnemiopsis leidyi*. However, in 2009 scientists carried out genetic analyses of samples of *M. leidyi* and found out that specimen recently identified as *M. leidyi* were in fact *Mertensia ovum*, an arctic comb jelly (Maiju Lehtiniemi, pers. comm.). American comb jelly *M. leidyi*, nevertheless, occurs at least in the Southern Baltic Sea.

In the Baltic and elsewhere, the increased invasion rate (Figure 6.7.1, Box 6.7.2) can be related to several factors: (i) increased number and size of ships, (ii) increased speed of ships, resulting in better survival of organisms during the voyage, (iii) use of separate tanks instead of cargo tanks for ballast water (less polluted ballast water), (iv)

Box 6.7.2. How do we know which species is a human-mediated newcomer?*)

For most of the alien species recorded in the Baltic Sea, there is evidence of their origin achieved through studies of:

- paleontological and archaeological records (absence of shells and other remnants),
- historical data (absence in previous surveys and check lists, documented first collection or first release),
- biogeographical patterns (discontinuous distribution, known as introduced from other regions),
- dispersal mechanisms (links to human-mediated vectors, direct evidence of transport),
- molecular genetic evidence, and
- ecological evidence (short larval survival time, community association (e.g., fouling on ship hulls), post-introduction range expansion).

However, it is often difficult to determine whether a species is native or introduced; such species with an unknown origin are termed cryptogenic (Carlton 1996).

*) Based on lectures given in 1997 by Prof. James T. Carlton (Williams College, Mystic, Connecticut, USA) at Åbo Akademi University.

successive opening of new trade routes in the post-war era, (v) opening of canals, supporting both natural and human-assisted migration along inland waterways, and (vi) intentional introductions for aquaculture and stocking purposes. In the former Soviet Union, tens of Ponto-Caspian crustacean species were transplanted into the Baltic catchment area as potential prey items to stimulate fish production in lakes and water reservoirs in the 1950s to 1970s. Some of these species have expanded their range along rivers to coastal waters (Ojaveer et al. 2002).

In the Baltic Sea, the dispersal of alien species has been rapid and effective, as demonstrated by some of the most successful invaders. The minimum rates of secondary, within-basin spread were estimated for some ship-mediated animals: the American barnacle *Balanus improvisus* 30 km per year; the North American bristle worm *Marenzelleria* spp. 170–480 km per year, and the mud snail *Potamopyrgus antipodarum*, native to New Zealand, 20–50 km per year (Leppäkoski & Olenin 2000).

Origin of the invaders

The worldwide transport of alien species is reflected in the origin of the species, with the most important donor areas for the inner Baltic Sea being North America and the Black and Caspian Sea region (Figure 6.7.3). Brackish-water seas are especially open to species introductions for several reasons. In the Baltic Sea, horizontal and vertical gradients (salinity range from < 2 to about 20 psu) allow for a greater range of opportunities for alien species of different origin (Paavola et al. 2005). Invasion pressure is two-directional, through both oceans and seas and inland waterways; several freshwater invasion corridors open into the Baltic via rivers and canals from southeast to the southern Baltic and the Gulf of Finland. In addition, important ports worldwide are located in brackish reaches of estuaries. Hence, brackish fauna and flora are more commonly loaded with ballast water. Generally, most brackish-water species are tolerant to wide salinity and temperature ranges, resulting in better survival in ballast water compared to strictly freshwater or marine organisms. In brackish waters, the ratio of non-native to native species may be as high as 1:5 (in estuaries or lagoons) compared with 1:20 at open coasts and 1:40 in European marine waters (Reise et al. 2006).

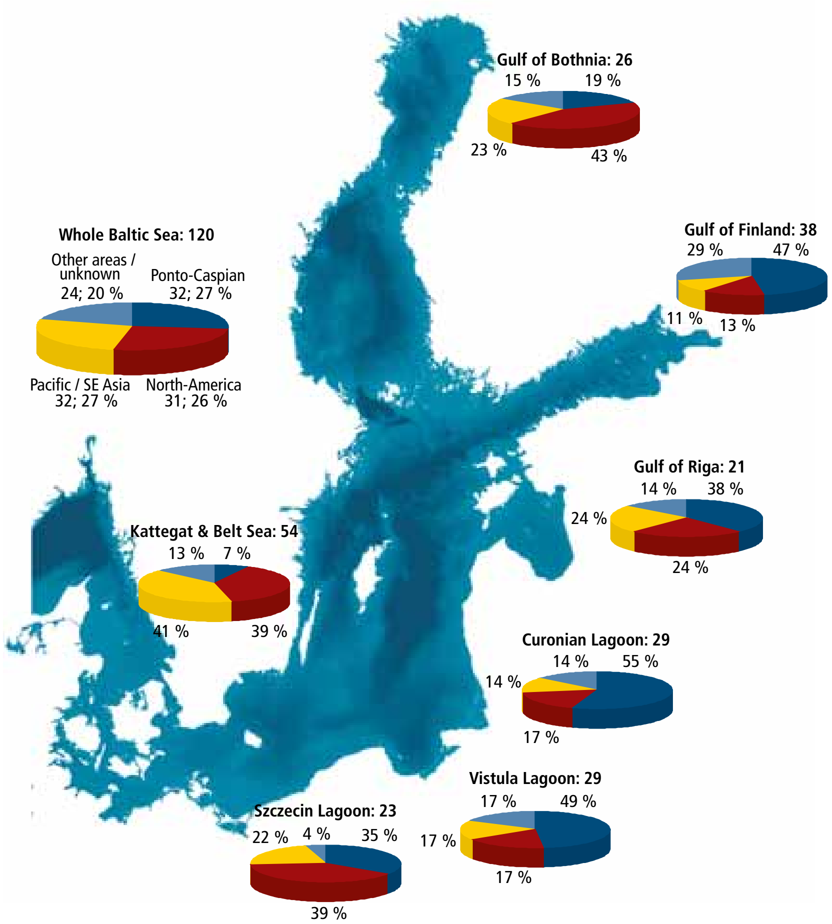


Figure 6.7.3. Number of alien species recorded (including also those not established in order to illustrate the invasion pressure) in the Baltic Sea according to their area of origin. Of 120 species found, 77 are known as established, 18 as not established, while for 24 species the establishment status is unknown. Based on Leppäkoski & Olenin (2001), current data derived from the Baltic Sea Alien Species Database in October 2008.

Ecological impacts

Alien species affect the structural and functional properties of ecosystems at local (Figure 6.7.2), regional, and basin-wide scales. Several invaders represent a new functional group in the invaded community and differ substantially from natives in life form and efficiency of resource utilization (Table 6.7.1).

In many cases, the ecological impacts of alien species on the Baltic Sea ecosystem have been difficult to observe or they are poorly understood owing to a lack of focused studies. However, the increasing spread increases the risk that native species or habitats of high conservation value will be impacted, and an established population may adapt physiologically and ecologically to the Baltic environment, increasing the risk of ecological and environmental impacts. These impacts are due to changes in resource competition (food,

Table 6.7.1. Examples of ecological impacts caused by Ponto-Caspian invasive species in the Baltic Sea, inland European freshwater bodies and North American Great Lakes (modified and completed from Ojaveer et al. 2002). Species included: *Cordylophora caspia* (brackish-water hydroid polyp), *Cercopagis pengoi* (fishhook water flea), *Chelicorophium curvispinum* (brackish-water amphipod), *Hemimysis anomala* (mysid shrimp), *Dreissena polymorpha* (zebra mussel), and *Neogobius melanostomus* (round goby).

Function/Species	Brackish-water polyp	Fishhook water flea	Brackish water amphipod	Mysid shrimp	Zebra mussel	Round goby (fish)
Modifies rocky bottom or sediment substrate	X		X		X	
Provides shelter from predators and currents	X				X	
Traps and accumulates organic particles from water	X			X	X	
Increases water clarity (= lowers amount of particles)	X				X	
Affects large aquatic plants	X				X	
Redirects energy from water to bottom or vice versa	X		X	X	X	
Provides prey to plankton- and/or bottom-eating fish		X	X	X	X	X
Provides food for waterfowl			X	X	X	X
Excludes competing species			X		X	X
Increases soluble (bioavailable) nutrients					X	

space), changes in habitat (physical and biological), changes in the trophic web, toxins produced by alien algal species, introduction of new disease agents and parasites (or introduction of a species that is a missing link as host in the life cycle of a parasite), genetic effects on native species (hybridization, loss of native genotypes), and, as a worst-case scenario, extinction or drastic reduction of native species. In this way, it is possible to distinguish between the types of impact but not to assess the scales of impact; much remains to be explored in the field of invasion biology.

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). In these areas, the impacts related to bottom-living alien animals are relatively well understood (Table 6.7.1), while there is much to learn about the ecological roles of planktonic invaders, such as the fishhook water flea (*Cercopagis pengoi*, first found in 1992) and the highly invasive American comb jelly (*Mnemiopsis leidyi*, first found in 2006). The further spread, biology and feeding ecology (especially their potential impacts on Baltic food webs) of these species must be monitored carefully.

Every single species establishment in a novel region and ecosystem opens new opportunities for ecological research. These usually unintentional 'transplantation experiments' can be used for the study of concepts such as adaptive strategies, niche dimensions, interspecific relationships, and dispersal mechanisms (Leppäkoski 2002).

Socio-economic impacts

The newcomers affect the ecosystem services available for humans, such as primary production, degradation capacity, fish production, recreational uses and amenities.

From this point of view, the most unwanted alien invaders in the Baltic are (1) fishery disrupters, (2) fouling organisms, and (3) boring species. Impacts of fishery disrupters are anticipated but not yet proven. The recently detected comb jellies (*Mnemiopsis leidyi* and *Mertensia ovum*) are now abundant in parts of the Baltic Sea. The American comb jelly *Mnemiopsis leidyi* likely contributed to the collapse of Black Sea commercial fisheries in the late 1980s, and a similar collapse in the Caspian Sea in the early 2000s. Fouling organisms such as the Ponto-Caspian water flea *Cercopagis pengoi* cause clogging of gillnets. The zebra mussel *Dreis-*

sena polymorpha affects cooling systems and fouls beaches with its sharp shells, and the barnacle *Balanus improvisus* and the colonial hydroid *Cordylophora caspia* are sessile biofoulers common on boat hulls and underwater installations. The boring shipworm *Teredo navalis* has expanded its range in the southern Baltic and threatens, e.g., the numerous and well-preserved historical wrecks and other wooden structures.

The recent findings (in the early 2000s) of dense populations of Conrad's false mussel (*Mytilopsis leucophaeata*) in the cooling water discharge areas off Finnish nuclear power plants must be taken seriously. This species has its original distribution in the subtropical and temperate Gulf of Mexico area and is tolerant to the entire salinity range found in the Baltic Sea. In Western Europe, it has become a serious biofouling organism in cooling water systems, with economic impacts for water-dependent industries (Laine et al. 2006). The species may benefit from the future expected climate change-associated temperature increase.

Some of the aquatic alien species are beneficial (e.g., in the Baltic, the North American rainbow trout in aquaculture). Perhaps more importantly, many non-native species and their larvae play an important role in the coastal food webs, serving as food sources for commercially important native species.

6.7.2 Major international frameworks that address invasive species

Eradication of established aquatic alien species is a challenging and often hopeless task. Prevention of further arrivals is the most effective way to address alien species introductions and, thus, is a crucial issue for the biosecurity of the Baltic Sea area. Ships are currently the most important vectors for alien species. The 2004 International Convention for Control and Management of Ships' Ballast Water and Sediments (BWM Convention) under IMO will be the global instrument to regulate the management, treatment and release of ballast water once it enters into force.

A road map for the implementation of the BWM Convention in the HELCOM area was included in the BSAP with the ultimate goal of ratifying the Convention by all Baltic Sea countries by 2013 at the latest. As part of the road map, a list of non-indigenous or cryptogenic species in the Baltic Sea and a list of HELCOM target species that may impair or damage the environment, human health, property or resources in the Baltic Sea have been developed, based on the Baltic Sea Alien Species Database (www.corpi.ku.lt/nemo) and the report to HELCOM by Leppäkoski & Gollasch (2006). These lists will serve as an aid in the implementation of the specific provisions of the BWM Convention and the related IMO Guidelines, e.g., related to risk assessments, and they will be updated on a regular basis and their accuracy enhanced as new information becomes available.

All HELCOM countries have agreed to join the initiative by the OSPAR Commission to request vessels transiting the Atlantic or entering the North-East Atlantic from routes passing the West African Coast to conduct, on a voluntary basis, ballast water exchange before arriving in the OSPAR area or passing through the OSPAR area and heading towards the Baltic Sea, and the IMO was notified of this action (BWM.2/Circ.14). The General Guidelines on the Voluntary Interim Application of the D1 Ballast Water Exchange Standard in the North-East Atlantic have been applicable from 1 April 2008. Similarly, Guidelines to address vessels leaving the Baltic and transiting through the OSPAR maritime area to other destinations are being


The comb jelly *Mertensia* sp.


Mytilopsis leucophaeata

developed to avoid ballast water exchange until the vessel is 200 nautical miles off the coast of North-West Europe in waters deeper than 200 m.

Following the road map, work has also started to develop and agree on criteria to distinguish between routes which pose a risk for secondary spreading and for which ballast water management (ballast water exchange, ballast water treatment) could reduce this risk, and those routes where natural spreading cannot be avoided (and for which exemption from ballast water management could be granted). This work is also to ensure that a unified exemption system is created in the Baltic and to serve as a basis for risk assessments for voyages outside the Baltic.

6.7.3 Conclusions

Alien species are a major threat to indigenous biodiversity, leading to the restructuring of communities that formerly consisted of native species but are, to an increasing extent, dominated by alien invaders. As far as is known, no native species has become extinct in the Baltic Sea owing to the introduction of alien species, but it cannot be guaranteed that this will be the case in the future. Xenodiversity (structural and functional diversity caused by non-native species) tends to reach and even exceed native biodiversity in terms of the number of species and life forms, especially in coastal lagoons and river mouths. This trend towards increasing homogeneity of flora and fauna between, for example, the European and North American continents is one of the most important changes of the geography of life since the retreat of the continental glaciers (Crosby 1972, Leppäkoski & Olenin 2001).

Effective reduction in the number of ship-mediated ‘stowaways of the seas’ is a high-priority goal and there are a number of onboard ballast water treatment systems being developed. It is obvious that no single treatment technique alone will be able to eliminate all types of organisms. A combination of different physical (filtering, centrifugation, ultraviolet light and ultrasound treatment) and chemical techniques may prove to be the most effective means. Some basic differences between bioinvasions (biological pollution) and other forms of marine pollution should be kept in mind. While chemical and physical pollution can be reduced or stopped, living organisms tend to reproduce and spread if they meet hospitable environmental conditions in the water body into which they were initially released through shipping or other vectors. Chemicals do not spread actively. Furthermore, chemicals tend to decrease over time through degradation, whereas established alien aquatic species are permanent, and the impacts of invasive species are usually irreversible.

In the future, climate change may enhance northward transport of species of southern origin with distinct advantages over the native species. In addition, future scenarios are dependent on economic development and political decisions, such as those related to EU transport policy (e.g., trends to develop inland waterways traffic, deepening and widening of canals), and the increase of ship traffic, for example, along the Volga-Baltic Waterway.

6.8 Noise pollution

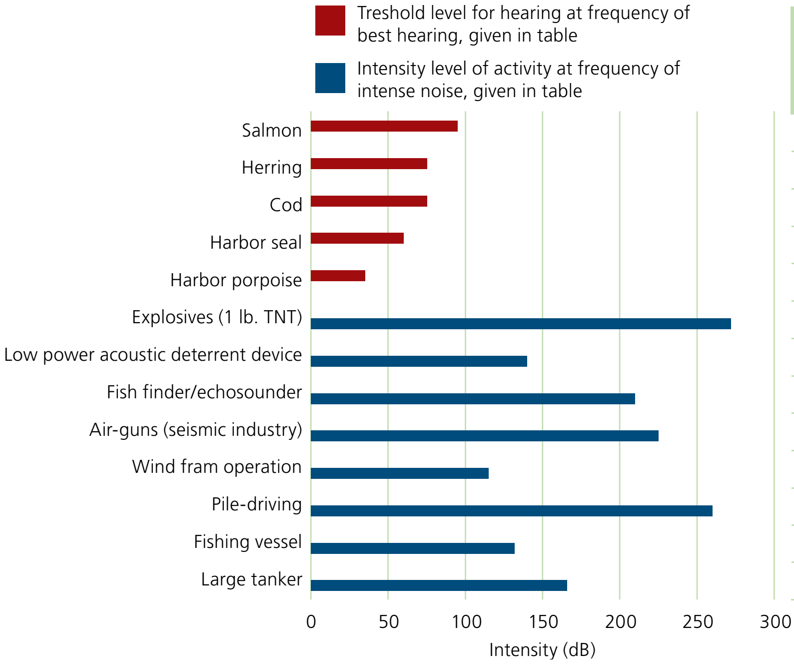
Several anthropogenic activities produce underwater noise pollution in the coastal and marine environment, for instance ship and boat traffic, their echo-sounders, seismic surveys, drilling, pile-driving, SONARs, underwater explosions, extractions, gas pipeline work and operation and wind farm operations. Marine animals that rely on hearing are at risk of being affected by underwater noise either by interference with biological signals, exclusion from natural habitats, stress, and even by direct physical harm and tissue damage.

Information on ambient noise levels and their actual impact on animals in the Baltic Sea area are largely missing. This section gives an overview of noise generation from activities that are present in the Baltic Sea and the known sensitivity of mammals and fish to noise in their habitat.

6.8.1 Hearing in the marine environment

The impact of noise depends on the intensity level (loudness) and frequency, the duration as well as the frequency of repetition of the sound, the transmission loss from a source to the animal, and the hearing sensitivity of the animal. An animal can detect the sound when the frequency of the source overlaps with the animal's frequency window for hearing, and if the noise is more intense than the animal's threshold level for hearing. Figure 6.8.1 shows the hearing threshold levels for harbour porpoise (*Phocoena phocoena*), harbour seal (*Phoca vitulina*), and selected fish species as well as the intensity levels of some common anthropogenic activities in the Baltic Sea.

When anthropogenic noise has frequencies similar to biological signals, the noise may interfere with signals used for communication and location, an effect that is called masking. Known behavioral changes of mammals in response to noise include changing surfacing and breathing patters, changing their communication frequencies, disruption of social connections, stress etc. and may result in active avoidance of areas with high sound levels and also greatly reduce the distance over which communication is possible. In the immediate vicinity of some anthropogenic activities such as using airguns and certain SONARs, the noise can be loud enough to cause immediate and permanent hearing damage to both mammals and fish. For a more complete list of impacts on and responses of cetaceans to anthropogenic noise, see Nowacek et al. (2007).



At frequency (kHz)	Frequency range of hearing/activity (kHz)
0.16	0.03 - 1
0.1	0.03 - 1
0.16	0.03 - 1
8 - 16	0.1 - 100
16 - 140	0.25 - 140
1	Broad-band
2.5 - 10	2.5 - 160
50/200	
0.05 - 0.3	0.01 - 3
0.125	0.01 - 0.5
0.2	0.02 - 20
0.1	0.02 - 10
0.1	0.02 - 10

Figure 6.8.1. Hearing sensitivity of marine animals (red) in the Baltic Sea and intensity levels of common activities (blue). Intensity levels for all activities are given at a reference pressure of 1μPa. The information stems from specific systems and models. Variations occur. Sources: NRC 2003, Thomsen et al. 2006 and references therein.

