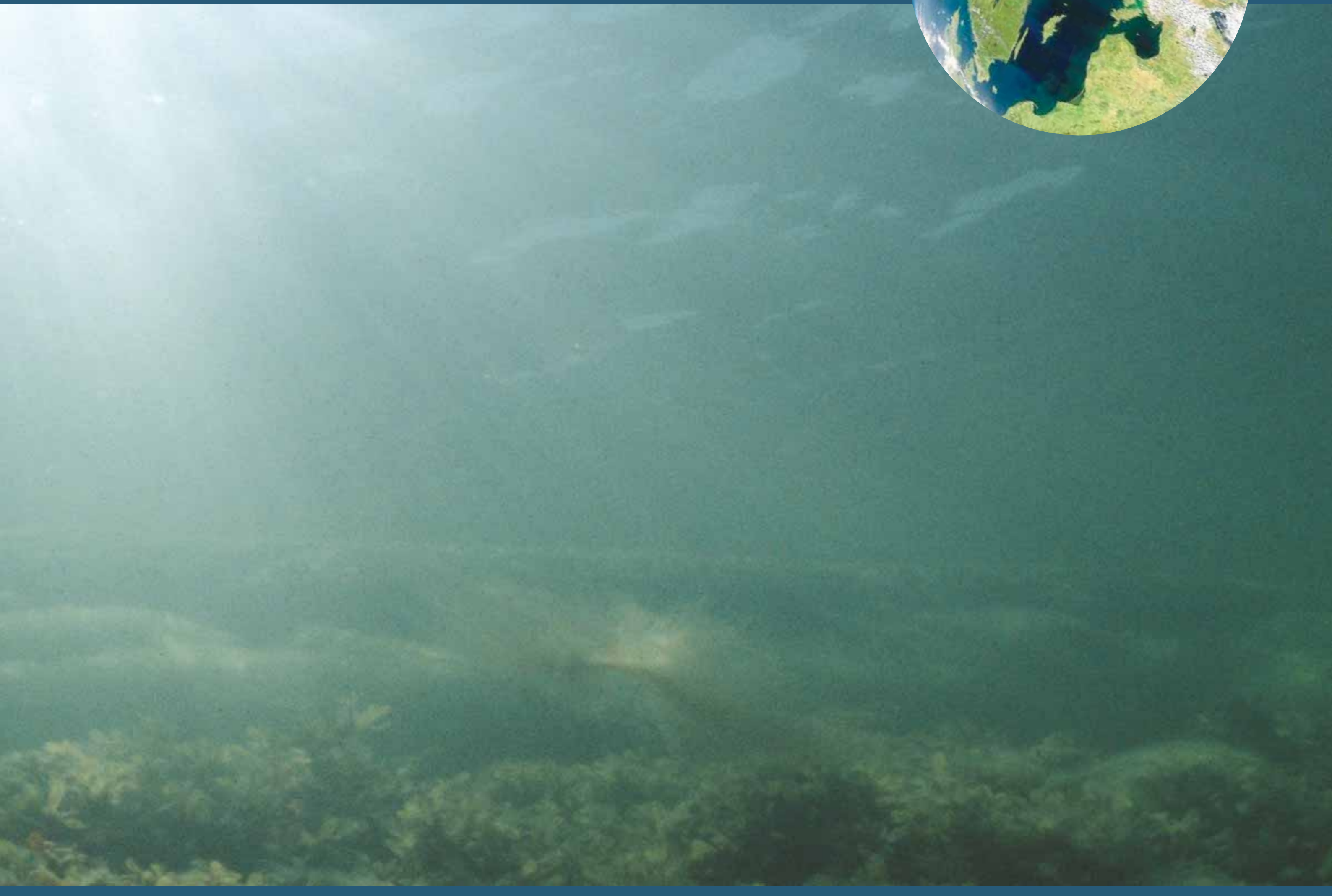
Baltic Sea Environment Proceedings No. 87

The Baltic Marine Environment 1999–2002



Helsinki Commission

Baltic Marine Environment Protection Commission

2003

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Preface

Riku Lumiaro / FIMR

The Helsinki Commission has been assessing the effects of nutrients and hazardous substances on ecosystems in the Baltic Sea for the past 25 years. The resulting assessment reports are unique compilations of data and analysis based on the scientific research carried out around the Baltic Sea, including the special monitoring programmes co-ordinated by HELCOM.

The previous scientific background assessment covered the years 1994–1998. This new report contains an updated scientific evaluation of the state of the Baltic marine environment between 1999 and 2002, and examines the latest trends.

The most up-to-date information is always available on HELCOM's web site: www.helcom.fi

Riku Lumiaro / FIMR

Introduction

Riku Lumiaro / FIMR

The Baltic Sea is a small sea on a global scale, but as one of the world's largest bodies of brackish water it is ecologically unique. Due to its special geographical, climatological, and oceanographic characteristics, the Baltic Sea is highly sensitive to the environmental impacts of human activities in its catchment area, which is home to some 85 million people.

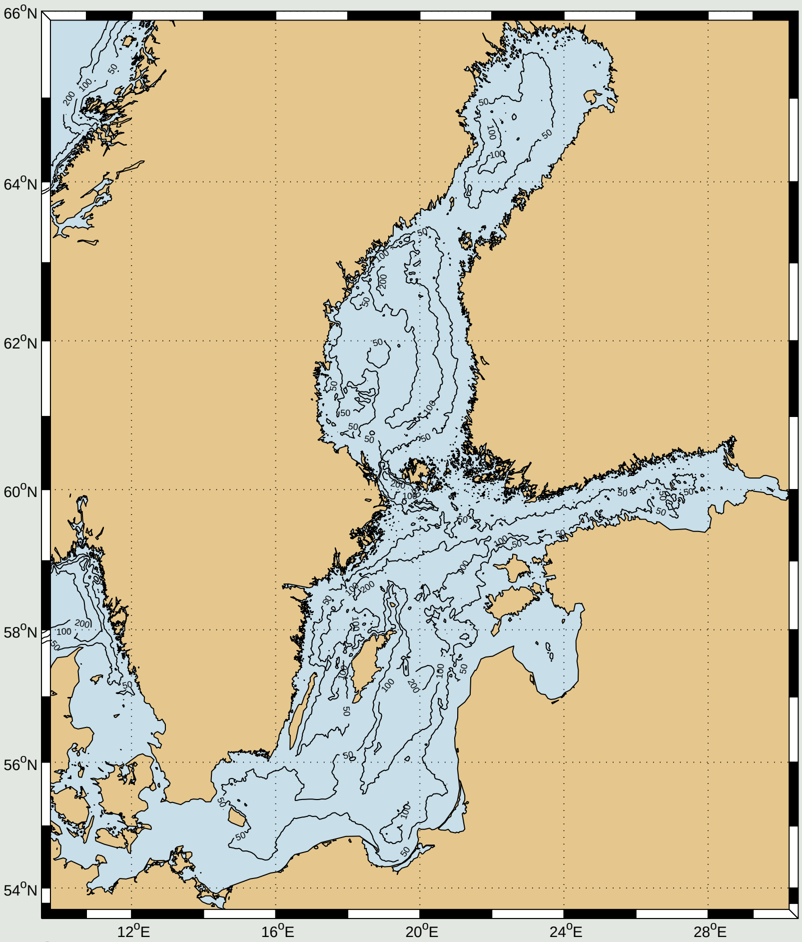


Figure 1. Depths in the Baltic Sea

Table 1. Main characteristics of the Baltic Sea (See Figure 3 for locations of the sub-regions)

Sub area	Area (km^2)	Volume (km^3)	Maximum depth (m)	Average depth (m)
Gulf of Bothnia	11,5638	6,381	293	55
Gulf of Finland	29,509	1,104	115	37
Gulf of Riga	18,558	412	56	22
Baltic Proper	207,911	13,006	451	63
Belt Sea	10,660	138	54	13
Kattegat	22,088	506	100	23
Total	404,364	21,547	451	53

What makes the Baltic so sensitive?