6.8.2 Activities generating noise in the Baltic Sea

Industrial activities

Industrial noise frequently originates from few, more or less stationary sound sources during resource exploration, extraction, construction and operation of wind turbines as well as use of deterrent devices in fisheries such as pingers.

During pile-driving operations associated with construction, e.g. of wind farms, noise is produced at high intensity levels at broad-band frequencies. Pile-driving is estimated to be audible for harbour porpoises and harbour seals at least 80 km from the source (Thomsen et al. 2006) Within this zone the noise can potentially interfere with communication and echolocation clicks. The zone where behavioral changes can be expected range from a few up to 20 km, and hearing loss may occur within a few hundred meters up to a few kilometers from the pile-driving. Hearing capability differs considerably between fish species (Figure 6.8.1). For cod and herring that have relatively good hearing the audible zone is estimated at up to 80 km and behavioral changes are considered possible close to the pile-driving activity (Thomsen et al. 2006).

Underwater explosion

Operational noise of wind turbines is of lower intensity than pile-driving and the impact on both mammals and fish is likely to be restricted (Madsen 2006). However, noise simulations show that even operating turbines may have a potentially masking effect at least at short ranges in the open sea (Lucke et al. 2007). Direct studies on the response of mammals to operating wind farms are currently taking place in the Danish wind farm "Nysted" (Diederichs et al. 2008, Teilmann et al. 2008).

High pressure airguns are commonly used in seismic surveys to produce sound pulses of low frequency and high intensity. There are several observations of behavioral change of mammals associated to airgun operation, in particular involving avoidance of the area surveyed (Gordon et al. 2003) as well as ceased communication and physical effects on cetaceans (Nowacek et al. 2007). In the immediate vicinity of airgun operation fish kills have been observed. Reduced catches of fish, e.g. cod, have also been noted in areas of seismic surveys, lasting up to several days after the activity has ceased (Engås et al. 1996).

Industrial seismic surveys use large arrays with multiple airguns to locate geological structures associated with oil and gas. Airguns are also used in geological mapping in the Baltic Sea area, usually involving fewer airguns with lower impact than those used for exploration surveys. However, all air guns can be heard over very long distances under water.

High-frequency SONARs (>10 kHz) that are commonly used to map the seafloor or to locate fish are within the hearing frequency of many marine mammals, but they have a limited transmission range in water. Masking effects cannot be disregarded although concrete evidence is still lacking. Recent research (M. Lahtinen, pers. comm.) indicates that depth and fishing echo-sounders using 50 kHz frequency can be problematic for toothed whales and possibly seals, as this frequency is in their important hearing range. Even small boats and fishing vessels have these echo-sounders on almost continually whenever map plotters are being used.

Ship traffic

Shipping constitutes a rather diffuse and omnipresent sound source that is difficult to quantify and evaluate. However, large cargo vessels are considered to be significant contributors to anthropogenic noise in the marine environment. In the period 1950–2000 it is estimated that noise from shipping increased the sound level in the world's oceans by 16 dB, i.e. it has doubled several times.

The noise emitted from ships varies considerably between vessels, but basically the larger the ship and the older the ship, the louder they are. The intense sound levels are mainly of low frequency (<1 kHz). At reasonable distances, the sound produced by shipping is not considered to cause immediate harm to fish and mammals, but may cause the masking of biologically important signals (Southall 2005).

Furthermore, the impact of fast ferries such as catamarans has long been recognized as a threat to cetaceans, both for the risk of ship strikes and for their noise emissions. Jet skies are not just fast and noisy but also highly mobile and frequently used very close to the shore thus impacting a habitat that may be less impacted by other noise sources (Koschinski 2008).

Noise from shipping has also been shown to cause increased level of stress hormones in a number of freshwater fish species, among them perch (Wysocki 2006).

Military activities

Mid-frequency SONARs for military purposes have been linked to mass strandings of mammals in several oceanic areas, particularly of deep-diving beaked whales (*Ziphius* spp.), indicating that they may trigger a fatal behavioral response of the species (Nowacek et al. 2007). Fatal behavioural responses to military SONAR appear to be less likely in the rather shallow water body of the Baltic Sea.

Another source of military underwater noise pollution in the Baltic Sea are detonations, either when testing new vessels (smaller charges) or when blasting underwater unexploded ordnance (UWUXO), e.g. usually originating from World War II. Underwater explosions are the loudest point source of anthropogenic marine sound. These have the potential to kill or seriously harm marine mammals and fish. Marine mammals exposed to an explosion with a charge weight of 350 kg can be killed by the intense shock wave at a radius of 4 km (Thiele [1998] unpubl. report to the Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik [FWG], Kiel/Germany). The zone of hearing impairment for a harbour porpoise can extend for over 30 km (Koschinski 2007).

6.8.3 Possible mitigation measures

Bubble curtains consist of a fine stream of bubbles constantly rising to the surface thus forming a circular wall around a sound source, e.g., a detonation or pile-driving activities (Würsig et al. 2000). The different densities at the water-air-water interfaces provide a sound reflector and have proven to reduce shock waves by 12 to 18 dB thus reducing the danger area for marine animals by 95 to 98% (Nützel 2008). For the remaining danger zone effective deterrent measures such as pingers, seal scarers and small explosives (charge weight < 20 g) and marine mammal observer schemes are alternatives to lower the impact. The additional noise emitted into the water column is aimed at driving the animals at risk out of the danger zone, but it will also exclude animals from their preferred habitat. Therefore, this kind of habitat exclusion should only be used for hours at a time with intermittent brakes.

To protect marine mammals, threshold levels have been suggested for a noise exposure criterion combining sound pressure level (200 dB pp re 1 μPa) and sound exposure level (164 dB re 1 μPa2/Hz) to be applied for anthropogenic activities (Lucke et al. 2008).

A number of governments have committed themselves to reducing the impact of noise pollution in the marine environment. For this common goal, several binding resolutions have been adopted in international fora such as conventions and agreements (e.g., ASCOBANS, ACCOBAMS, CMS, IWC, and IUCN — see the respective web sites for details). These efforts may lead to generally accepted guidelines for the mitigation of underwater noise pollution (Southall et al. 2007, Weir & Dolman 2007).

6.8.4 Conclusions

As presented in this overview of the impact of noise, there are a number of anthropogenic activities that can cause immediate harm to both mammals and fish in the Baltic Sea area. These activities are often localized and short-term, but whenever they proceed during extended periods, they may exclude animals from vital feeding or breeding areas thus causing temporary habitat degradation. As far as the impact of noise pollution is concerned, industrial activities such as construction and extraction appear to be of particular concern in the Baltic Sea besides the increasing volume of shipping.

Noise of less critical frequencies to marine animals but of a chronic nature, such as that derived from shipping, operating wind farms and high-frequency ship SONAR, may in the long-term pose a more serious risk to marine animals e.g. by masking important biological signals. With an anticipated increase in marine traffic (see Chapter 6.2, Maritime activities) and an increasing number of existing and planned technical installations (see Chapter 6.3, Physical damage and disturbances), noise pollution must be considered to be a growing pressure to the biodiversity of the Baltic Sea.

6.9 Hunting

Regardless of the stepping into an industrialized world, hunting has continued to be an important part of human activities, also in the Baltic Sea area. Only quite recently, it can be said that hunting no longer provides a significant food source for people. Nevertheless, hunting is still a popular recreational activity and can in some cases be considered also as a management measure in nature conservation or in mitigating harmful interactions between man and nature. However, in this section hunting is perceived mainly as a pressure to biodiversity in the Baltic Sea.

6.9.1 Hunting of sea birds

Waterfowl hunting has a long tradition in the Baltic Sea littoral states. However, in recent times hunting has decreased as seen in the declining bag size of ducks. One reason for this decrease are hunting restrictions due to the EU Birds Directive. Furthermore, the general interest of hunting seabirds seems to decline (Bregnballe et al. 2006). On the other hand, the bag size of geese shows an increasing trend in several countries (e.g. Poland, Estonia, and the German Federal State Schleswig-Hostein). One reason may be the increasing populations of greylag goose (*Anser anser*) and Canada goose (*Branta canadensis*) in the Baltic Sea area.

The most important group of game birds are ducks, both dabbling and diving ducks. The species number for which hunting is permitted varies among the countries. In Denmark and Finland, for instance, hunting is practised on 6 dabbling duck and 8 diving duck species, in Sweden on 3 and 8, respectively, whereas the hunting law of the German Federal States Schleswig-Holstein and Mecklenburg-Vorpommern assigns hunting seasons only for 3 dabbling and 2 diving duck species.

Among the diving ducks, the eider (*Somateria mollissima*) was, and still is, one of the most important target species for hunters, especially in Denmark, Sweden, and Finland (Figure 6.9.1). The total eider bag of the Baltic Sea area has declined from 150 000–250 000 birds in the 1980s to currently 70 000–80 000. The strong hunting pressure in the 1980s did not prevent the population from growing, though it possibly led to a decline of growth rates. On the other hand, hunting is certainly not the main reason for the currently negative population trend, but it may enhance the decline.

Another important game duck is the mallard (*Anas plathyrhynchos*). The Danish bag of this species was 554 000–731 000 ducks between 1999/00 and 2003/04. However, the majority of the birds was released from breeding stations just for hunting purposes. In Finland, the mallard bag was 210 000–295 000 birds between 2003/04 and 2006/07. In the German Baltic Federal States Schleswig-Holstein and Mecklenburg-Western Pomerania, the mallard accounts for more than 90% of the duck bag.

The most important game goose in the south-western Baltic Sea (Denmark and Germany) is the greylag goose (*Anser anser*), but white-fronted goose (*Anser albifrons*), bean goose (*Anser fabalis*), pink-footed goose (*Anser brachyrhinchus*), Canada goose (*Branta canadensis*) and barnacle goose (*Branta leucopsis*) are also being hunted. Goose hunting is also practised in Finland, Sweden, Estonia and Poland (Table 6.9.1). In Finland, the bean goose holds the largest share of the goose bag, followed by greylag goose and Canada goose. In Sweden, the top three species are the same but in an opposite order.

Gulls have been shot in high numbers during the 20th century with the aim to control the population number. The Danish annual gull bag during the 1960s/1970s was in the magnitude of 150 000–230 000 birds (Strandgaard & Asferg 1980). Since then it has declined to 28 000–36 000 (mainly herring gull *Larus argentatus*, followed by great black-backed gull *Larus marinus*; Bregnballe et al. 2006). In Finland, the annual permits for gulls (mainly *L. argentatus* and *L. marinus*) are in "tens of thousands" (BirdLife Finland). In Sweden, about 22 000 gulls were shot in 2005/2006, the bag consisting mainly of common gull *L. canus* and herring gull. The gull

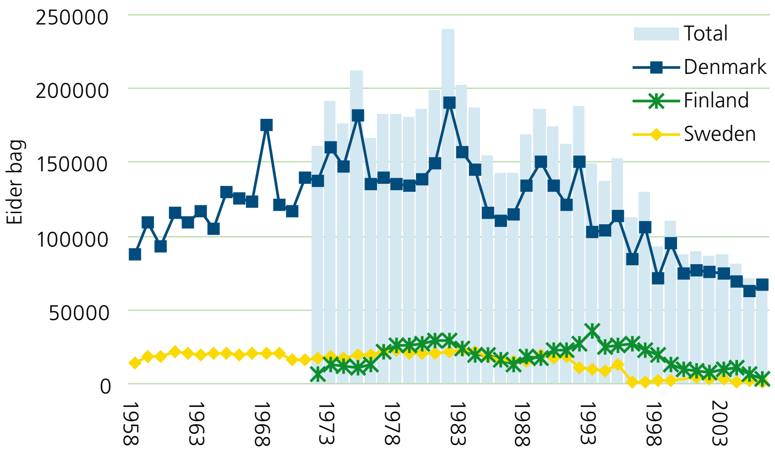


Figure 6.9.1. The development of the eider bag in Denmark, Finland and Sweden. The Finnish data does not include Åland. Data provided by the Danish National Environmental Research Institute, Finnish Game and Fisheries Research Institute and the Swedish Association for Hunting and Wildlife Management.

Table 6.9.1. Waterfowl bag of the Baltic Sea littoral countries.

Country	Bird group	Annual hunting bag	Remarks	Source
Denmark	Ducks	200 000–250 000	1999/00–2003/04	Bregnballe et al. (2006)
	Geese	18 000–29 000		
	Gulls	28 000–36 000		
	Cormorants	2 400–4 900		
Estonia	Ducks	7 000–17 700	1992/93–2007/08	Statistics Estonia http://pub.stat.ee
	Geese	900–4 800		
	Gulls	0–200		
	Cormorants	0–354		
Finland	Ducks	443 000–608 000	2003/04–2007/08	Hunters' Central Organisation & Finnish Game and Fisheries Research Institute
	Geese	15 000–24 000		
Germany – Schleswig –Holstein	Ducks	60 000–70 000	1996/97–2006/07	MLUR SH 2007
	Geese	4 500–8 500		
	Gulls	800–1 100	2005/06–2006/07, no gull hunting 2002–2005	
	Cormorants	100–1 100	1992/93–2006/07	
Germany – Mecklenburg-Western Pomerania	Ducks	7 100–15 500	1992/93–2007/08	LU MV 2006
	Geese	2 300–11 700		
	Gulls	100–300	2005/06–2007/08	
	Cormorants	200–1 600	1992/93–2007/08	
Latvia	Waterfowl	2 500–3 000	2005–2006	
Lithuania		no information		
Poland	Ducks	100 000–160 000	1990/91–2007/08	Research Station of the Polish Hunting Association
	Geese	4 000–17 000		
	Gulls	no game bird		
Russia, Kaliningrad region		no information		
Russia, St Petersburg region		no information		
Sweden	Ducks	101 000	2005/06	Swedish Hunting Association
	Geese	32 000		
	Gulls	22 000		
	Cormorants	2 000		

bag of the two German Baltic Federal States is currently between 1 000 and 1 500 birds, more than 50% being herring gulls. In Estonia, the annual gull bag (2000–2007) varies between 50 and 200 birds.

The cormorant is not a game bird in the EU Member States, since it is not listed in Annex II of the EU Birds Directive. However, the national authorities may allow harassment activities against cormorants, including shooting, in order to prevent damages on fishery or negative impacts on other species, e.g. salmon smolts. On this legal basis, cormorants are shot since the mid-1990s in Denmark, Germany, and Sweden (Table 6.9.1). In Estonia, shooting of cormorants was started in 1997, but the bag remained low in all years, reaching a maximum of 354 in 2006. In Åland, permission to shoot 100 cormorants was given in 2008. The total number of cormorants shot in the Baltic Sea area probably does not exceed 10 000–15 000 birds annually. In Mecklenburg-Western Pomerania, Germany, culling of young cormorants just before fledging off was practiced from 2001–2005, but was then stopped because of strong public protests.

6.9.2 Hunting of seals

The grey seal (*Halichoerus grypus*) population has steadily increased after decades of low abundance in the northern parts of the Baltic Sea (see Chapter 4.2, Seals). Along with the seal population increase, conflicts between fishermen and seals have also increased. All three seal species are still legally protected in the countries around the Baltic Sea but annual permits to shoot grey seals are given in Sweden and Finland.

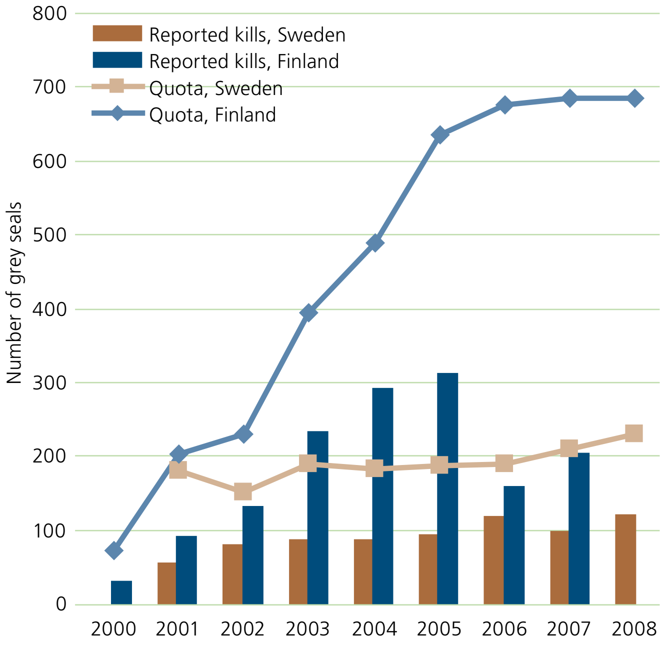


Figure 6.9.2. Quotas and killed grey seals in Finland (excl. Åland) and Sweden during 2000–2008.

In Sweden, all three seal species of the Baltic Sea were protected during 1989–2000. Since 2001 controlled hunting of grey seals has been allowed from Kalmarsund (North of the Öland Bridge) and northwards according to quotas set by the Swedish Environmental Protection Agency. The geographic delimitation north of the Öland Bridge has been set to avoid mistaken shooting of the small and genetically distinct harbour seal population (*Phoca vitulina*) in the Kalmarsund area. In Finland, quotas have been set from 2000 onwards. The grey seal quotas in Sweden, Finland and Åland were 230, 590 and 450 individuals in 2008, respectively (Figure 6.9.2). In Sweden and Finland, individual permits can be applied for shooting harbour seals and ringed seals (*Phoca hispida botnica*). Between 12–26 harbour seal permits have been granted annually in Sweden in 2003–2007 and the first ringed-seal permits were granted in 2008 in Finland. Sweden has a management plan for grey seal, action plans for ringed seal and harbour seal in the Baltic proper, and a management plan for harbour seal in the Kattegat is under development[7]. There are management plans for both grey seal and ringed seal in Finland[8]. Seal hunting is not allowed and permits not given in any other country in the Baltic Sea area.

6.9.3 Major international frameworks regulating hunting of seabirds and seals

The main legal frameworks regulating hunting in the Baltic Sea area are the EU Habitats and Birds Directives. All the seal species in the Baltic Sea are protected by the Habitats Directive and the Birds Directive protects all the seabird species in the area. However, Member States can set specific

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[7] Available at: http://www.naturvardsverket.se/upload/04_arbete_med_naturvard/jakt/forvplan.pdf
[8] Available at: http://www.mmm.fi/sv/index/framsida/fiske_vilt_renar/Viltvard/forvaltningsplaner/forvaltningsplanenforostersjonssalstammar.html


Hailuoto, Bothnian Bay, Finland

quotas for game species and their hunting is regulated temporally and spatially. Permits to shoot other than game species must be individually applied for from national authorities. However, the hunting of birds has been limited only to autumn and the Member States are obliged to adjust the quotas and individual permits of the species in order to not threaten the breeding populations of the species. The Bern Convention on the Conservation of European Wildlife and Natural Habitats lists all the three seals in its Annex III as *protected species*, hunting of which is strictly regulated.