An almost enclosed sea

The Baltic Sea is only connected to the world's oceans by the narrow and shallow waters of the Sound and the Belt Sea (Figure 1). This limits the exchange of water with the North Sea, and means that the same water remains in the Baltic for up to 30 years – along with all the organic and inorganic matter it contains.

The Baltic Sea consists of a series of sub-basins, which are mostly separated by shallow sills. These basins each have their own water exchange characteristics.

Runoff enters the shallow Baltic Sea from a large catchment area

At an average depth of just 53 metres, the Baltic Sea is much shallower than most of the world's seas. It contains 21,547 km^3 of water (Table 1), and every year rivers bring about 2% of this volume of water into the sea. The Baltic Sea's catchment area is almost four times larger than the sea itself (Figure 3).

Brackish water

The brackish water of the Baltic Sea is a mixture of sea water from the North Sea and fresh water from rivers and rainfall. The salinity of its surface waters varies from around 20 PSU (≅parts per thousand) in the Kattegat to 1–2 PSU in the northernmost Bothnian Bay and the easternmost Gulf of Finland, compared to 35 PSU in the open oceans.

A stratified sea

Salinity levels also vary with depth, increasing from the surface down to the sea-floor. Saltier water flowing in through the Sound and the Belt Sea does not mix easily with the less dense water already in the Baltic, and tends to sink down into deeper basins. At the same time, the less saline surface water flows out of the Baltic. The boundary between these two water masses, known as the *halocline*, consists of a layer of water where salinity levels change rapidly. In the Baltic Proper and Gulf of Finland, for instance, the halocline lies at a depth of around 60–80 m. Like a lid, the halocline limits the vertical mixing of water. This means that the oxygen content of the deep basins of the

Baltic Proper (see Figure 7) is mainly replenished by oxygen-rich saltwater flowing in from the North Sea along the sea floor. In the Gulf of Bothnia, the halocline is very weak or absent.

In summer a *thermocline* – a distinct layer of water where the temperature changes rapidly – divides surface waters into two layers: a wind-mixed surface layer down to a depth of 10–25 m, and a deeper, denser and colder layer extending down to the sea-bed or the halocline.

Limited biodiversity

Compared to other aquatic ecosystems, only relatively few animal and plant species live in the brackish ecosystems of the Baltic Sea – although this limited diversity does include a unique mix of marine and freshwater species adapted to the brackish conditions, as well as a few true brackish-water species. Where salinity levels are low, in the Baltic's northern and eastern waters, fewer marine species can thrive, and marine habitats are dominated by freshwater species, especially in estuaries and coastal waters.

But the limited number of species involved in Baltic Sea food webs means that each individual species has a special importance in terms of the structure and dynamics of the whole ecosystem. The disappearance of a single key-species could destroy the functioning of the whole system. Such ecosystems are considered to be very vulnerable to external disturbances (Figure 2).

In the northern Baltic Proper, for example, the bladder wrack *(Fucus vesiculosus)* is the only large seaweed species found in coastal waters with rocky sea-beds. Bladder wrack colonies provide food, shelter and spawning sites for many species, including fish and marine invertebrates. If bladder wrack declines, all the other species that depend on it will also suffer.