6.9.4 Conclusions

According to current knowledge and assessments, waterfowl hunting in the Baltic Sea area in general seems to be sustainable. Most species for which hunting is permitted have a favourable conservation status and stable or increasing populations (Bregnballe et al. 2006). However, there are also some species with decreasing population trends and unfavourable population status (e.g. eider, greater scaup *(Aythya marila)*, long-tailed duck *(Clangula hyemalis)*). For these species, a Baltic-wide hunting ban should be strived for, since hunting, though certainly not being the main reason for the current negative trends, may put an additional pressure on the populations and contribute to their decline.

Hunting of seals and sea birds cannot be seen as a management measure from a biodiversity point of view. However, shooting of american mink and raccoon dog, which are non-indigenous mammals in the Baltic Sea coastal and archipelago areas, have resulted in increased biodiversity in the region. For example, in Finland their bags range between 85 000 and 135 000 annually, which has led to improved breeding success of many seabird species and increased species richness in archipelago areas. In Meckleburg-Western Pomerania, Germany, predatory mammals are strictly excluded from breeding islands of coastal birds in order to secure the breeding success. Thus, hunting cannot be seen only as a pressure but also as a way to mitigate the impact of predators that have been either introduced or promoted by human activities (e.g. rabies vaccination).

6.10 Projected future climate change

The Intergovernmental Panel on Climate Change (IPCC) indicates that warming of the climate system has been unequivocal, with a 0.74°C increase of near-surface global air temperature over 1906–2005 (IPCC 2007). The IPCC also indicates that most of the observed increase since the mid-20th century is very likely due to the observed increase


Fish swarm on kelp *(Laminaria* sp.) Kattegat

in anthropogenic greenhouse gas concentrations. The panel is also clear in its view that, if continued at current or higher rates, emissions of greenhouse gases will cause further warming and induce many changes in the global climate system during the 21st century.

According to the BACC project (BALTEX[9] Assessment of Climate Change in the Baltic Sea Basin, see BACC Author Team 2008), the air temperature in the Baltic Sea region has warmed by 0.08°C per decade on average during the period 1871–2004, a trend that is slightly steeper than in the global time series (Heino et al. 2008). The Baltic Sea time series shows positive trends for all seasons, with a stronger warming in the southern compared to the northern parts of the area.

Climate has a profound effect on hydrology, hydrography, and consequently the marine environment of the Baltic Sea. The climate in the Baltic Sea area is influenced by major northern hemisphere air pressure and atmospheric circulation systems. A leading mode of circulation variability during wintertime is the North Atlantic Oscillation (NAO), which affects the atmospheric circulation and precipitation in the Baltic Sea area. The North Atlantic pressure fields affect Baltic hydrography because the water exchange between the Baltic Sea and the North Sea is largely driven by patterns of strong and persistent easterly and westerly winds (Lass & Matthäus 1996).

During recent decades, there has been a decreased frequency of salt-water pulses from the North Sea into the Baltic Sea (Heino et al. 2008). Observational data also show that annual surface water temperature has increased by approximately 1°C in the southern Baltic Sea (Beaugrand et al. 2008), whereas in the northern Baltic Sea the observed changes are mainly seasonal (Rönkkönen et al. 2004). The length of the ice season has also decreased by 14–44 days during the last century. These changes have had a measurable effect on the distribution, reproductive output and stock sizes of

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[9] Website of the BALTEX project: http://www.baltex-research.eu/

the Baltic biota (see, e.g., Chapter 3, Fish communities and Zooplankton communities). However, it has not been possible to establish a distinct causal link between these changes and anthropogenically induced climate changes, partly because of the large natural climate variability, but also owing to possible impacts from other human pressures (Dippner et al. 2008). The observed changes, however, point to the considerable impacts that climate-related factors have on the Baltic Sea biodiversity.

Regional climate models for the Baltic Sea area project increased precipitation during the 21st century which may cause a decrease in salinity. Hydrographic models also project a higher seawater temperature in the Baltic Sea. This section addresses impacts of these possible future climate changes on the Baltic Sea biodiversity.

6.10.1 Projected changes in climate in the Baltic Sea region

Most recent regional climate projections indicate that near-surface air temperatures will further increase by 3–5°C during this century in the Baltic Sea area (Graham et al. 2008). Depending on the future climate scenario, this would translate into a two- to six-week longer growing season in the region. Conversely, this means shorter and warmer winter seasons, and the length of the ice season would decrease by 1 to 2 months in the northern Baltic Sea and 2 to 3 months in the central parts.

During the 21st century, anthropogenic climate change is expected to increase precipitation, particularly in the north, while summers are expected to become drier in the south (Graham et al. 2008). This is projected to cause 15% higher riverine runoff during winters (averaged for the whole area), possibly causing decreased salinity in the Baltic Sea and higher nutrient loads from the surrounding catchment area. Average annual sea surface temperatures could increase by approximately 2–4°C by the end of the 21st century (Döscher & Meier 2004, Räisänen et al. 2004).

Because the oceans are a major sink for CO_2, storing about 30% of the anthropogenic CO_2 emissions, a long-term increase in CO_2 results in acidification of the ocean water (Sabine et al. 2004). According to the IPCC, the pH in the world oceans would drop by 0.30 by 2100 assuming an increase of CO_2 concentration to 650 ppm (Caldeira & Wickett 2005). In the Baltic Sea, acidification by 0.15 pH units has already been observed during the past 20–30 years (Perttilä 2008). Acidification of seawater leads first to a decrease of calcification and, in the lower pH regime, to dissolution of calcified structures of, for example, certain plankton groups, bivalves and snails. In the Baltic Sea, where calcification is already lower owing to low salinity, this effect may be more pronounced than in the oceans.

Ecosystem effects of increased seawater temperature and changes in sea ice regime

Globally, rising water temperatures have already caused range shifts and changes in abundance of algae, plankton and fish in some freshwater and marine systems (IPCC 2007). An increase in water temperature may also increase bacterial activity, which can affect the recycling and biological uptake of nutrients (HELCOM 2007d). Higher summer temperatures and milder winters will likely bring new species, alter migration patterns of birds, and result in exclusion of some native species or ecosystem functions of the Baltic Sea. Warming may, for example, stimulate typical warm-water species such as cyanobacteria, whereas cold-water species, such as diatoms, may decrease in the system (Dippner et al. 2008). Because ringed seals and grey seals give birth to pups on ice, a reduc-


Ringed seal (*Phoca hispida*) pup

tion of ice cover, either through reduced ice extent or a shortening of the ice season, is expected to reduce the reproductive success of these species (ICES 2005a). As grey seals can also breed on land, a lack of sufficient ice and snow cover is more harmful for ringed seals. Some ringed seals have been observed to give birth on land, but in such cases pups are exposed to predation, hypothermia and occasionally also to human disturbance. Therefore, the majority of pups born on land can be expected to die before weaning.

A lack of ice, and particularly a lack of ice-scraping in shallow-water areas, may also cause changes in littoral communities. Ice-scraping plays an important role in successive plant dynamics in the Baltic Sea, for both vascular plants and algae (e.g., Kiirikki 1996). Moreover, the ice cover supports a specialized microscale food web because microbial organisms occupy interstitial crevices and salt-water channels within the ice (Granskog et al. 2006). Such a unique microbial system would be drastically reduced or potentially lost, if the current projections for the sea-ice season will be realized.

Effects of projected increased runoff and decreased salinity

The projected increase in riverine runoff would result in higher loading of nutrients and sediment, with a larger change expected in the northern parts of the region. An increase in nutrient loading will have an influence on phytoplankton species composition and primary production, and may be expected to contribute to increased eutrophication. Increased riverine sediment loads, caused by increased river runoff, will also cause rocky habitats to deteriorate as the hard substrata would disappear. This would happen particularly within and near estuaries. On the other hand, increased organic matter in the water column will reduce water transparency and may stimulate the growth of bacteria, resulting in a food web more based on heterotrophy, with reduced productivity at higher trophic levels as a consequence (Berglund 2007). Impacts on the ecosystem level are clearly difficult to predict at present.


Flounder (*Platicthys flesus*)

According to regional climate and Baltic Sea model projections, a possible scenario for the second half of the 21st century is a decrease in surface water salinity in the Baltic Sea owing to increased precipitation, and a smaller outflow of less saline water through the Danish Straits. This would lead to stronger stratification of the water column and a displacement of the halocline to greater depths, with a possible reduced mixing of the deeper water layers and a higher probability of oxygen depletion in deep basins. Deepening of the halocline would result in a larger area of oxygenated sediments, increasing the area available for colonization of macrofauna above the halocline (Dippner et al. 2008).

Species that are clearly limited by salinity may become important indicators for assessing the impacts of climate change. Although it is too early to predict the changes at the species level, the first candidates to be impacted are likely to be species living in the northern parts of the Baltic Sea. Many Baltic marine species meet their salinity limit in the northern Baltic Sea and this is where freshwater inflow is projected to increase the most. Thus, many ecologically significant species would probably disappear from the northern Baltic Sea, such as bladder wrack (*Fucus vesiculosus*), eelgrass (*Zostera marina*), blue mussel (*Mytilus trossulus*), flounder (*Platichthys flesus*), turbot (*Psetta maxima*), and many red algal species (Laine 2008).

In the southern parts of the Baltic Sea, there are several algal species that require high salinities for proliferation. In the projected low-salinity conditions, many algae would thus be expected to disappear from their former ranges, e.g., the brown alga *Fucus serratus*, the kelp *Laminaria saccharina*, various crustose red algae (e.g., *Lithothamnion gla-*

ciale), the red alga *Delesseria sanguinea*, and the green alga *Ulva lactuca*.

Many littoral invertebrate species in the northern Baltic Sea, living among macroalgae and vascular plants or in soft bottoms, have their lowest salinity limits close to 4–6 psu (e.g., the shrimp *Crangon crangon*, the isopod *Idothea baltica* and the soft-shelled clam *Mya arenaria*). Similarly, in the southwestern Baltic Sea, many oceanic species may withdraw from the Baltic side of the Danish Straits. Such invertebrates may include, for example, the crabs *Carcinus maenas* and *Hyas araneus*, and the *Littorina* snails.

Spawning of the most important commercial fish species in the Baltic Sea, namely cod, is dependent on a salinity higher than 11 psu. Thus, reduced salinity together with potentially increased hypoxia in the Baltic Sea would diminish the volume of the cod spawning habitat (Nielsen & Kvaavik 2007). Because many of the above-mentioned species are key species in the Baltic Sea ecosystem, the cascading impacts will most likely resonate in other species in both the marine ecosystem as well as terrestrial coastal communities.

Secondary effects of decreased salinity are also possible. Changes in environmental conditions may give opportunities for non-native species to invade the ecosystem. Moreover, marine species living at their low-salinity tolerance limit are more sensitive to other metabolic stresses such as higher temperatures and hazardous substances. Higher temperatures and/or lower salinity could therefore affect the species' ability to deal with toxic substances and the different physiological regulation processes involved in the detoxification of hazardous substances. The bioavailability of metals increases with decreasing salinity (Dippner et al. 2008); hence, the tolerance and the metabolic stress of some species may be exceeded, with consequences that are unfavourable to the conservation aims of Baltic Sea biodiversity.

6.10.2 Conclusions

Hydrographic changes in the Baltic Sea have already altered the distributions and ecological interactions of the Baltic biota, and the regional climate model projections of anthropogenic climate change indicate that even more pronounced changes can be expected during this century. As the strongest abiotic parameter regulating the Baltic biota is salinity, the projected decrease in salinity is expected to change the geographic distribution limits of many species and even exclude native species from the Baltic Sea. Most likely, the emerging freshwater species would replace some of the functions of marine species, but the capability of freshwater species to compensate for the loss of habitat-forming marine species is difficult to predict. By monitoring certain indicator species, known to be sensitive to a changing hydrographic regime, the climate-induced ecosystem effects could be better understood, assessed, and, hopefully, predicted.


Anklamer Stadtbruch, Germany

The changing climate is expected to put considerable stress on the Baltic Sea ecosystem, making it even more important to mitigate other human pressures. Known associations between salinity, temperature, toxic substances and the establishment of invasive species, for example, indicate that polluted environments that also undergo hydrographic changes experience the highest establishment rates of non-indigenous species. In addition, climate change is likely to exacerbate eutrophication, which may require enhanced efforts to decrease nutrient loads to the Baltic Sea.

7 STATUS OF THE NETWORK OF MARINE AND COASTAL BALTIC SEA PROTECTED AREAS

The aim of a Baltic Sea network of coastal and marine protected areas is to contribute to the protection of the entire ecosystem with all its components and functions and not only specific species or habitats. Baltic Sea Protected Areas (BSPAs) should therefore be adequately distributed across the Baltic Sea and its different sub-regions to include all species, habitats and ecosystems, thus ensuring genetic diversity in the network.

According to the HELCOM Baltic Sea Action Plan (BSAP), improvement of the protection efficiency of the network of marine BSPAs is a central action to attain all HELCOM ecological objectives (HELCOM 2007a).

Although in most cases BSPAs are not designed as no-take or no-use zones, they can serve many different purposes (Kelleher 1999, Salm et al. 2000) such as:

- Help stop degradation of the marine ecosystem and facilitate its regeneration.
- Contribute to the protection of biodiversity and increased productivity.
- Help protect genetic diversity.
- Contribute to the protection of natural habitats and species.
- Maintain natural reference areas (for research and education).
- Provide refuges and living space for different life stages of exploited species (e.g., from fisheries).

The aim of this chapter is to assess the current status of the BSPA network in the Helsinki Convention area (Figure 7.1).

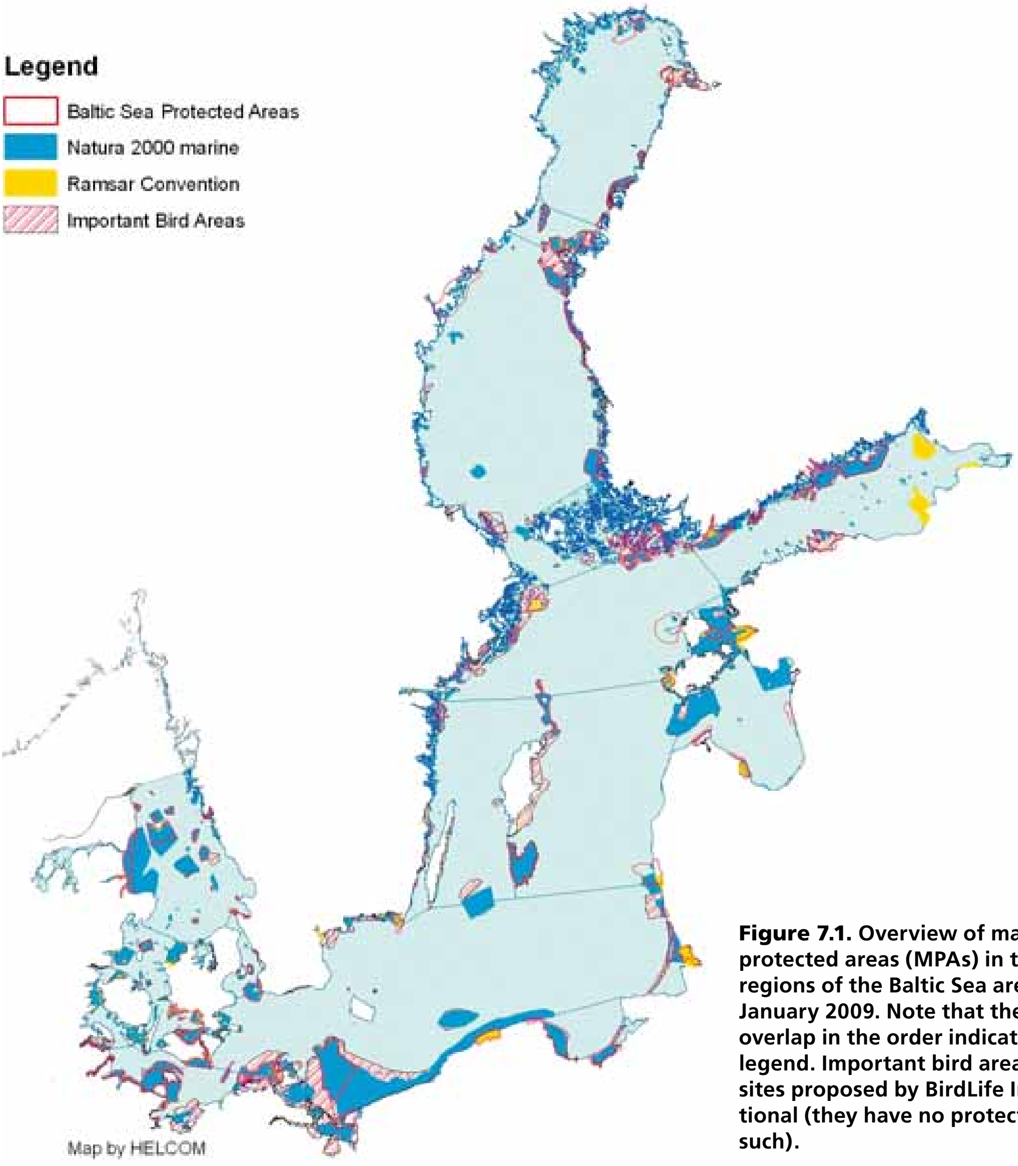

Figure 7.1. Overview of marine protected areas (MPAs) in the sub-regions of the Baltic Sea area, as of January 2009. Note that the sites overlap in the order indicated in the legend. Important bird areas are sites proposed by BirdLife International (they have no protection as such).

7.1 History of marine and coastal Baltic Sea Protected Areas

Initial suite of 62 BSPA sites

HELCOM started as early as 1994 to establish a system of marine and coastal Baltic Sea Protected Areas (HELCOM Recommendation 15/5). All Contracting Parties to the Helsinki Convention contributed by identifying and nominating an initial suite of 62 sites towards establishing a coherent network of BSPAs. Contracting Parties committed themselves to define definite boundaries and management measures for these sites as soon as possible, and to include additional BSPAs, particularly offshore sites outside their territorial waters.

In order to implement Recommendation 15/5, the HELCOM Working Group on Nature Conservation and Biodiversity agreed in 1996 on Selection Guidelines for BSPAs. In addition, it compiled a comprehensive overview of all existing coastal and marine protected areas (not only BSPAs) in the Baltic Sea area (HELCOM 1996a). This work was followed by an intensive assessment showing that there already existed a wide range of coastal terrestrial and nearshore marine protected areas in all Baltic Sea states. However, many of these were not included in the BSPA system, although they would have qualified according to expert opinion. Additionally, the assessment showed that there was a lack of offshore protected sites in the Baltic Sea as a whole. Consequently, an expert was commissioned to identify potential offshore BSPAs. Hägerhäll & Skov (1998) proposed 24 ecologically significant offshore sites, but only some of them have subsequently been designated as new BSPAs (Table 7.1).


Land uplift shore in the Outer Bothnian Threshold Archipelago, Finland (The Quark)

In 2003, the HELCOM and OSPAR Commissions met for the first time in Bremen, Germany. At the high-level meeting, ministers reaffirmed their commitments to establish a coherent network of well-managed marine protected areas by 2010 (hereafter referred to as the 2010 target) and adopted a Joint Work Programme (JWP) for the OSPAR and HELCOM Convention Areas.

Nomination of Natura 2000 sites as BSPAs

Natura 2000 is a network of protected areas legislated by the European Union (Box 7.1). Currently within HELCOM, eight of the nine member countries are EU Members and thereby bound by its directives, with Russia the only exception. The Emerald Network under the Bern Convention is complementary to EU's Natura 2000 network in non-EU countries on the entire European continent and in some countries in Africa. Although Russia has not signed the Bern Convention, it may nominate sites to the network. For Russia, the relevant international agreements related to marine protected areas (MPAs) are the Ramsar Convention, the Convention on Biological Diversity and the Helsinki Convention.