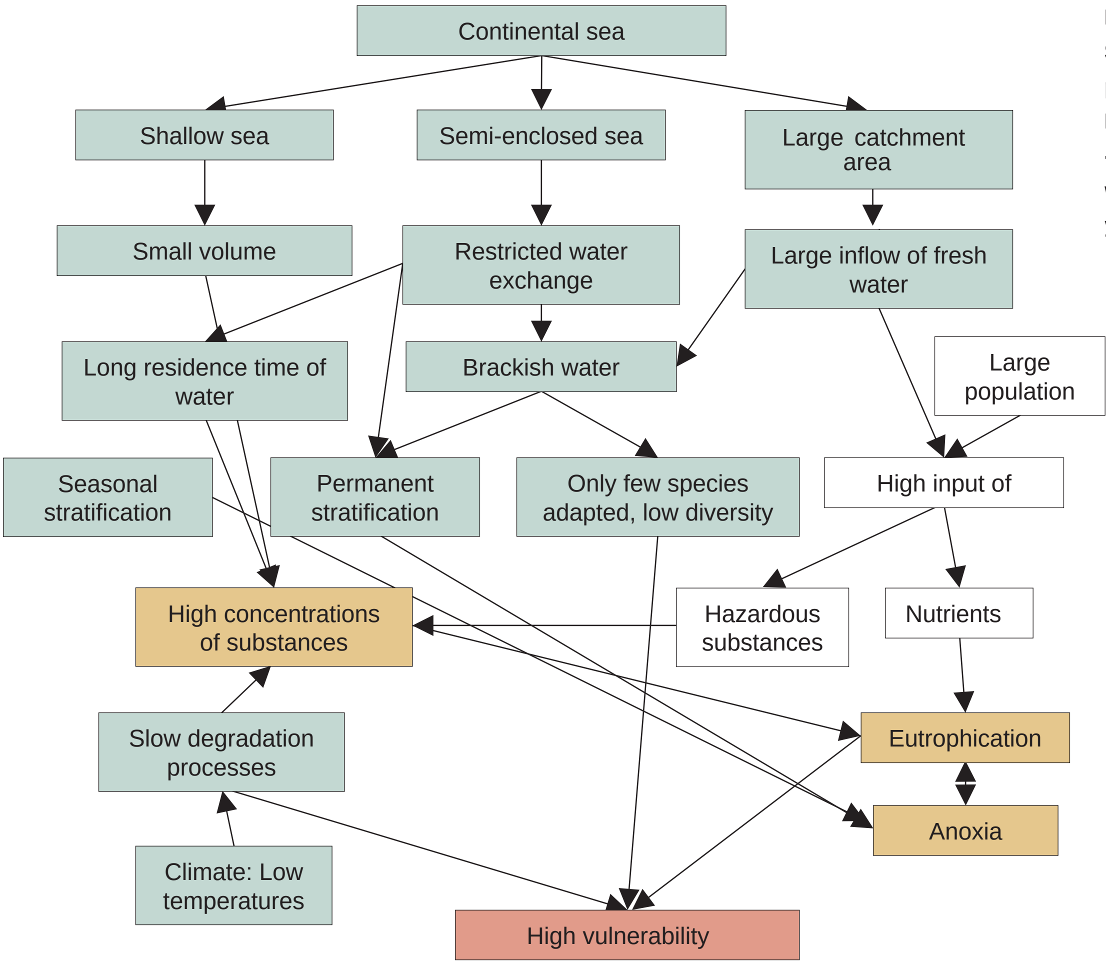
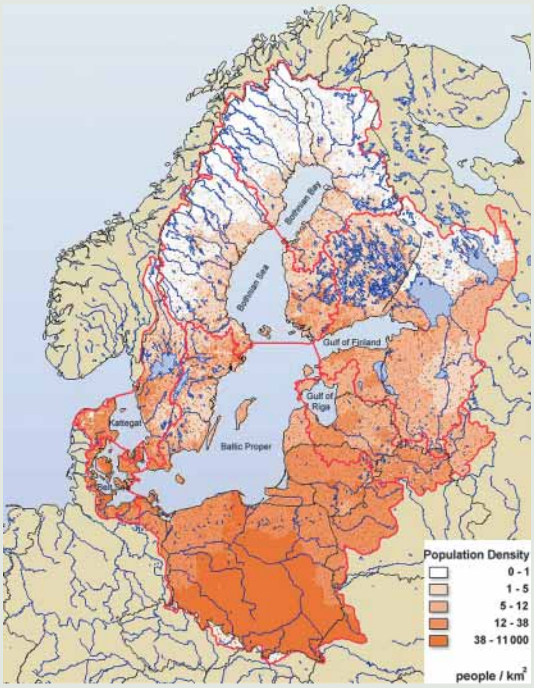


Figure 2.
Specific features and processes which make the Baltic Sea sensitive (green - natural characteristics, white - human impacts, yellow - harmful effects)

Figure 3.
Population density in the Baltic Sea drainage area varies greatly from north to south (Source: GRID-Arendal).