HELCOM sought to combine efforts with the European Union to implement the HELCOM/OSPAR Joint Work Programme on MPAs. In this context, HELCOM decided in 2005 that *"…the designation of NATURA 2000 sites by the EU Member*

Table 7.1. The history of the designation status of BSPAs.

	1994 (HELCOM Rec. 15/5	2003 (JWP agreed)	2006 Assessment	Actual number of sites (end of 2008)
Designated and/or managed BSPAs	None	10	78	89

Box 7.1. Natura 2000 network of protected areas in the European Union

Natura 2000 is a network of protected areas legislated by the European Union. This network is based on requirements according to the Birds Directive[1] and the Habitats Directive[2] adopted in 1979 and 1992, respectively. The overall objective of the Natura 2000 network is to achieve or maintain favourable conservation status of European biodiversity features. In order to do so, each EU Member State must establish a suite of Special Protection Areas (SPAs) for birds and Special Areas of Conservation (SACs) for non-bird species and habitats listed in the annexes to the directives and manage these protected areas appropriately. The mere designation of an SPA and/or a SAC is not enough to ensure favourable conservation status but must be followed by specific species and/or habitat protection measures, in particular, management measures. In relation to this, it is important to note that BSPAs may protect a wider range of marine species, habitats, biotopes and natural processes than those listed in the nature directives if the corresponding HELCOM lists are taken into account (HELCOM 2007b). The Habitats Directive stipulates specific criteria for the identification and assessment of sites proposed by EU Member States in accordance with the Directive.

[1] Council Directive 79/409/EEC on the Conservation of Wild Birds
[2] Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora

States and other sites by the Russian Federation as BSPAs is accepted by HELCOM as the adequate implementation measure with regard to HELCOM Recommendation 15/5 and a contribution to the Joint Work Programme on MPAs. In such cases, Contracting Parties are under no obligations to take any further action in respect of these areas than those which arise from the Birds and Habitats Directives of the European Union …"

In contrast to the network of marine protected areas of HELCOM, which is based only on a recommendation, the establishment and management of the Natura 2000 network are legally binding and the European Commission can therefore take legal action against EU Member States in case of non-compliance with the Birds and Habitats Directives.

Guidelines for the Management of BSPAs

Based on the work conducted jointly by HELCOM and Germany, HELCOM and OSPAR have commonly developed practical guidance for establishing management plans for BSPAs and OSPAR MPAs (HELCOM 2006c). This guidance is based on an IUCN model (Salm et al. 2000) and contains detailed instructions and stipulations on the management of BSPAs. It also includes guidance on international regulatory options for conflicting maritime activities for which coastal states have only limited legal competence, in particular for shipping and fisheries (for EU Member States).

However, where Natura 2000 sites are reported as BSPAs, Contracting Parties may manage them according to the legally binding requirements of the EU Habitats and/or Birds Directives. This means that with regard to Natura 2000 sites, it may be sufficient to define and implement management measures without necessarily producing comprehensive management plans (although such plans are identified in the Habitats Directive as a valuable instrument).

Reaffirmation by the Baltic Sea Action Plan

In the Baltic Sea Action Plan, signed in November 2007 in Krakow, Poland, the governments of the Contracting Parties recalled their former commitments to establish a coherent network of BSPAs. They decided to *"designate by 2009 already established marine Natura 2000 sites, where appropriate, as HELCOM BSPAs and to designate by 2010 additional BSPAs especially in the offshore areas beyond territorial waters"*.

Furthermore, they agreed to improve the protection efficiency of the BSPA network by 2010, by assessing the ecological coherence of the BSPA network together with the marine Natura 2000 sites and, where possible, to finalize and implement management plans or management measures.

The importance of marine protected areas according to the Marine Strategy Framework Directive

As the BSAP will serve as a regional approach to implement the EU Marine Strategy Framework Directive (MSFD) in the Baltic Sea, it is also of utmost importance for the protection of the Baltic Sea under the coming European Maritime Policy. EU Member States are to report by 2012 on the ecological status of their marine waters, which includes assessments of the conservation status of marine species, habitats and landscapes as well as of human impacts on the marine environment. In this context, information on the marine environment, collected in the BSPA database and other HELCOM databases, should also be considered in the regional implementation process of the MSFD, e.g., when identifying indicators under the MSFD.

The MSFD additionally requires Member States to make information on MPAs publicly available by 2013 and to identify by 2015 and to undertake by 2016 chosen actions to reach and/or maintain good ecological status of the marine environment.

7.2 Assessment of the ecological coherence of the BSPA network

The Joint Work Programme (JWP) obliges Contracting Parties to *"consider how Baltic Sea Protected Areas … in the waters under the jurisdiction of EU Member States, together with the Natura 2000 network, can constitute a coherent network of marine protected areas"*. Therefore, HELCOM agreed on objectives and criteria for the assessment of the status and the ecological coherence of the network, as listed in Box 7.2, which are based on the work of Day & Roff (2000) and Laffoley et al. (2006). The HELCOM definition of ecological coherence includes four criteria: adequacy, representativeness, replication, and connectivity. In practice, these criteria take into account MPA size and shape, coverage of species, habitats and landscapes, location of the MPAs across biogeographic scales, replication and connectivity at different scales. The EU Interreg III B project BALANCE (Piekäinen & Korpinen 2008) and OSPAR (2007) have provided further advice

Box 7.2. HELCOM objectives and criteria for the assessment of the status and the coherence of the BSPA network(1)

1. A BSPA should give particular protection to the species, natural habitats and nature types to conserve biological and genetic diversity.
2. It should protect ecological processes and ensure ecological function.
3. It should enable the natural habitat types and the species' habitats concerned to be maintained at or, where appropriate, restored to a favourable conservation status in their natural range.
4. The network should protect areas with:
   - threatened and/or declining species and habitats
   - important species and habitats
   - ecological significance
     - a high proportion of habitats of migratory species
     - important feeding, breeding, moulting, wintering or resting sites
     - important nursery, juvenile or spawning areas
     - a high natural biological productivity of the species or features being represented
   - high natural biodiversity
   - rare, unique, or representative geological or geomorphological structures or processes
   - high sensitivity.
5. The minimum marine size of a BSPA should preferably be 3000 ha for marine/lagoon parts.
6. The system should be enlarged stepwise by additional areas, preferably purely marine areas.
7. Criteria for the assessment of the ecological coherence[2]: Adequacy, representativeness, replication of features, connectivity.

(1)The objectives and criteria are based on the Joint HELCOM/OSPAR Work Programme on Marine Protected Areas (Bremen 2003, available at: http://www.helcom.fi/stc/files/BremenDocs/Joint_MPA_Work_Programme.pdf), HELCOM Recommendation 15/5 on the System of Coastal and Marine Baltic Sea Protected Areas (BSPA, available at: http://www.helcom.fi/Recommendations/en_GB/rec15_5/), and to the Minutes of the Eight Meeting of Nature Protection and Biodiversity Group (HELCOM HABITAT 8/2006, available at: http://meeting.helcom.fi/c/document_library/get_file?p_l_id=16352&folderId=73533&name=DLFE-29471.pdf).

(2)According to the EC Habitats Directive, a coherent European ecological network of special areas of conservation (Natura 2000) is composed of sites hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, and enables the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range.

on how the criteria on ecological coherence can be made operational.

In 2004, HELCOM developed a comprehensive database on Baltic Sea Protected Areas (http://bspa.helcom.fi) that is used together with the HELCOM GIS for assessments and spatial analyses. Currently (as of October 2008), the BSPA database contains information on 113 sites, of which 89 are officially nominated as BSPAs. The BSPA database contains information on size and boundaries, legal protection, management as well as the occurrence of species, habitats and biotopes within the sites, that are used to assess the ecological coherence of the BSPA network. In order to meet the requirements of the JWP, HELCOM produced a first assessment of the BSPA network in 2006, with the conclusion that the network was neither coherent nor complete (HELCOM 2007h). That assessment has been updated for this report. The HELCOM assessment relied on the HELCOM lists of threatened and/or declining habitats/biotopes and species (HELCOM 2007b) and the information in the BSPA database. A spatial GIS analysis was used to assess aspects of coherence of the network.

In addition to the HELCOM assessment of the BSPA network, the BALANCE project conducted a complementary assessment of the ecological coherence of the BSPA and Natura 2000 networks in the Baltic Sea (Piekäinen & Korpinen 2008). This assessment was based mainly on benthic marine landscape maps (see Chapter 2.1, Marine landscapes), which in the absence of continuous maps of benthic habitats at the Baltic Sea scale were used as proxies for the broad-scale distribution and extent of ecologically relevant entities of the seafloor (Al-Hamdani & Reker 2007). The analysis was carried out using spatial analyses to determine, for example, the distribution of sites as well as the coverage of marine landscapes within the protected sites compared to the total amount, distribution and coverage in the entire Baltic Sea. Unlike the HELCOM assessment, BALANCE assessed all sites in the HELCOM BSPA database that were classified as ‘notified and designated’ as well as those that were ‘proposed by Recommendation 15/5, but still not designated’—at that time a total of 92 sites.

The combined conclusions of the two analyses carried out by HELCOM and BALANCE[10] are described below.

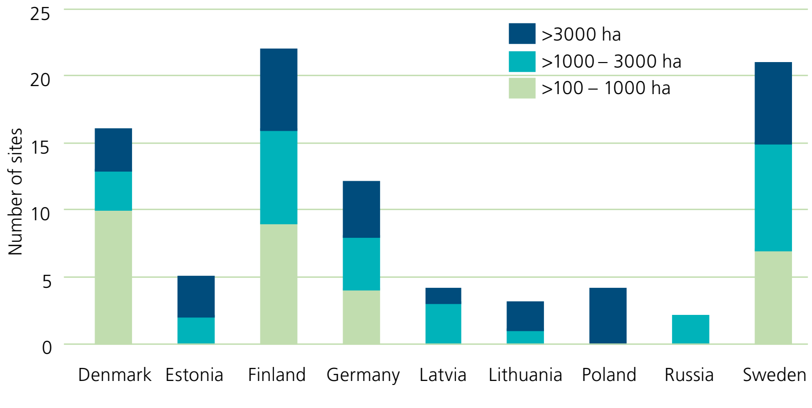

Figure 7.2. The size distribution of BSPAs in HELCOM Contracting Parties.

Adequacy of BSPAs

An adequate MPA has an appropriate size, shape, location and quality to ensure the ecological viability and integrity of the populations, species and communities for which it was selected. As a set, the individual MPAs should together fulfil the aims of the entire MPA network. For example, protection efficiency, the level of influence from the adjacent environment (e.g., anthropogenic disturbance), and the location of MPAs (pelagic vs. coastal) are important considerations when assessing the adequacy of a site. At present, the BSPA network can be described as follows:

Size: HELCOM Recommendation 15/5 and its specific Guidelines state that the minimum size for a terrestrial site should be 1000 ha and for a marine/lagoon BSPA 3000 ha[11]. The size of almost all (94%) of the 89 designated and managed marine BSPAs (excluding terrestrial parts) exceeds 1000 ha and 78% of the sites are larger than 3000 ha. The size distribution of BSPAs in each of the HELCOM Contracting Parties is shown in Figure 7.2.

Total coverage and distribution: The World Summit on Sustainable Development, and subsequently the Convention on Biological Diversity, adopted a global target of 10% of all marine ecological regions to be effectively conserved by

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[10] The BALANCE information on ecological coherence, which is quoted in this section, is taken from Piekäinen & Korpinen (2008).

[11] Available at: http://www.helcom.fi/Recommendations/guidelines/en_GB/guide15_5

Table 7.2. **Number and size of the designated and managed sites in the HELCOM BSPA database by country, as well as information on the marine proportion of the BSPAs.**

Country	Number of BSPAs	Total area of BSPAs (km^2)	Proportion protected (%)	Marine proportion of the BSPAs (%)	Marine area (km^2)	Marine proportion of BSPAs in EEZ (%) a
Denmark	16	3 022	6.8	87.6	2 647	19.5
Estonia	5	2 560	6.9	63.0	1 612	0
Finland	22	6 100	7.4	90.4	5 512	0
Germany	12	4 780	31.5	93.7	4 480	54.8
Latvia	4	1 154	4.0	74.8	863	0.1
Lithuania	3	6 208	9.5	3.6	223	0
Poland	4	2 045	6.9	63.5	1 299	0
Russia	2	3 427	1.4	7.2	246	0
Sweden	21	6 781	4.5	83.9	5 687	2.0
Total	89	27 405	6.6	82.4	22 569	1.2

a) Exclusive Economic Zone excluding territorial waters.

Table 7.3. **Proportion of the marine area designated as BSPAs in relation to the total marine area in HELCOM marine sub-regions and the larger sub-regions according to the BSPA database.**

HELCOM 18 Sub-regions	BSPA coverage (%)	Sub-regions	BSPA coverage (%)
The Gulf of Gdańsk	20	Baltic Proper	5
The Gulf of Riga	4		
Eastern Gotland Basin	5		
Western Gotland Basin	2		
Southern Baltic Proper	4		
Northern Baltic Proper	5		
Bothnian Bay	3	Bothnian Bay	5
The Quark	18		
Bothnian Sea	4	Bothnian Sea	4
Åland Sea	2		
Archipelago Sea	4		
Gulf of Finland	9	Gulf of Finland	9
Kattegat	8	Kattegat	12
The Sound	14		
Little Belt	4		
Great Belt	11		
Kiel Bay	36		
Bay of Mecklenburg	18		

2012[12]. According to the HELCOM database, currently approximately 6% of the Baltic Sea marine area is covered by the 89 designated and managed BSPAs, with a total area of 22 569 km^2 (Table 7.2). However, it should be pointed out that HELCOM itself has not yet agreed on any target for the percentage of the Baltic Sea marine area to be covered by BSPAs. If adding also terrestrial sites, the network covers in total 27 405 km^2.

The network of BSPAs covers examples in all the sub-basins of the Baltic Sea (Figure 7.1). According to the BSPA database, the coverage varies from 2% to 36% in the 18 HELCOM sub-regions, with the lowest coverage, less than 5%, in the largest sub-regions, e.g., the Eastern and Western Gotland Basin and the Bothnian Bay (Table 7.3). Although the current network of BSPAs covers coastal ter-

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[12] Convention on Biological Diversity, COP7 Decision VII/30/ Annex2, target 1.1. UNEP/CBD/COP/7/21 (20 February 2004), e.g. at page 385.
Convention on Biological Diversity, COP7, Integration of outcome-oriented targets into the programmes of work of the Convention, taking into account the 2010 biodiversity target, the Global Strategy for Plant Conservation, and relevant targets set by the World Summit on Sustainable Development, Annex .
World Summit on Sustainable Development (2002). Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August-4 September 2002, e.g. at paragraph 44.

restrial, nearshore marine, and offshore marine areas, a considerably larger share is found within the territorial waters (i.e., coastal waters extending up to 12 nautical miles from the baseline) where, according to the current situation, about 7.6% of the total sea area is covered by BSPAs, compared to the Exclusive Economic Zone (EEZ) where only about 1.2% of the area is covered. Table 7.2 shows that most countries have not yet designated offshore BSPAs in their EEZs.

The network of designated BSPAs has grown significantly since the Joint Work Programme was agreed in 2003 (Tables 7.1 and 7.2), especially in the EEZ. Sweden (2% of EEZ) and Denmark (19.5% of EEZ) have designated one offshore site each within their EEZ, and Germany (54.8% of EEZ) has designated three sites. Additionally, Sweden and Denmark have two sites and Latvia has one site designated partly within their EEZs.

Legal protection and management: Relevant and efficient management is crucial to secure long-term protection of the sites. According to HELCOM (1996a) and the BSPA database (in October 2008), 67 of the 89 designated BSPAs have at least parts of the total area protected under national legislation; that is, they are classified, for example, as national parks or nature reserves (Figure 7.3). All sites in Poland and the majority of the sites in Finland, Latvia and Lithuania are protected by national legislation, while in the other countries only about half of the BSPAs are protected partly or fully under their legislation. Nearly all BSPAs (98.6%) are also designated as EU Natura 2000 sites, thus ensuring the protection of at least the habitats and species listed in the annexes to the Birds and Habitats Directives. Within the EEZ, five of the ten sites—either fully or partly in the EEZ—have national protection, whereas 20% are partly and 30% not at all protected by national legislation. Because 90% of the EEZ BSPAs are also Natura 2000 sites, the level of international protection in the EEZ is high for these sites.

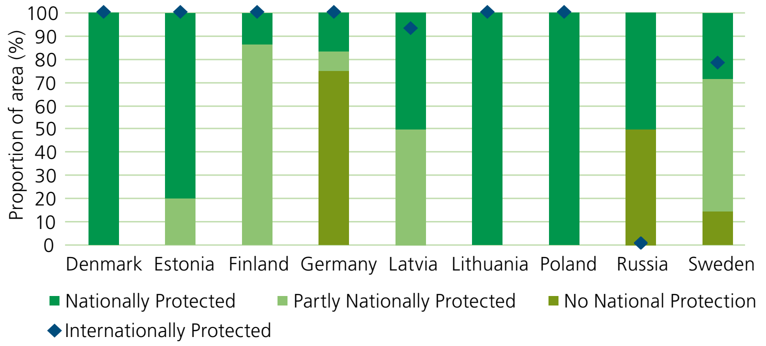

Figure 7.3. The protection status of Baltic Sea Protected Areas according to national and international legal protection status in HELCOM Contracting Parties. The exact area (km^2) and the number of sites per country are presented in Table 7.2. International protection includes the EU Natura 2000 network, Emerald network, OSPAR MPAs and the Ramsar Convention for wetland protection. Note that national and international protection status is shown independently of each other.

Currently, management plans have been implemented in 28 BSPAs. In addition, draft plans exist for six BSPAs, but have not been implemented, and management plans are under preparation for 35 sites. For 20 designated BSPAs, the management plan either does not exist or the database does not contain any information about it.

Representativeness

To contribute to the protection of the entire ecosystem, the full range of species, habitats, landscapes and ecological processes present within a sea area should be adequately represented within the BSPA network.

Species: In the HELCOM BSPA database, a total of 207 species are reported to exist within the 89 designated BSPAs. The majority are birds, including nesting, migratory and wintering species (Figure 7.4). Only 10% of the reported species are plants, 5% mammals and 1% algae. Most of the 21 vascular plant species reported to be included within the current network are terrestrial and fewer than 25% are partially submerged species. However, for 31 BSPAs in the database there is a complete lack of information on species. It is obvious that the database is deficient in information on widespread and common species.

The HELCOM lists of threatened and/or declining species and biotopes/habitats of the Baltic Sea area (HELCOM 2007b) contain 61 species that are in urgent need of protective measures and for which protection is also highlighted in the BSAP. Bird and mammal species on the HELCOM list are well-represented in BSPAs, whereas the other taxa are more poorly represented. According to the BSPA database, 29 of the 61 threatened and/or declining species are not included in the current BSPA network.