Species' distributions are also affected by climatic conditions, which range from temperate in the south to sub-arctic in the north. Important climatic factors include the winter sea-ice cover, water temperature and the length of the growth season.

Human impacts

The Baltic Sea catchment area extends over some 1.7 million km^2, and is home to nearly 85 million people. Population densities vary from over 500 inhabitants/km^2 in the urban areas of Poland, Germany and Denmark, to less than 10 inhabitants/km^2 in northern parts of Finland and Sweden (Figure 3 and Table 2). There are 11 cities with more than 500,000 citizens in the catchment area, and almost 15 million people live within 10 km of the coastline. Nutrients and hazardous substances originating from cities, farmland, commercially managed forests, industrial and energy plants, transport and other human activities from the whole catchment area drain into the sea via rivers. Pollutants from an even larger area can enter the Baltic from the air. Emissions and discharges from shipping and fish farms also directly enter the sea.

Excessive inputs of nutrients and hazardous substances are considered to be behind the major environmental problems in the Baltic Sea. Increasing shipping raises the risk of a serious oil-spill, and also leads to the inadvertent introduction of exotic species. Commercial fisheries have also profoundly affected Baltic Sea ecosystems.

Table 2.
Percenage of population in the catchment area of the Baltic Sea.

Country	Metropolitan [a]	Other urban [b]	Rural [c]	Total Basin
Belarus	0.00	6.59	6.02	4.71
Czech Rep.	2.77	2.47	0.00	1.83
Denmark	7.34	5.94	2.53	5.31
Estonia	2.23	1.65	1.81	1.85
Finland	2.25	9.30	4.06	5.94
Germany	2.61	3.69	4.52	3.65
Latvia	4.07	2.54	3.24	3.14
Lithuania	4.55	3.95	4.76	4.34
Norway	0.00	0.02	0.10	0.04
Poland	35.92	41.17	58.46	44.86
Russia	22.82	9.30	6.40	11.96
Slovak Rep.	0.00	0.60	0.00	0.27
Sweden	11.77	11.88	5.61	10.02
Ukraine	3.66	0.90	2.50	2.08
Total:	100.00	100.00	100.00	100.00

a. Metropolitan _ Population > 250 000
b. Other urban =. Population between 200–250 000
c. Rural = Population < 200
Source: Sweitzer et al. 1996

Changing natural conditions

Riku Lumiaro / FIMR

Nutrients and hazardous substances enter the sea in runoff

The amounts of freshwater runoff entering the sea from its catchment area determine the quantities of nutrients entering the sea, and also affect salinity levels and the stratification of the sea water into layers of different densities. The rain and snow that fall directly into the sea only play a minor role in the water balance of the Baltic Sea, but they account for most of the atmospheric nitrogen load entering surface waters. Climatic factors such as precipitation and evaporation determine levels of runoff.

During the last 50 years, annual runoff into the Baltic Sea has remained approximately stable. While long-term cyclical fluctuations with alternating wet and dry periods are observable, year-to-year variations are dominant (Figure 4) along with the annual runoff cycle. This assessment period was relatively wet compared to previous years.

Weather conditions regulate the exchange of water with the North Sea

The inflow of water from the North Sea represents a lifeline for Baltic ecosystems. A small inflow of water at and below the halocline feeds saltwater into the Baltic more or less continuously. But the more massive “pulses” of oxygen-rich saltwater, which are so vital in maintaining oxygen levels in deep waters, are regulated by weather conditions (air pressure and storms).

These major inflows from the North Sea are also affected by levels of precipitation in the catchment area, and the subsequent volume of fresh water entering the Baltic Sea in rivers, especially during the winter.