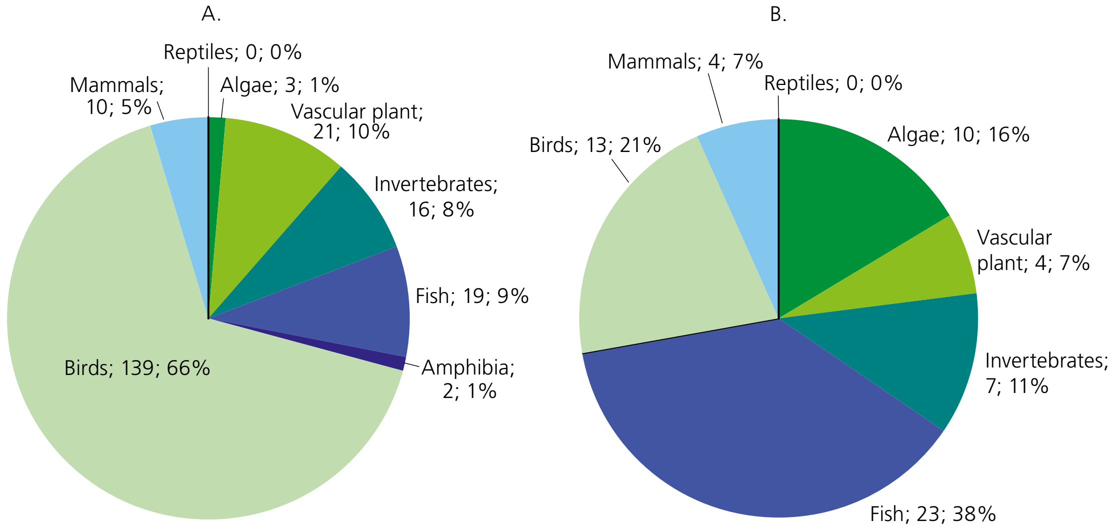

Figure 7.4. Number and percentage of species reported in the BSPA database. (A) All species reported within the BSPA network (207 species) and (B) species on the HELCOM list of threatened and/or declining species (61 species), only 32 of which have been reported within the BSPA network.

Habitats, biotopes, landscapes: The HELCOM lists of threatened and/or declining species and biotopes/habitats of the Baltic Sea area (HELCOM 2007b) also include 16 biotopes and habitats that are in urgent need of protective measures and for which protection is also postulated in the BSAP. Currently, seven of these biotopes and habitats are reported to be present within the BSPA network. However, the database lacks information on several biotopes and habitats, including seagrass beds; macrophyte meadows and beds; gravel bottoms with *Ophelia* species; Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation; maerl beds; and sea pens and burrowing megafauna communities. Owing to data deficiency, it is difficult to assess whether these are adequately covered by the BSPA network.

To assess whether the species and habitats are adequately represented in the BSPA network, it is also necessary to take into account the proportion of the total distribution of different species and habitats in the Baltic Sea that is covered by protected sites. Several marine studies and international conventions have suggested that ecologically functional networks of marine protected areas need to cover *at least* 20% of each habitat in a region to secure long-term viable populations and protection of the ecosystem (reviewed in Piekäinen & Korpinen 2008), but that regionally rare, sensitive and threatened habitats and species may need a larger proportion protected.

In the BALANCE project, a spatial analysis was carried out to estimate the proportion of the total area of the benthic marine landscapes covered by the BSPA network. The analysis showed that as many as two thirds (41) of the 60 benthic marine landscape types are insufficiently represented within the BSPA network compared to the recommended minimum 20% level (Figure 7.5). The 19 landscape types having the highest representation comprise mostly landscape types in the shallow euphotic zone. Moreover, areas where the bottom substrate is dominated by bedrock, hard-bottom complex or sand have the highest proportionate coverage, whereas there is a much lower representation of mud and hard clay areas. Thus, it can be concluded that the major gaps in marine landscape representativeness are in the deep-water areas where landscapes are dominated by hard clay and mud.

Replication

Adequate replication of features in MPA networks, within and across biogeographic regions, is needed to ensure that the natural variation of the feature is covered at a genetic level, within species or within habitat and landscape types and also to spread the risk against damaging events and long-term changes. This enhances the resilience of the ecosystem, increases representativeness and also adds to the number of connections between sites.

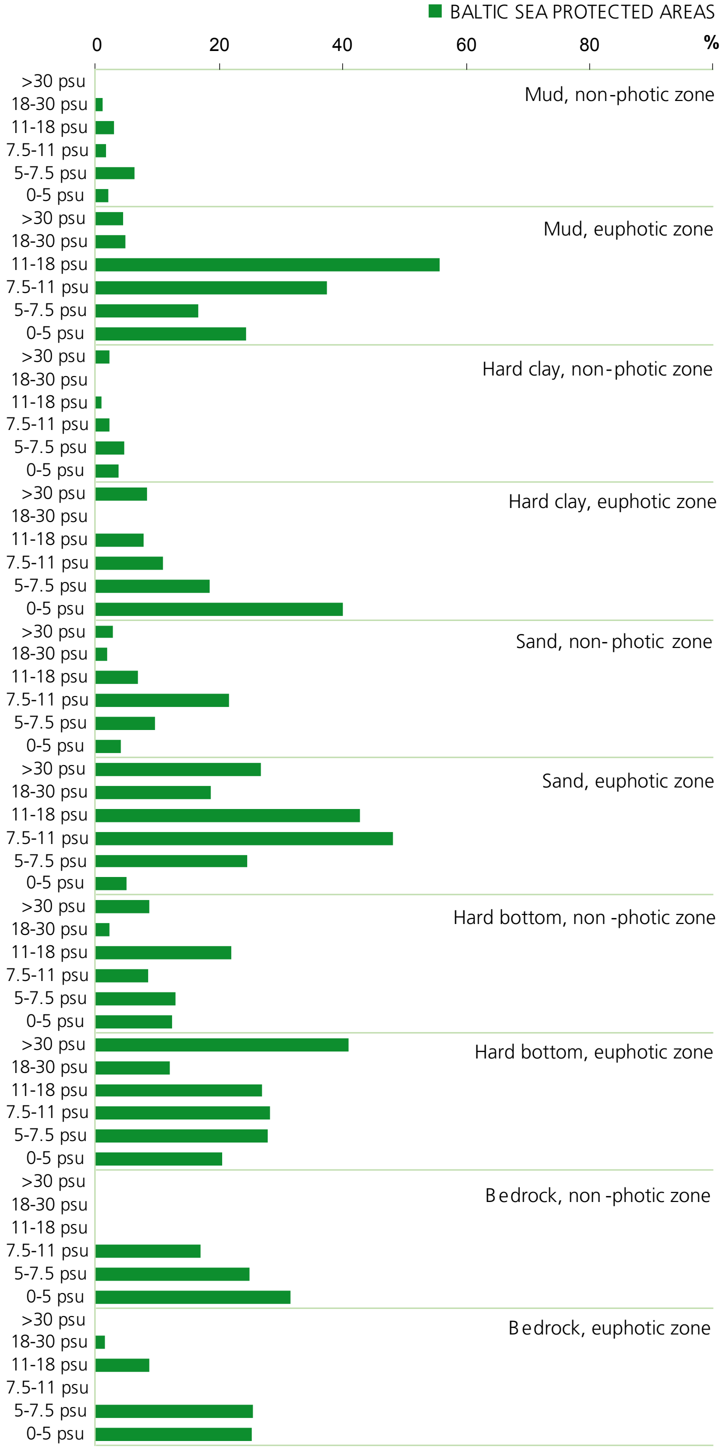

Figure 7.5. Proportion of the 60 benthic marine landscapes represented within BSPAs (horizontal axis). Salinity categories are grouped according to substrate type and photic depths (vertical axis). Source: Piekäinen & Korpinen 2008.

Replication can be assessed by determining the number of spatially separated patches of each protected feature within the network, e.g., individual seagrass meadows or rocky reefs. Because the overall distribution of habitats and species is still poorly known in the Baltic Sea, this cannot be fully assessed at present.

Based on the information in the BSPA database, 62 of the total of 207 species reported within the BSPA network are found in ten or more BSPAs. Of these 62 species, 60 are birds and two are mammals. However, half of the 207 species are reported from fewer than three sites within the BSPA network. Thus, according to the database, many species lack spatial replication. To fully assess the replication in the BSPA network, reliable information on algae, amphibians, vascular plants and invertebrates is needed.

In the BALANCE project, a spatial GIS analysis was carried out to determine the number of spatially separate replicates of different marine landscapes covered by the BSPA network. The results of the analysis showed that replication of the benthic marine landscape patches is very variable, ranging from zero to hundreds of replicates for different landscape types. The majority of the poorly replicated landscape types were bedrock and hard clay landscapes. The shallow euphotic bedrock landscapes had no or only one replicate, as was the case for non-photic bedrock, and most euphotic and non-photic hard clay landscapes. As BSPAs are generally rather large, the within-site replication of landscape patches is relatively high while the number of sites hosting the replicates and thereby the between-site replication is often low. However, the ecologically meaningful minimum number of replicates and the minimum size for a replicate are strongly dependent on species characteristics.

Connectivity

To ensure good connectivity, the BSPA network should offer sufficient opportunities for dispersal and migration of species within and between MPAs. Connectivity depends mainly on the *dispersal distance* of the individual species (including larvae and juveniles) and the *distance between preferred habitats* for those species. Evaluating connectivity is somewhat problematic as the network aims to protect a wide range of species which have very different ranges of dispersal and mobility, both between species and at different stages in their life. Many bivalve larvae (e.g., mussels and cockles) have dispersal distances as long as 100 km, while for swimming crustaceans and some seaweeds the distance is at most 25 km. The network should therefore take into account different aspects of connectivity and not be focused on one element or one species to the detriment of others. The network design should also take into account the different life history stages of species. It has, however, been repeatedly suggested that, if the network is not targeted to a certain species, an average distance of 25 km can be used between MPAs (Botsford et al. 2001, Shanks et al. 2003, Palumbi 2003, Halpern et al. 2006).

Because the HELCOM database contains no spatial information on habitat or species distribution and such data are currently not available, an approach using hypothetical straight-line connectivity with a 20 km and a 50 km radius (i.e., 40 km and 100 km connectivity distance) was used in the HELCOM assessment (Figure 7.6). The assessment showed areas of good connectivity but also indicated major gaps, particularly in offshore areas.

In the BALANCE project, connectivity was assessed between protected patches of similar benthic marine landscapes, both by using a fixed 25 km distance and by using a species-by-species approach whereby the considered landscapes and distances were set depending on the specific requirements for selected species. With the 25 km distance, the landscape patches within the BSPAs are relatively well-connected to each other for most landscape types. However, the deep-sea landscape types showed very low connectivity. When using the species-specific approach, the analysis showed relatively high connectivity among landscape patches suitable for widespread species with high dispersal abilities such as Baltic telling (*Macoma balthica*). For short-distance dispersers, however, the BSPA network is not well-connected. Furthermore, water currents affect dispersal, either inhibiting or enhancing it, and thus the fixed distances in the BALANCE assessment should only be seen as a preliminary ‘rule of thumb’.

The BALANCE analysis also showed that because BSPAs, on average, are relatively large, the main part of the connectivity reflects *within-site connectivity* between landscape patches inside an individual BSPA, whereas *between-site connectivity* is much weaker. While between-site connectivity is important for long-distance dispersers, the within-site connectivity is important for short-distance dispersers. In addition, as most of the BSPAs are situated in coastal areas, the connectivity is very weak across the deeper offshore areas of the Baltic Sea and the network does not support good connectivity for species inhabiting these areas.

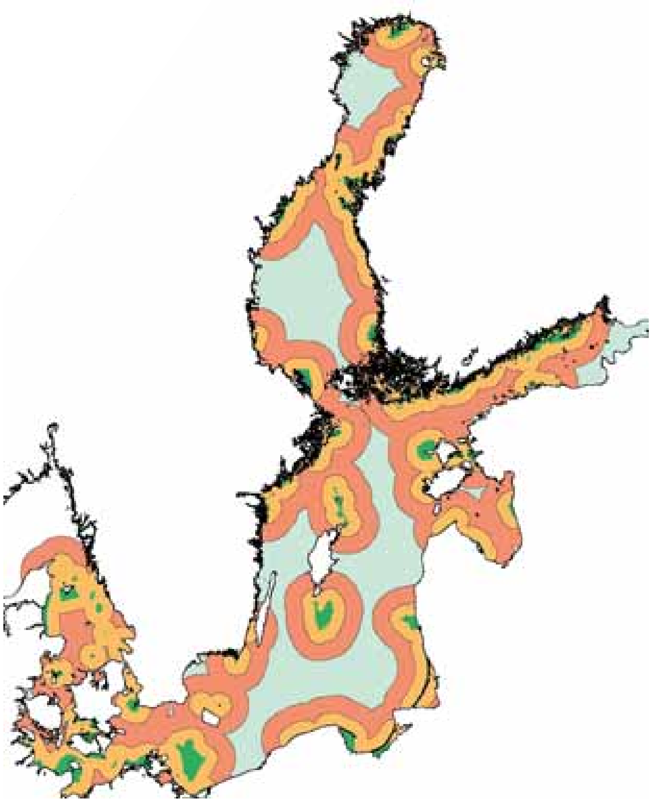

Figure 7.6. Connectivity between the BSPAs (in darker green) with a 20-km (light orange) and a 50-km (dark orange) radius indicating 40 km and 100 km, respectively, connectivity distance between the sites.

7.3 Current status of the legal protection and management of the BSPA network

Establishment of an ecologically coherent and well-managed network of Baltic Sea Protected Areas requires relevant legal protection and management measures. Most existing sites lack implemented management plans or other means of site management, and predominantly aim to protect birds or terrestrial species. Although many sites including in marine areas enjoy some national protection, in most cases it is not clear

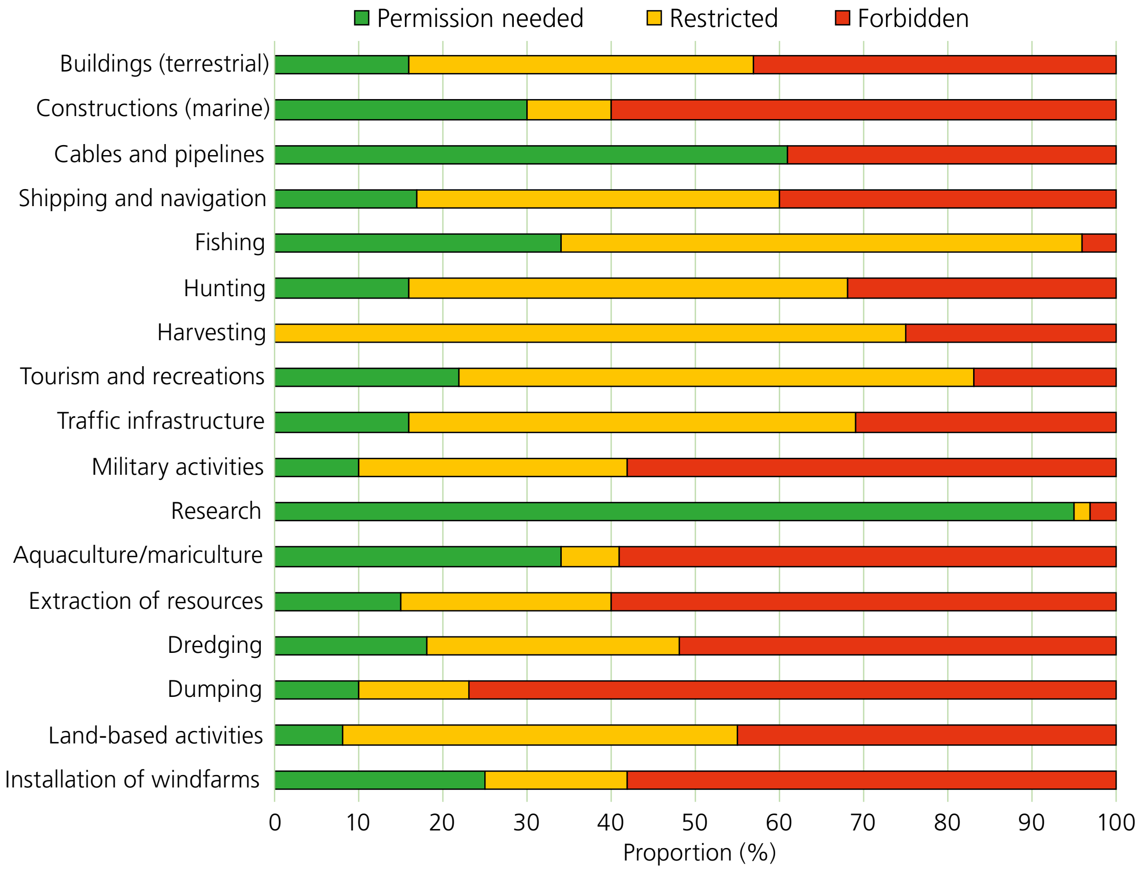

Figure 7.7. Activities forbidden, restricted or requiring permission within BSPAs.

which species or habitats within the site are the protected features. Because nearly all BSPAs are also EU Natura 2000 sites, this should ensure that at least the habitats and species covered by the Habitats and Birds Directives are protected. However, as the species and habitats considered in the Habitats Directive only cover part of the existing biodiversity values in the Baltic Sea, more is needed to create a truly representative and coherent network of MPAs in the Baltic Sea. The HELCOM lists contain more marine habitats and species than the Habitats and Birds Directives and therefore the BSPA network is an important complement to Natura 2000.

In order to properly manage a protected area, harmful activities must be controlled and regulated. Figure 7.7 illustrates regulated activities in those BSPAs which are partly or fully managed. Fishing, harvesting, tourism and recreation can be restricted activities within BSPAs. As pointed out above, however, some human activities cannot be regulated by the coastal states themselves. For example, within the EU, Member States have almost no power to regulate harmful fishing activities by other Member States in their national waters and EEZ. A similar situation occurs with regard to the regulation of disturbances from shipping—a coastal state has no sovereignty to regulate shipping outside its territorial waters, although each state is obliged to implement the Joint Work Programme beyond these waters. Owing to these circumstances, it is of the utmost importance that HELCOM Contracting Parties work closely together to encourage appropriate regulations by those international bodies that have the power to regulate fishing and shipping activities (EU Common Fisheries Policy and IMO, respectively). It should be noted that the Baltic Sea, except for Russian waters, has been designated as a Particularly Sensitive Sea Area (PSSA) by IMO. At the request of Sweden, IMO designated two Swedish offshore BSPAs, Hoburgs Bank and Norra Midsjöbanken, as 'areas to be avoided' for environmental protection; all ships with a gross tonnage of 500 t or more should avoid these areas.

7.4 A regional and systematic approach to selecting a representative network of MPAs: an example from the BALANCE project

To enhance the development of the Baltic Sea MPA network, the BALANCE project developed and tested a regional, systematic approach to selecting a representative and coherent network of MPAs in the Baltic Sea. Based on the best available data, this is the first holistic approach to optimize the Baltic Sea MPA network; it aims to represent the full range of biodiversity and ecosystem functions in the Baltic Sea and thereby help to fulfil the objectives of international conventions and agreements such as the Joint Work Programme. At the same time, this approach intends to build on existing MPAs and minimize the cost and impact on other interests. For more details, see Liman et al. (2008).

Based on its successful use in other parts of the world, BALANCE introduced the computer-based decision-support tool MARXAN (Ball & Possingham 2000, Possingham et al. 2000) into the Baltic Sea context. Tools such as MARXAN are helpful in systematic site-selection processes where consideration is required of large amounts of spatial data and an enormous number of possible combinations of sites.

This type of site-selection process should include as much data as possible to ensure that the biodiversity in the region is well represented in the selected MPA network. As there is a lack of Baltic-wide data on biodiversity, the project relied on a broad-scale representation of all benthic marine landscapes present in the region. In addition, reliable spatial data on species and habitats were also included. These covered cold-water corals (only in the Skagerrak), Important Bird Areas (IBAs), and haul-out sites for grey seals. This site-selection exercise is an example, and should be considered an iterative and constantly improving process. Other conservation features should be included when more and better information becomes available.

Conservation targets and principles

The aim was to set the conservation targets in line with both scientific recommendations and existing political agreements. Three scenarios were explored according to three levels of conservation ambition, i.e., three different minimum levels of benthic marine landscape representation:

1) Representing ≥20% of each marine landscape (recommended minimum level of protection);
2) A lower ambition (≥10%);
3) A higher ambition (≥30%)


Chalk cliff, Jasmund, Germany

In addition to the conservation targets for marine landscapes, targets were also set for the species mentioned above (cold-water corals, important birds, and grey seals). Moreover, criteria for spatial representation in the region were set to guarantee that the MPA network fulfils some basic principles. One of the main principles was that existing protected areas should be included in the network selected and that new sites should be identified to complement the already designated sites to meet the conservation targets (in this specific case, the Natura 2000 Special Areas of Conservation, SACs). Another important principle was that each conservation feature should be represented to its conservation target within each ecologically different sub-region[13] and each country to ensure a certain amount of replication and to guide the spatial distribution of sites so that there would be an even distribution between countries. Socio-economic

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[13] HELCOM sub-regions (Bothnian Bay, Bothnian Sea, Gulf of Finland, Baltic Proper, Kattegat) and Skagerrak.

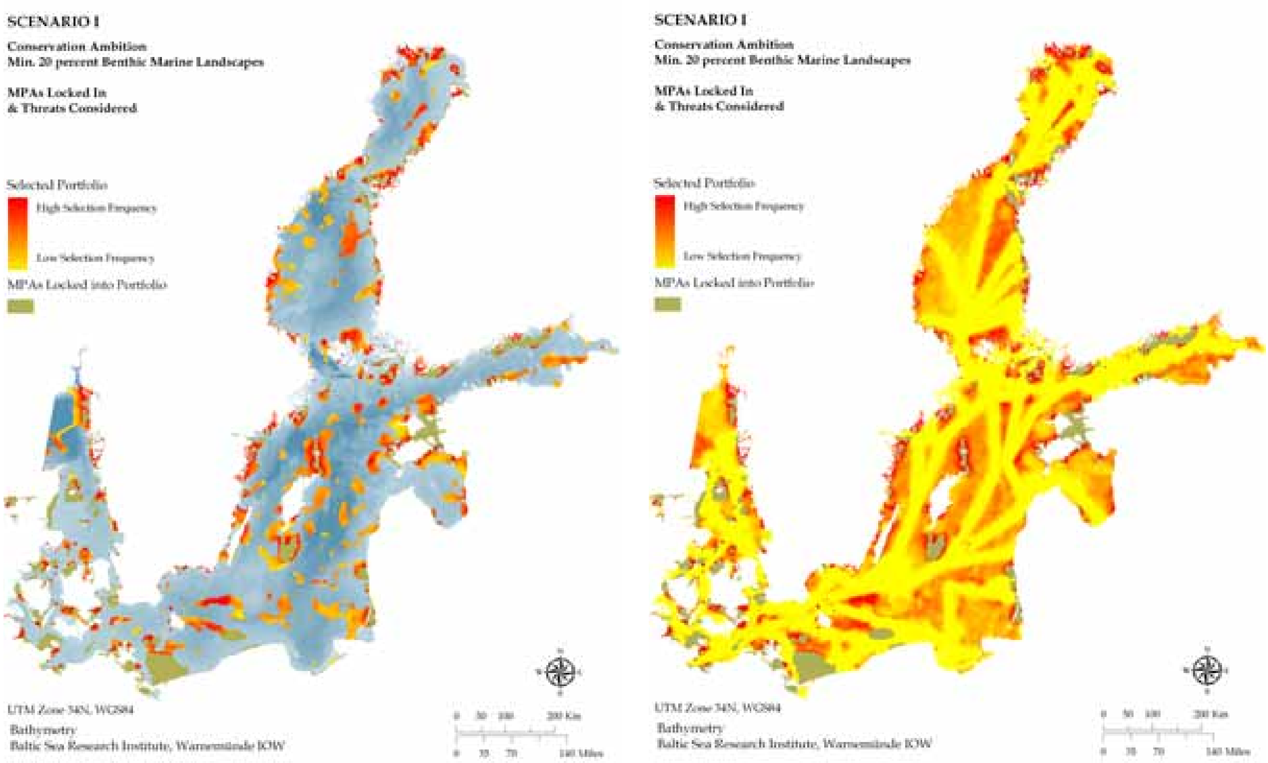

Figure 7.8.a. MARXAN 'best portfolio'. This set of selected areas provides the best fit to the targets chosen for the network. b. MARXAN selection frequency. The deeper red colours indicate areas that were selected more often than others (more yellow), indicating the importance of selecting them for inclusion in the MPA network. Technical details: The figures reflect targets set to represent a minimum of 20% of all benthic marine landscapes and IBAs, 60% of all grey seal haul-out sites and 100% of all cold-water coral occurrences (60% of the dead structures). The portfolio adds complementary sites to Natura 2000 SACs, using BLM=2.5 (Boundary Length Modifier that determines the level of clustering of planning units into conservation areas to improve spatial cohesion of the portfolio), stratified targets and a measure of suitability. The selection was conducted using simulated annealing with iterative improvement using 2 million iterations in 100 runs and a 'penalty value' of 1.1 for all features. All targets were met. From: Liman et al. (2008).

factors[14] and the suitability of sites were also taken into account, meaning that the conservation targets should be met with a minimum impact on other interests and that the relative suitability of potential conservation sites should be considered. The size of the sites selected should also reflect the broad-scale objective of the exercise, meaning that relatively large sites should be selected for protection of the ecosystem on a regional scale.

Results

The scenario presented here was developed with the aim of demonstrating a systematic approach to selecting sites that represent the broad-scale variation in the Baltic Sea. It should therefore be emphasized that the results presented below are only examples of what a representative MPA network in the Baltic Sea could look like given the specific criteria applied in this assessment. The results presented in Figure 7.8 relate to the scenario representing a minimum of 20% of all benthic marine landscapes. To view results of the other scenarios, namely, the 10% and 30% scenarios, see Liman et al. (2008).

Figure 7.8a shows the one set of sites (selected during repeated MARXAN runs) that meets all the above-mentioned conservation targets and principles in the most efficient manner. According to this particular analysis, the area of the additional sites needed, as a complement to the existing sites, to fulfil the recommended 20% representation target corresponds to approximately three times the area of the existing SACs[15]. The selected network of sites in Figure 7.8a, with its combination of selected and already existing sites, covers an area

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[14] Socio-economic factors in the analysis were oil terminals, harbours, potential ship accident areas, major shipping lanes, recommended shipping routes and human population density.

[15] It must be kept in mind that marine features protected under the Habitats Directive do not include most of the benthic marine landscapes.

equivalent to approximately 30% of the entire Baltic Sea water area. This number relates to the specific analysis criteria applied in this assessment, but it gives a clear indication of what a representative MPA network in the Baltic Sea would look like.

Figure 7.8b shows how frequently different areas were selected in a set of repeated independent MARXAN runs; the more frequently selected, the more important that area is for meeting the conservation target. It also shows the flexibility of including different areas when building an efficient and representative MPA network. The red colour indicates areas that are crucial to efficiently meet the targets, for example, because they cover species/landscapes that only exist in that specific site or are adjacent to an existing protected area and therefore easy to include by extending an existing site, while yellow indicates areas that are more flexible in the sense that many alternative areas can equally efficiently contribute to meeting the same target. The generally high flexibility in the result arises from the fact that there are only a few geographically overlapping conservation features (because of the small number of data sets on landscapes, habitats and species). The suitability of individual planning units is, therefore, an important factor determining the spatial selection of sites, with, for example, threats to or conflicts with socio-economic interests indicating low suitability and location adjacent to an existing MPA implying high suitability. If more species and habitat information and more socio-economic considerations were included, the targets would be more difficult to reach and flexibility would decrease. However, areas of importance for several conservation features would be identified.

This site selection exercise clearly shows that a regional systematic approach to site selection is feasible in a multinational area such as the Baltic Sea region. If the aim is to establish a representative network, the use of a systematic approach to site selection instead of selecting MPAs site by site is recommended. This maximizes the chance of creating a network that is representative and efficiently contributes to the protection of the entire Baltic Sea ecosystem and at the same time takes socio-economic factors into consideration. The methodology and results presented here should, however, be viewed as a first step in this direction and should be further improved. The quality of the results depends to a large extent on the formulation and agreement of conservation objectives and criteria, and on the data available. More detailed spatial data is a prerequisite for future site-selection analyses.

7.5 Conclusions

Both the HELCOM and the BALANCE evaluations indicate that the current BSPA network does not fulfil the criteria for an ecologically coherent network. Therefore, at present, and with respect to the full implementation of HELCOM Recommendation 15/5, the Joint Work Programme and the BSAP, the BSPA network cannot be considered sufficient. In summary:

The BSPA network can be considered **adequate** in terms of the size of most sites designated so far, whereas the geographical coverage and distribution of the BSPAs in the current network *cannot* be considered adequate—the network covers less than 10% of the entire Baltic Sea and the proportionate coverage of sites differs significantly between coastal and offshore waters, sub-regions and countries.

The BSPA network is *not* **representative** with respect to its representation of species, habitats or benthic marine landscapes. The need to increase representation is, however, most obvious in deepwater areas.

Replication of species as well as of many landscape types is adequate in the current BSPA network. However, hard clay and bedrock landscapes have relatively *few* replicates. In order to assess replication comprehensively, information on species and habitat distribution must be improved in the BSPA database.


Stony reef community, Fehmarnbelt

The BSPA network is relatively well **connected** in relation to species with long dispersal distances, but it does *not* sufficiently support connectivity of the short and mid-distance dispersers. Some indications of relatively good within-site connectivity were found in larger sites. Owing to gaps in representation in the offshore areas, the network does *not* support connectivity of the species across larger basins.

Although the BSPA database contains some information on the parameters used to assess the ecological coherence, the information in the database is patchy and therefore it is not possible to undertake a comprehensive assessment based on the current level of information and data.

Ecological coherence can only be reached by better protection of all important features of marine biodiversity *in well-managed areas*, which is why national protection and management measures are essential and must be reported to HELCOM for further assessments.

The example of a site-selection analysis clearly shows that a regional systematic approach to site selection is indeed feasible in a multinational region such as the Baltic Sea. Such an approach maximizes the chance of creating a network that is representative and coherent and, when well managed, could protect the whole range of biodiversity in the region while considering socio-economic factors at the same time.

7.6 Recommendations and proposed actions to meet the HELCOM 2010 target

The forthcoming implementation process of the Marine Strategy Framework Directive will be of particular importance for the protection of species and habitats within and between the BSPAs, provided that HELCOM will bring these conclusions and the following recommendations into this implementation process. Based on the gaps identified, the following actions are proposed to be carried out by the Contracting Parties and HELCOM:

- Use the BSPA network as one measure to protect the entire ecosystem and the whole range of species, habitats and ecological processes in the region, including the threatened and/or declining species, habitats, biotopes and biotope complexes, and habitat-building species.
- Designate all marine Natura 2000 sites as BSPAs and designate additional offshore areas of ecological importance as BSPAs.
- Develop and implement management plans or, where more appropriate, measures and routines for all BSPAs.

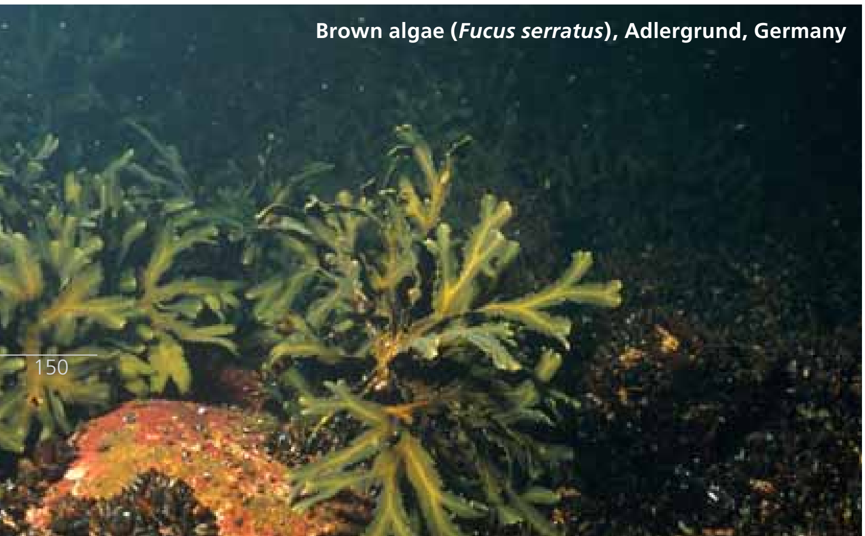
Complete the HELCOM BSPA database with all data required, in particular with data on marine landscapes, species and habitats inside BSPAs and in the entire Baltic Sea in order to:

- assess how well habitats and species are represented and protected in the network;
- assess how well important nursery, juvenile, spawning, feeding, moulting and wintering areas of threatened or declining (and important) species are represented and protected in the network;
- assess how well rare, unique or representative geological or geomorphological structures or processes are represented and protected in the network.

Use the marine landscapes, as demonstrated within BALANCE, to protect a wide range of species, habitats and ecological processes, especially when there is a lack of more detailed data.

Use a regional and systematic approach to site selection as it maximizes the chance of creating a BSPA network that meets the conservation targets in an efficient way and at the same time minimizes the impact on other interests.

Integrate BSPA designation in an overarching spatial planning and management process in combination with other management tools.


Brown algae (*Fucus serratus*), Adlergrund, Germany

8 SYNTHESIS: TOWARDS A FAVOURABLE CONSERVATION STATUS OF BALTIC SEA BIODIVERSITY

The biodiversity segment of the HELCOM Baltic Sea Action Plan (BSAP) reflects the aim to reach a favourable conservation status of Baltic biodiversity by 2021. The variety of management measures agreed in the Action Plan, such as those for combating eutrophication or diminishing inputs of hazardous substances, should, when implemented, result in a better conservation status. In order to follow up the effects of actions taken by the HELCOM Contracting Parties, the status of biodiversity and the state of its conservation need to be regularly evaluated. Hence, the need to develop a harmonized approach to assessing the conservation status was identified in the BSAP.

This report provides the first comprehensive assessment of the status of biodiversity and human pressures impacting biodiversity in the Baltic Sea. Recommendations on how to reach individual targets of the Action Plan have been provided throughout the report in association with the discussion of the relevant components of biodiversity. This synthesis provides an overview of the results of the assessment, discusses the challenges and opportunities for protecting the Baltic Sea biodiversity, and identifies the work necessary to develop future biodiversity assessments.

8.1 Overview of the results

Current status of biodiversity and nature conservation in the Baltic Sea

It is clear that the biodiversity of the Baltic Sea has undergone major changes during the past decades. However, the lack of comprehensive data and the natural variability in biodiversity make it difficult to specify the human contribution to these changes.

The Baltic Sea is inherently a highly dynamic system and concurrently with the observed changes in biodiversity, large-scale climate fluctuations have influenced the Baltic. This has caused changes in the salinity and oxygen concentrations in the deep basins, as well as in sea-surface temperature (Matthäus & Nausch 2003), which in turn have affected the distribution of species and the ecosystem structure. The changes in climate, whether natural or anthropogenic, thus make it challenging to distinguish natural variation from human-induced modifications of the Baltic Sea biodiversity. Nevertheless, there is no doubt that various human pressures have contributed to the observed changes in biodiversity. While many of the observed changes in biodiversity are slanting towards a deteriorating state, there are also positive trends reported for selected species.

Signs of change and deterioration:
Phytoplankton. The assessment of phytoplankton indicates that a number of changes in the community composition have occurred during the past thirty years, e.g., a shift in dominance from diatoms to dinoflagellates during spring bloom periods. Seen over a longer time period, nutrient enrichment has resulted in increased phytoplankton productivity, i.e., eutrophication with more prevalent algal blooms. The blooms themselves are a manifestation of reduced biodiversity within the phytoplankton community.

Habitat-forming species. Important habitat-forming species such as bladder wrack, eelgrass, and stoneworts have decreased in abundance in many coastal areas. The decrease is most pronounced in highly polluted and eutrophied areas as well as areas subject to physical disturbance to the bottom. For bladder wrack, a decline has also been observed in areas with low disturbance, indicating that large-scale hydrological and hydrographical changes in the Baltic Sea area may influence the population.

Zooplankton. The zooplankton community has also displayed significant changes over recent decades. Climate-driven changes in salinity and temperature are likely important factors behind the observed changes in the offshore copepod communities in the Baltic Proper and the southern Baltic Sea presented in this assessment. In addition, eutrophication has contributed to the decreasing volume of oxygenated water below the halocline in offshore areas, thereby reducing the volume of water suitable for the reproduction of zooplankton species that require higher salinities.

Soft-sediment macrofaunal communities in the open-sea areas of the Baltic Sea are naturally constrained by the strong horizontal and vertical gradients in salinity. Currently, macrobenthic communities are severely degraded and abundances are below a 40-year average in the entire Baltic

Bubbling reef, Kattegat

Sea. The increased prevalence of oxygen-depleted deep water is perhaps the single most important factor influencing the structural and functional biodiversity of benthic communities in the open-sea areas of the Baltic Sea.

Fish. Since the mid-1980s, the Baltic fish community has undergone a shift from a dominance of demersal communities to clupeids. The shift was caused by a combination of natural (i.e., climate variability) and human-mediated factors such as eutrophication and fishing. In a number of coastal areas, species benefiting from or tolerating eutrophication such as percids and cyprinids are currently flourishing. Warm summers may also have contributed to this development. In many areas, fish stocks have declined owing to high fishing pressure. Several stocks of migratory fish species are in a poor condition because of damming or blocking of migratory pathways.

Birds. Among the bird species assessed, a long-term population decline is evident for dunlin, as well as a recent decline for eider and long-tailed duck. The causes behind these declines are not well understood, but climate change (in the case of the dunlin), and shipping-induced oil spills, fisheries by-catch and habitat deterioration (in the case of the ducks) may have contributed to the decline.

Mammals. Among the mammals, the population of harbour porpoise, especially in the Baltic Proper, is in a precarious state and the status of ringed seals is still unfavourable. The grey seal population has increased steadily since 1988, but the recovery of grey seals south of 59° N, where they were regularly present before they were hunted to extirpation in the beginning of the 20th century, is still very slow. Fisheries by-catch and prey depletion are among the most prominent and continuing threats to these populations, while the impacts of hazardous substances on seals have been reduced.

Alien species. About 120 alien species have been recorded in the Baltic Sea since the early 19th century. So far, alien species have mostly had an impact in coastal areas, while there are only a few alien species that have been introduced into the open-sea environment. Certain coastal lagoons, especially in the southern Baltic, have been heavily impacted by introduced species. Most of the observed alien species that have spread to the Baltic Sea have not yet become invasive and have, in fact, enriched the species and functional biodiversity of the Baltic Sea. However, new introductions pose a threat to the entire ecosystem and its functions, and the risk of new invasions remains high.

Threatened and declining species. There are currently 59 species that are considered as threatened or declining in the Baltic Sea. The only known extirpated species is the sturgeon. All mammals are under threat or in decline, at least in some parts of the Baltic. The largest single group of threatened or declining species is fish and lampreys, which includes 23 species.

Biotopes. Coastal biotopes and habitats are largely in an unfavourable conservation status and continue to be under increasing pressure in many sub-regions. Many, if not all, habitats are impacted by eutrophication. In addition, physical disturbances such as dredging, disposal of dredged material, and construction of structures or installations are rated as major pressures on these coastal habitats. The poor environmental status of the habitats has implications far beyond the local scale because the habitats are important living, feeding, reproduction and nursing environments for associated flora and fauna.

The Baltic Sea biodiversity is inherently sensitive to disturbances owing to its relatively limited number of species, low genetic variation, and few species within important functional groups. Deterioration of the status of biodiversity, as manifested by the decline of communities and key species, is critical because it diminishes the resilience or buffering capacity against large-scale shifts in the Baltic Sea ecosystem and increases the risk for escalating deterioration of the environment.

Signs of improvement:

The protection of threatened species has been a central theme in nature conservation in the Baltic Sea area since the 1950s and improvements have been achieved among bird and mammal populations that have been subject to protective measures.

Birds. The previously threatened white-tailed eagle and great cormorant show considerable increase in population size, particularly in comparison to the beginning of the 1980s.

Grey seals. The population of grey seals in the northern Baltic Sea is increasing at rates almost maximal for the species.

Fish. There are several positive signs for Baltic fish in recent times. These include, amongst others, an improvement in the natural smolt production of certain salmon populations, improvement of sea trout populations in the western Baltic, significant improvement of the smelt stock in the Gulf of Riga, and an increase in the share of piscivorous fish and the trophic level of fish communities in some coastal areas.

Aquatic vegetation. In a number of coastal areas of the Baltic Sea, e.g., in the northwestern and northeastern Baltic Proper, submerged aquatic vegetation is showing signs of recovery after years of deterioration.

These improvements show the results of restrictions or bans on hunting, reductions in inputs of certain hazardous substances, protection of important habitats, biotopes and species and, to some extent, improvement in water quality. The improvements also show that concerted and inter-sectoral management actions have reversed the precarious state of certain species in the Baltic Sea to a better status.

A crude Baltic-wide overview of the conservation status of Baltic biodiversity was compiled based on the status of some of the elements of biodiversity, mainly species and communities addressed in this assessment with sufficient data availability (Table 8.1). Favourable conservation status of species,

Table 8.1. A crude Baltic-wide overview of the conservation status of biodiversity in approximately 2000–2006 in the different sub-regions of the Baltic Sea presented as an estimation of favourable (green) or unfavourable (red) conservation status of different elements of biodiversity based on the information compiled in this assessment report and expert judgement. NA – Not applicable, ? – data not available.

Biodiversity element	Kattegat and Danish Straits	Southern Baltic Proper	Northern Baltic Proper	Gulf of Riga	Gulf of Finland	Gulf of Bothnia
Benthic invertebrate communities	?	🟥	🟥	?	🟥	🟩
Harbour porpoise	🟥	🟥	🟥	NA	🟥	NA
Grey seal	🟥	🟥	🟩	🟩	🟩	🟩
Ringed seal	NA	NA	🟥	🟥	🟥	🟥
Harbour seal	🟩	🟥	NA	NA	NA	NA
White-tailed eagle	🟩	🟩	🟩	🟩	🟩	🟩
Cormorant	🟩	🟩	🟩	🟩	🟩	🟩
Long-tailed duck	🟥	🟥	🟥	🟥	NA	NA
Dunlin	🟥	🟥	🟥	🟥	🟥	🟥
Bladder wrack	🟥	🟥	🟩	🟩	🟥	NA
Eelgrass	🟥	🟥	🟥	?	?	NA
Charophytes	🟥	🟥	🟥	🟩	🟩	?
Pseudocalanus	🟥	🟥	🟥	?	🟥	NA
Acartia	🟩	🟩	🟩	🟩	🟩	🟩
Temora	🟩	🟩	🟩	🟩	🟩	NA
Limnocalanus	NA	NA	🟥	🟥	🟩	🟩

taxonomic groups and communities is more prevalent in the northernmost sub-basins of the Baltic Sea, especially the Gulf of Bothnia. This result is in agreement with the pilot testing of the Biodiversity Assessment Tool BEAT (see Chapter 5) and also the results of the integrated thematic assessment of eutrophication (Chapter 6 and HELCOM 2009a) where areas not impacted by eutrophication were mainly found to be located in the Gulf of Bothnia.

The better conservation status in the northern parts can likely be attributed to the lower degree of human disturbances and eutrophication in the relatively less populated drainage basins of the Bothnian Bay and Bothnian Sea. In addition, the Gulf of Bothnia is physiographically less prone to oxygen depletion and associated impacts.

Extent of human pressures

The Baltic Sea biodiversity at all levels, be it landscape, community or species, is affected simultaneously by various human pressures and activities. Quantitative information on the extent of these pressures is in many cases scarce and geographically scattered. However, based on the available information, this assessment shows that many pressures are of a considerable magnitude and not sufficiently covered by management plans or regulations to protect the biodiversity in the Baltic Sea.

Eutrophication has long been identified as the major problem of the Baltic Sea ecosystem having a significant impact on biodiversity (HELCOM 2007a). The HELCOM integrated thematic assessment of eutrophication reported that most of the Baltic Sea is a eutrophication problem area (HELCOM 2009a). However, there are also signs of improvement since a slight decrease in nutrient inputs to the Baltic Sea has been recorded between the late 1990s and 2001–2006 and decreasing nutrient concentrations have been observed in a number of areas. Nevertheless, solving the eutrophication problem will take time owing to time lags caused by long water residence times. In addition, oxygen-depleted deep bottom sediments coupled to internal loading, especially of phosphorus, maintain the vicious cycle of eutrophication and slow down the process of nutrient burial in sediments.

Fishing on Baltic cod stocks has been unsustainable for many years. In the Baltic Sea, as well as globally, unsustainable fishing on top predators has resulted in trophic cascades affecting biodiversity far beyond the targeted population (Frank et al. 2005, Casini et al. 2008). In addition to the critical effect on the trophic structure of the ecosystem, fisheries by-catch is also causing considerable negative impact on birds and mammals in the Baltic Sea.

Alien species continue to enter the Baltic Sea resulting in the Baltic Sea biodiversity becoming more similar to that of other regions. The risk that alien species become invasive increases with other disturbances to the ecosystem. In the Black and Caspian Seas, an initial disturbance to the ecosystem caused by excessive fishing and deterioration of water quality is believed to have triggered massive invasions of the jellyfish *Mnemiopsis leidyi* (Daskalov et al. 2007). This species has now been observed in the Baltic Sea.

Physical disturbances, such as sand and gravel extraction, dredging, dumping of dredged spoils, and construction of coastal defense structures and offshore installations, may cause harm and degradation to benthic communities and habitats. Indirect effects on pelagic and coastal communities are also significant. Seafloor resource exploitation and wind farm construction have increased steadily during recent years and numerous plans for future activities are currently under evaluation.

Hazardous substances. The inputs of heavy metals, such as cadmium, mercury and lead, and of certain organic chemicals including PCDD/Fs to the Baltic Sea have decreased since the early 1990s and a reduction in the concentration of these particular contaminants has also been observed in Baltic biota. However, the concentrations of certain new compounds, such as PFOS and HBCDD, are increasing and their impacts on species and the ecosystem are often largely unknown.

Maritime traffic contributes increasingly to nutrient enrichment, physical disturbance and operational oil spills. Above all, the increasing maritime transport adds a considerable threat to the Baltic biodiversity owing to the risk of a major oil spill which under Baltic conditions would cause deep, long-lasting and widespread harm. In addition, maritime transport is the primary vector of alien species.

Noise in the Baltic Sea is a less-studied concern, but it is potentially harmful particularly for mammals but also to fish species that depend on hearing. With the anticipated increase in maritime traffic and coastal construction works, noise in the Baltic Sea environment will increase in the future.

Recreational activities add stress, primarily locally in coastal areas. They often cause physical disturbance to shallow benthic habitats; they may be a source of nutrients, marine litter and noise, and through recreational fishing and hunting they contribute to the disturbance and decline of some species.

Climate change. The projected changes in climate as a consequence of global warming may have profound implications for Baltic biodiversity. In particular, the predicted decrease in salinity is expected to shift the distribution limits of several important habitat-structuring species and key species in the Baltic ecosystem, such as bladder wrack, eelgrass, blue mussel and cod. The projected increase in temperature and decrease in ice cover is also likely to have an impact on species ranges. As examples, decreasing ice cover will have a direct impact on ringed seals whose breeding is linked to the ice and, with increasing temperatures, alien species of southern origin will be more prone to spread to the Baltic. Climate change is also likely to exacerbate eutrophication through changes in precipitation, river inflows, and hydrography and increase the effects of eutrophication on biodiversity. Climate change is thus expected to add considerable stress to the Baltic biodiversity, in addition to the present human activities.

Taken together, eutrophication and fisheries stand out as the two most prominent human pressures behind observed changes in biodiversity in offshore areas of the Baltic Sea. Climate-driven changes in salinity and sea-surface temperature, as well as deep-bottom oxygen depletion, have enhanced the negative impacts of eutrophication and fisheries during recent decades. This view is supported by other recent reports on the Baltic Sea (HELCOM 2007d, ICES 2008a). In coastal areas, physical disturbance, such as construction works and the almost ubiquitous human impact, add significant stress on the biota.

Baltic herring trawling, Bothnian Bay.

Furthermore, the assessment indicates that many pressures are anticipated to increase in the Baltic Sea in the near future. This is the case for activities that make direct use of the sea and seabed such as maritime traffic, coastal and offshore technical installations, and recreational activities. Currently, these activities have a minor impact on the environment compared to inputs of nutrients and hazardous substances from land-based activities or the impact of commercial fisheries. However, unless properly regulated, the relative contribution from these activities will increase.

8.2 Challenges and opportunities for the protection of the Baltic Sea biodiversity

Protection of the marine environment of the Baltic Sea has evolved in HELCOM to embrace a full ecosystem approach to the management of human activities. The Baltic Sea Action Plan is a strategy for implementing the ecosystem approach at the Baltic Sea regional level.

A key feature of the ecosystem approach is the recognition of the tight interconnectedness between the *eco*-system and the *human*-system, including the need of humans to use the goods and services provided by an ecosystem. Use of ecosystem goods and services should, however, be carried out in a way that assures the long-term survival and sustainability of all ecosystem components. The need to ensure the sustainable use of natural resources by taking appropriate measures within the Baltic Sea area is also recognized in Article 15 of the Helsinki Convention.

The results of this assessment show that the management of human activities in the Baltic Sea area is still far from satisfactory and does not put the principles of an ecosystem approach to the management of human activities into practice. There are, therefore, numerous challenges ahead before the BSAP goal of a favourable conservation status of Baltic biodiversity by 2021 will be achieved, but there are also numerous opportunities available. The improvements that have already taken place due to changes in management practices show that the potential for recovery of the Baltic ecosystem is in many cases substantial.

Throughout this report, recommendations on how to achieve specific targets of the Action Plan have been provided. This section gives an overview of the more overarching policy options and management measures that provide opportunities for reversing the—in many cases—unfavourable state of biodiversity in the Baltic Sea.

Windpark, Nysted

The challenge: decoupling economic development and environmental degradation in the Baltic region

Even though economic growth is currently facing a slow-down, economic development tends to be coupled to increasing environmental degradation. According to Eurostat, the Baltic Sea region has been one of the economically fastest growing regions in Europe during the past decade (http://epp.eurostat.ec.europa.eu/). This has resulted in increased pressure on the Baltic Sea ecosystem. A concrete example from the Baltic Sea region is the increase in maritime transport and the resulting increase in the risk of major oil spills, nitrogen emissions and spreading of alien species. In addition, agriculture, in particular animal farming, in the region has developed from small-scale farms to industrialized enterprises. EU policies such as the Common Agricultural Policy support the shift in the newest Baltic region EU Member States to modern practices with intensified use of chemical fertilizers and larger units of animal rearing, resulting in increased nutrient pollution to the Baltic Sea especially in the southern and southeastern area. Moreover, the World Tourism Organization forecasts that the increase in tourism will be larger in the Baltic Sea region compared to other regions (HELCOM & NEFCO 2007).

Actions to combat climate change, such as the requirements adopted by the EU to reduce CO_2 emissions and to achieve a level of renewable energy of 20% of all energy consumed in the EU by 2020 (e.g., Anonymous 2008a), may have an indirect negative effect on Baltic Sea biodiversity. It is highly likely that such a target will result in an increased number of wind farms being located in the Baltic Sea, putting further pressure on the use of the marine space. Growing demand for carbon capture and sequestration technologies and sites, as is also being put forward by the EU institutions (Anonymous 2008b), may mean that potential sites will be explored from the Baltic seafloor with as yet unknown effects on the benthic ecosystems. The energy targets will also likely be linked to installations of new underwater cables and pipelines. An increase in bioenergy production, such as increased cultivation of energy crops, may result in an increase in the use of land currently set aside and also of chemical fertilizers, leading to increased nutrient loading.

Thus, while the biodiversity of the Baltic Sea is already exposed to high levels of human pressures, future activities may result in even more extensive pressures. Hence, it is of the utmost importance that development will be sustainable and take into account the potential impacts on Baltic Sea biodiversity. For the purpose of better linking the environmental impacts and human economic activities, true policy integration in the Baltic Sea region needs to be enhanced.

Enhancing policy integration and developing spatial planning as a practical means for integration

An important task set out by the ecosystem approach and the implementation of the BSAP is to shift to truly integrated management with involvement of all economic sectors and stakeholders and to a system in which the environmental targets and objectives are integrated with economic and socio-economic goals.

Policy integration requires an institutional framework that promotes the incorporation of environmental concerns into sectoral policies and bridges the common sectoral compartmentalization. While policy integration has been called for in a number of global high-level policy documents, such as the UN Conference on Environment and Development in 1992, and is part of the EC Treaty, as well as the Marine Strategy Framework Directive Article 1, there are still relatively few examples of its successful implementation across European countries (EEA 2005). With integrated policies in place, it will be possible to avoid the current situation in which policies not directly related to the environment are commonly adjusted only in response to negative environmental impacts that have already occurred.

Marine spatial planning is a tool providing an opportunity for the practical manifestation and implementation of policy integration. It must be based on good scientific knowledge of the natural features and of the mechanisms by which human activities affect them. Regional spatial controls currently implemented in the Baltic Sea include marine protected areas and Traffic Separation Schemes (TSS), but a Baltic-wide coordinated means of addressing spatial issues in the form of marine spatial planning does not yet exist. With the BSAP, the HELCOM Contracting Parties committed themselves to develop, by 2010, as well as to test, apply and evaluate by 2012, in cooperation with other relevant international bodies, *"broad-scale, cross-sectoral, marine spatial planning principles based on the Ecosystem Approach"*. Fulfilling this task will be the beginning of a better integration of planning systems.

Integrated management has previously been addressed by the EU recommendation concerning integrated coastal zone management in Europe (2002/413/EC) and by HELCOM Recommendation 24/10 on Integrated Marine and Coastal Area Management of 2003. These recommendations recognized spatial planning as a component of integrated management in the coastal zone.

Designation of protected areas

The network of Baltic Sea Protected Areas (BSPAs) was the first European regional network of marine protected areas covering a whole regional sea (HELCOM 1996a), but the network is still not ecologically coherent. In recent years, the BSPAs have been integrated with the Natura 2000 network and the areas are thereby subject to legally binding regulations for Natura 2000 protected features.

The completion of an ecologically coherent network of well-managed BSPAs by 2010 is a fundamental target set forward already by the 2003 Bremen Ministerial Meeting. Establishment of protected areas is also an explicit measure of the Habitats Directive, Birds Directive and Marine Strategy Framework Directive, as well as of the Convention on Biological Diversity. As presented in this assessment, however, the network of BSPAs is not yet ecologically coherent and recommendations on how to fulfill this commitment by 2010 have been outlined in detail (Chapter 7). The recommendations include, for example, the designation of additional BSPAs, particularly in offshore areas, and the development and implementation of management plans or measures for all BSPAs.

Importantly, in order to maximize the benefit of the protected areas, there is a clear need for a multinational perspective in the designation of BSPAs and Natura 2000 sites in the Baltic Sea. With site-selection tools such as the MARXAN tool exemplified in this assessment, it is possible to apply a systematic Baltic-wide approach to ensure a proper distribution of protected areas that can improve the current network.

Reduction of human pressures

While protected areas can preserve landscapes and habitats of particular importance and protect against resource extraction, this measure must be complemented with efforts to reduce pressures that are affecting the water quality, protect the system against invasive species, and ensure sustainable resource use in areas outside the marine reserves.

At present, there is not enough information or knowledge to estimate the relative influence of individual pressures on the status of biodiversity in the Baltic Sea. Nonetheless, as indicated above, eutrophication, fisheries, and physical disturbance in the coastal zone are undoubtedly the cause of severe impacts on Baltic biodiversity. Implementation of the agreed provisional country-wise reductions of the nutrient load included in the eutrophication segment of the BSAP is, therefore, a prerequisite also for achieving the objectives of the biodiversity segment. The severe impacts of fisheries on the ecosystem structure and the status of birds and mammals, as shown in this assessment, emphasize the need to implement an ecosystem approach to fisheries management, as agreed in the BSAP, in order to ensure that fisheries are conducted with minimal impact on the ecosystem as a whole. The considerable impacts of physical disturbance in the coastal zone stress the importance of implementing integrated coastal zone management, as recommended already in HELCOM Recommendation 24/10 and the EU Recommendation 2002/413/EC.

However, while a number of dominant pressures on the Baltic Sea can be outlined, it is important that the magnitude and impact of all pressures and activities be considered when developing the means to control their impact: it is the cumulative and synergetic effects that determine the state of biodiversity. This again emphasizes not only the need for an integrated approach to the management of human activities, but also the application of six basic principles: the precautionary principle, the best environmental practices (BEP), best available technologies (BAT) and polluter pays principles, the compensation or substitution principle, and the avoidance principle. There are, however, several HELCOM recommendations in place that are based on these principles that, once fully implemented and applied, will help to mitigate conflicts between human activities and the marine environment.

Restoration of severely damaged components

In areas where the capacity of the system to recover has been severely reduced, active restoration measures may be necessary in order to reach the conditions that correspond to a favourable conservation status. Examples of restoration methods already in practice include the restoration of coastal wetlands, reconstruction of spawning sites and migratory routes for migrating fish species, and the re-establishment of water circulation in artificially enclosed bays. These are all based on reinstallation of the physical elements necessary for the recovery of natural communities and populations.

When the natural recovery rate is very slow, transplantation of selected biotic attributes such as seagrasses has been used to enhance recovery in other sea areas (Fonseca et al. 1998, Thom et al. 2005). The BSAP emphasizes the need for research on the possibility of reintroducing valuable phytobenthos species, especially in the southern Baltic Sea. Similarly, the BSAP includes the development of breeding and restocking practices for salmon and sea trout to safeguard the genetic variability of native stocks. In the case of extirpations, transplantations or restocking are the only alternatives. This is the case for the sturgeon, whose population in the Baltic Sea is virtually zero and for which natural recovery is considered impossible. However, transplantation and restocking are only alternatives when the causes behind environmental degradation have been identified and properly mitigated. Moreover, restorations are costly and clearly ‘last resort’ options. When viewed as such, and when conducted with best available knowledge and precautionary principles, restorations may however be a tool to ensure the return to a favourable conservation status of previously damaged components of biodiversity.

Adaptive management

Adaptive management with regular monitoring of the implementation of the plan, complemented with necessary review and adjustments, is an inherent feature of the BSAP. This approach includes recognition of the dynamic nature of ecosystems and the use of the most up-to-date environmental targets, data and information.

In the light of anthropogenic climate change, the need for an adaptive management framework will be ever more important. If the climate will change

Baltic esker island, Jurmo, Finland

as projected, so also will the potential abundance and distribution limits of specific species and communities. The highly likely acceleration of eutrophication resulting from higher runoff and changes in hydrography will also affect biodiversity. This means, for example, that management measures to protect Baltic Sea biodiversity also need to be adjusted and in some cases reinforced. This will require effective and continuous feedback between different activities such as monitoring programmes and management measures and, importantly, the results of assessments and analyses must be turned into decisions and implementation.

A good knowledge base to support well-informed and cost-efficient management decisions

The most cost-efficient protection measures can only be chosen based on good knowledge, including both environmental and economic considerations. Only in this way will it be possible to achieve the necessary balance among the three pillars of sustainable development: economic, social, and environmental.

There is a wealth of unrevealed biodiversity of underwater organisms and small organisms in the Baltic Sea, as well as of genetic diversity. There is also a lack of knowledge on the distribution of many underwater ecological features. Even for larger organisms including threatened or declining species, such as the harbour porpoise, the distribution information is incomplete. It is also surprising that despite the extensive research on the Baltic Sea ecosystem, many mechanisms of human impacts on species or habitats are still not known or are under heavy debate, such as the causes of the M74 syndrome of Baltic wild salmon, potential impacts of the fishing of top predators on eutrophication through food-web cascades, or the effects on Baltic biota of the numerous harmful substances that enter the Baltic Sea.

In order to protect as well as to assess Baltic biodiversity, it is necessary to increase our knowledge. In particular, it is important that causal interactions are better known, i.e., that the driving forces behind changes in biodiversity are understood and that human impacts can be distinguished from natural variations. Currently, cause-effect relationships have only been established for a limited number of interactions, such as the effect of some hazardous substances on selected biota like seals, the relationship between nutrient concentration and phytoplankton biomass, and the effect of fishing on fish population dynamics. However, cause-effect relationships between multiple pressures and the state of biodiversity are lacking and difficult to prove scientifically. Although a full understanding of all possible interactions is unrealistic, better knowledge can certainly be achieved by dedicated research and modeling directed towards selected components of biodiversity.

8.3 Necessary steps for future assessments of biodiversity in the Baltic Sea

The BSAP identified the need for continuous monitoring of the conservation status of biodiversity and the need for regular assessments of whether the targets of the BSAP have been reached. The BSAP also recognized the need to develop a harmonized approach to assess the conservation status of Baltic biodiversity in order to ensure comparability among the biodiversity assessments of different Baltic regions. The current assessment has tested the indicator-based Biodiversity Assessment Tool BEAT in a number of case studies (Chapter 5). However, in order to reach a fully functional and reliable tool, there is need for further iterative development.

Continue the development of suitable biodiversity indicators and develop an appropriate monitoring programme for biodiversity

The BSAP initiated the work of identifying suitable biodiversity indicators for the Baltic Sea and this assessment employed a number of indicators in both the theme-specific chapters and the testing of BEAT. However, the development of indicators should continue in order to arrive at a coherent core set of HELCOM biodiversity indicators for use in future assessments.

When a core set of biodiversity indicators has been established for the Baltic Sea, monitoring programmes must be considered with the specific aim of collecting the data necessary to assess the conservation status of Baltic biodiversity. For several of the indicators used in the test application of BEAT, it has not been possible to make a Baltic-wide evaluation because the geographic data coverage is limited. This is the case, for example, for coastal fish for which monitoring is lacking in Denmark and Germany. For a species such as the harbour porpoise, there are clearly not enough data or monitoring to follow-up the status or targets of the BSAP. For birds, monitoring data are already collected with good geographic coverage, but a Baltic-wide assessment framework is missing. These are only a few examples of biodiversity-relevant parameters that are currently not monitored at a scale or frequency necessary to provide regular and harmonized biodiversity assessments.

Establish reference conditions and acceptable deviations

Definition of reference conditions is a prerequisite for the use of indicators in the HELCOM Biodiversity Assessment Tool BEAT. The work of determining reference conditions for ecologically relevant indicators is ongoing in most countries in the Baltic Sea area as a follow-up to the EU Water Framework Directive. Implementation of the Marine Strategy Framework Directive will require similar work to be carried out for the open-sea ecosystem. However, for several of the parameters discussed in this assessment, indicators still need to be developed and reference conditions have to be set. As a starting point, more efficient data management and creation of Baltic-wide data sets, whenever appropriate, would greatly facilitate and improve the work of establishing reference conditions for biodiversity in the Baltic Sea. Further challenges will emanate from the highly likely changes in the ecosystem resulting from climate change. The changes will mean that reference conditions must be adapted to match the prevailing environmental conditions.

Another prerequisite of BEAT is the definition of a coherent classification system including acceptable deviations from the reference conditions for the chosen indicators. These values determine the classification into favourable or non-favourable status and provide a quantitative ecological target. In the test cases presented in this report, the acceptable deviation has often been set based on expert judgment. In preparation for future HELCOM biodiversity assessments, determination of acceptable deviations should take place through a process that takes into account the range of natural variation and threshold values that are linked to a risk of population collapse and regime shifts.

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ANNEX II: LIST OF ACRONYMS AND ABBREVIATIONS

ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BALANCE	Baltic Sea Management - Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning (an INTERREG III B project)
BEAT	HELCOM Biodiversity Assessment Tool
BLM	Boundary Length Modifier
BMP	Baltic Monitoring Programme
BSAP	Baltic Sea Action Plan
BSPA	Baltic Sea Protected Area
CBD	Convention on Biological Diversity
CFP	Common Fisheries Policy
DEM	Digital elevation model, a digital presentation of a topographic surface
DHI	international consulting and research organisation named originally after Danish Hydraulic Institute
EAM	Ecosystem Approach to Fisheries Management
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EUNIS	European Nature Information System
FIMR	Finnish Institute of Marine Research
GIS	Geographic Information System
GEUS	Geological Survey of Denmark and Greenland
GTK	Geological Survey of Finland
HELCOM	Helsinki Commission
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
IOW	Leibniz Institute for Baltic Sea Research Warnemünde
MPA	Marine Protected Area
NAO	North Atlantic Oscillation
IUCN	International Union for Conservation of Nature
MSFD	Marine Strategy Framework Directive
NERI	National Environmental Research Institute of Denmark
psu	practical salinity units
RAC	Regional Advisory Council
SAC	Special Areas of Conservation
SEA	Strategic Environmental Assessment
SGU	Geological Survey of Sweden
TIN	Triangular irregular network, points connected by lines to form triangles in order to construct a surface.

ANNEX III: CONSERVATION STATUS OF THE BALTIC COMPARISON TO HELCOM THREAT ASSESSMENT

N2k-Code	Natural Habitat Type	Denmark		Estonia		Finland		Germany	
		N2K	HEL	N2K	HEL	N2K	HEL	N2K	HEL
1110 MAR	Sandbanks which are slightly covered by sea water all the time	U2	3	FV	3	U1	3	XX	2
1130 BOR	Estuaries			FV	3	U2	3		
1130 CON	Estuaries			FV	3	U2	3		
1140 BOR	Mudflats and sandflats not covered by seawater at low tide			FV	3		3		
1140 CON	Mudflats and sandflats not covered by seawater at low tide	U2	3					U1	3
1150 BOR	Coastal lagoons			FV	3/P	U1	2/2		
1150 CON	Coastal lagoons	U2	3/P					U2	2/P
1160 BOR	Large shallow inlets and bays			FV		U1	3		
1160 CON	Large shallow inlets and bays	U2	3					U1	2
1170 MAR	Reefs	U2	3	FV	3	U1	3	XX	2
1180 MAR	Submarine structures made by leaking gases	U2	2-3						
1610 BOR	Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation		P			U1	2		
1650 BOR	Boreal Baltic narrow inlets					U1	3		

Abbreviations used in the table:
a. in relation to Natura 2000
N2K: Natura 2000, **FV**: Favourable- / **U1**: Inadequate- / **U2**: Bad- / **XX**: Unknown conservation status
CON: Continental Biogeographic Region of the EU; **BOR**: Boreal Biogeographic Region of the EU; According to the biogeographic regions of the EU, Baltic Sea EU members belong either to the Continental Region (Denmark, Germany, Poland), to the Boreal Region (Estonia, Finland, Latvia, Lithuania) or are assigned to both (Sweden). Russia, as non EU state, would belong with her St. Petersburg area to the Boreal Region and with the Kaliningrad oblast to the Continental Region.
MAR: These habitat types are in this case assessed for the entire Baltic Sea area, because they were not as clearly defined as the other habitats and therefore were subject to a scientific reservation by the Habitats Committee of the EU. Meanwhile new definitions exist (European Commission 2007).

b. in relation to HELCOM
HEL: Threat assessments according to the HELCOM Red List of Biotopes (HELCOM 1998).
Codes: refer to codes biotope types (numbers) or biotope complexex (letters) in HELCOM (1998).
Threat Categories according to HELCOM (1998): **0** - Completely destroyed, **1** - Immediately threatened, **2** - Heavily endangered, **3** – Endangered,
P - Potentially endangered, ρ - Presumably not endangered at present.

SEA MARINE NATURA 2000 HABITATS IN (HELCOM 1998).

Latvia		Lithuania		Poland		Russia	Sweden		HEL
N2K	HEL	N2K	HEL	N2K	HEL	HEL	N2K	HEL	Baltic-wide
FV				FV	3	2-3	U1	3	3 Codes: 2.4.2.3, 2.5.2.4
	2	FV	3		3	2	U1	2	2 Codes: I,J (complex)
	2	FV	3		3	2	U1	2	
	3		P			3	U1		3 Codes: 2.5.3.3, 2.5.3.2, 2.7.3.1, 2.7.3.2
					3	2-3	U1		
FV	2/1	FV	2/P			ρ	U2	3/ρ	2/P Codes: G (complex)/ 4.1.1.1, 4.1.1.2, 4.1.2.1, 4.1.2.2, 4.1.2.3, 4.1.3.1, 4.1.3.2
				U1	2/P	2-3/P	U2		
						3	U1		3 Codes: F (complex)
				U1			U1		
FV	3	FV		FV		ρ	U2	3	3 Codes: 2.1.1.2.3, 2.1.1.3.3, 2.1.2.2.3, 2.1.2.3.3, 2.2.2.3, 2.2.3.3
									P Codes: 2.10.2.1, 2.10.2.2
						ρ	FV	3	3 Codes: M (complex)
							U1	3	3 Codes: E (complex)

ANNEX IV: HABITAT OR SPECIES DISTRIBUTION MODELS IN THE BALTIC SEA AREA.

Country/Region	Project	Species/habitat	Area (km^2)	Model	Reference	Contact
Baltic Sea	MopoDeco	Blue mussel		DHI	Continuing	Henrik Skov, DHI
Baltic Sea	MopoDeco	Bladder wrack	120 000	Maxent	Continuing	Anna Engdahl, AquaBiota Water Research
Denmark, Kattegat	MAR-COAST	Blue mussel, Trough shell, Razor clam	100 000	DHI	Continuing	Henrik Skov, DHI
Denmark, Kattegat	BALANCE	Macroalgae	3+320	GLM	BALANCE interim report 21	Karsten Dahl
Denmark, Kattegat, Skagerrak	BALANCE	Demersal fish by shores		GRASP	BALANCE interim report 27	Claus R. Sparrevohn.
Great Belt, Denmark	Sund & Bælt AS	Blue mussel	15 000	DHI	Interim report	Flemming Møhlenberg, DHI
Limfjorden, Denmark	Danish counties in Limfjorden	Blue mussel	10 000	DHI	Interim report	Flemming Møhlenberg, DHI
Estonia	BALANCE	Bladder wrack		GRASP	BALANCE interim report 27	Jonne Kotta, EEI
Finland, Archipelago Sea	BALANCE	Bladder wrack		GRASP	BALANCE interim report 27	Anna Lena Nöjd
Latvia	BALANCE	Furcellaria lumbricalis		GRASP	BALANCE interim report 23	Bärbel Müller-Karulis
Lithuania	BALANCE	Furcellaria lumbricalis		GRASP	BALANCE interim report 27	Darius Danuas, Corpi
Poland	Ecosystem approach to marine spatial planning – Polish Marine Areas and the NATURA 2000 network	Macrophytes, blue mussel	277	GRASP	Continuing	Julia Carlström, AquaBiota Water Research
Sweden, all coasts	Governmental commission 25	Bladder wrack	81 500	Maxent	Continuing	Anna Engdahl, AquaBiota Water Research
Sweden, Bothnian Sea (Forsmark), Baltic Proper (Oskarshamn)	SKB biosphere project	Functional groups: macroalgae, carnivorous fish, zooplankton-eating fish, filterfeeders, zooplankton	230+180	GRASP	SKB R0750	Ida Carlén, AquaBiota Water Research
Sweden, Finland, Archipelago Sea	BALANCE	Fish recruitment habitats	100	GRASP	BALANCE interim report 27	Göran Sundblad, Swedish Board of Fishery
Sweden, Bothnian Sea, Gräsö	Governmental commission 25	Macrophytes, blue mussel, fish recruitment habitat, benthic macrofauna	730	GRASP	Continuing	Ida Carlén, AquaBiota Water Research
Sweden, Kattegat/ Skagerrak	Governmental commission 26	Macroalgae, mussels, lether coral		GRASP, CART	Continuing	Martin Gullström, AquaBiota Water Research Mats Lindergart, Gothenburg University
Sweden, Koster, Skagerrak	Governmental commission 25	Macroalgae, mussels, lether coral		GRASP	Continuing	Martin Gullström, AquaBiota Water Research
Sweden, Kattegat, Skagerrak	Effects on marine windparks on fish (Vindval Fisk)	Laminaria, mussels, several fish species	100+90	GRASP	Continuing	Ida Carlén, AquaBiota Water Research
Sweden, Missjö, Baltic Proper	Governmental commission 25	Macrophytes, blue mussel, benthic macrofauna	18	GRASP	Continuing	Julia Carlström, AquaBiota Water Research

Country/Region	Project	Species/habitat	Area (km^2)	Model	Reference	Contact
Sweden, Offshore, Baltic Sea	Offshore banks Survey	Macroalgae, mussels	4 200	GRASP	SEPA offshore report 5817	Sofia Wikström, AquaBiota Water Research
Sweden, Råneå, Gulf of Bothnia	Governmental commission 25	Macrophytes	350	GRASP	Continuing	Anna Engdahl, AquaBiota Water Research
Sweden, Skagerrak	BALANCE	Nephrops	500	GRASP	BALANCE interim report 27	Martin Isaeus, AquaBiota Water Research
Sweden, Skagerrak	Kosterhavet National Park	Lophelia reefs		CART	Internal report for SEPA	Mats Lindegarth, University of Gothenburg
Sweden, Stockholm	SAKU	Bladder wrack		Isaeus 2004	SEPA SAKU	Sandra Wenngren, Metria
Sweden, Stockholm, Askö	PhD Thesis	Macrophytes	640	GRASP	Sandman et al.(in press)	Antonia Sandman, Stockholm University
Sweden, Stockholm, Ornö	PhD Thesis	Bladder wrack	450	Isaeus 2004	Isaeus 2004	Martin Isaeus, AquaBiota Water Research
Sweden/Stockholm	Svenska högarna	Bladder wrack, epiphytes, charophytes, filamentous algae, detritus, H2S	33	GRASP	Svenska Högarna 2007	Ida Carlén, AquaBiota Water Research
Öresund	Sund & Belt AS	Eelgrass	5 000	DHI	Internal report	Flemming Møhlenberg, DHI
Sweden, Kattegat, Vinga/Fotö	Commission form Regional Council	EUNIS-habitats		CART	Report in Swedish	Mats Lindegarth, University of Gothenburg
Sweden, Kattegat, Marstrand	Commission form Regional Council	EUNIS-habitats		CART	To be started	Mats Lindegarth, University of Gothenburg

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ANNEX V: STATUS OF BREEDING AND WINTERING BIRD SPECIES IN THE BALTIC SEA SUB-BASINS

Breeding birds

Area name (1)	Sandwich tern (bp 2007)(2)	Cormorant (bp 2006/2007)(3)	Barnacle goose (2007)	Dunlin (2007)
Bothnian Bay and Bothnian Sea	-	6 100	2 000	50–60
Archipelago and Åland Seas	-	3 600		1–5
Gulf of Finland	-	6 800		1–5
Northern Baltic Proper and Gulf of Riga	600–900	26 000	70	200–250
Western Gotland Basin	30	16 100	5,300	50–80
Southern Baltic Proper, eastern parts	400	29 000	-	0–5
Southern Baltic Proper, western parts	160	11 800	??	0
Arkona Sea (including German, Swedish and Danish coastal waters)	700	11 000	??	7–8
Western Baltic (Belt Sea and Sound)	1 130	30 000	20–25	40–50
Kattegat	1 170	14 300	??	180–200

1) The areas refer to HELCOM sub-basins shown in Figure 6.5.1. 2) bp = breeding pairs. 3) Cormorant: including inland breeding pairs, but excluding Danish and German North Sea.

Wintering birds

Area name	Long-tailed duck (1988–1993)(4)	Razorbill (1988–1993)	Eider (1988–1993)	Steller's eider (2000–2007)
Bothnian Bay and Bothnian Sea	-	-	-	-
Archipelago and Åland Seas	0.14 % (6 000)	-	-	50–100
Gulf of Finland	0.62 % (26 500)	-	-	-
Northern Baltic proper and Gulf of Riga	23.4 % (1 Million)	2 800	-	1 100–2 300
Western Gotland Basin	35.1 % (1.5 Million)	11 000	600	50–100
Southern Baltic Proper, eastern parts	0.47 % (20 000)	2 000	150	100–900
Southern Baltic Proper, western parts	28.1 % (1.2 Million)	8 500	24 000	10
Arkona Sea (including German, Swedish and Danish coastal waters)	4.7 % (200 000)	-	3 000	-
Western Baltic (Belt Sea and Sound)	2.8 % (120 000)	1 200	580 000	-
Kattegat	0.33 % (14 000)	132 000	450 000	-

4) Proportion (%) per sub-basin and number of individuals (in brackets).

Note: For long-tailed duck, eider and razorbill, Baltic-wide data are only available from Durinck et al. (1994). Numbers have changed since then (e.g., declining wintering populations of eider and long-tailed ducks), but the importance of the different wintering sites is still the same.

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