Declining input from the North Sea

The exchange of water between the Baltic Sea and the North Sea has slowed in recent decades. This could be related to variations in the large-scale climatic conditions affecting the distribution of high and low pressure areas, winds and precipitation. These weather patterns are characterised by the North Atlantic Oscillation (NAO index), which varies from year to year, but also shows a tendency to remain in one phase for several years. The pronounced positive NAO index since late 1980s seems to correlate with low inflow frequency (Figure 5), but cannot alone sufficiently explain the pattern of inflow events during the whole 20th century.

Saltwater pulses can improve oxygen conditions

Inflows of saltwater into the Baltic Sea have been relatively frequent (Figure 5). However, during the last two decades the major inflows have become scarcer, resulting in dramatic reductions in oxygen

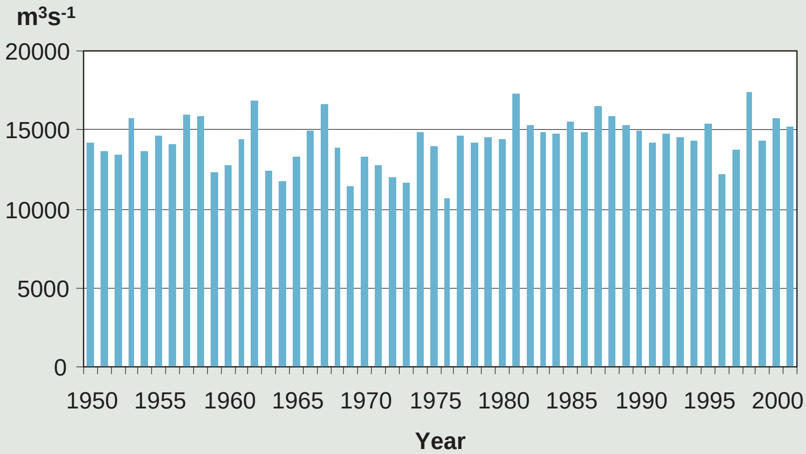


Figure 4.
Total runoff entering the Baltic Sea from 1950 to 2001 (m^3s^{-1}). (Data from 1950 to 1998 is based on observations, while data from 1999 to 2001 is based on hydrological model calculations) (Source: SMHI).

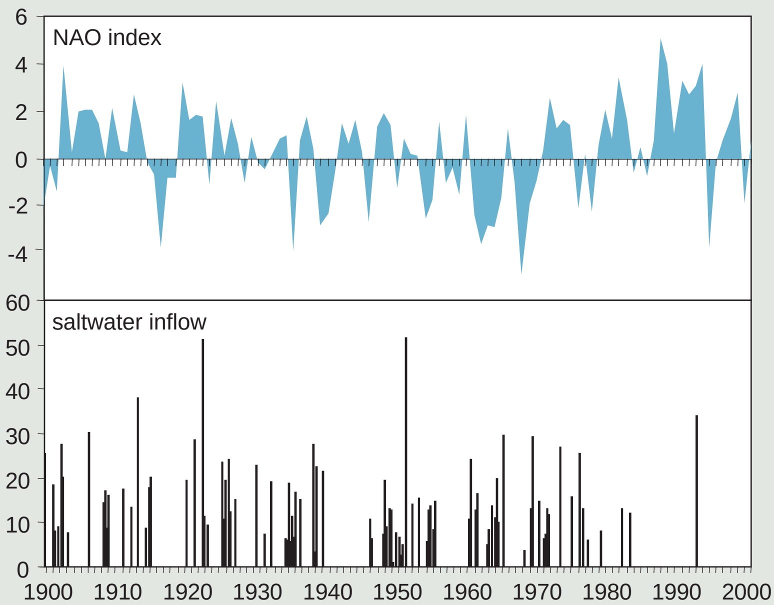


Figure 5.
The North Atlantic Oscillation (NAO) index and the saltwater inflow index for the Baltic Sea in the 20th century (Source: SMHI and IOW).

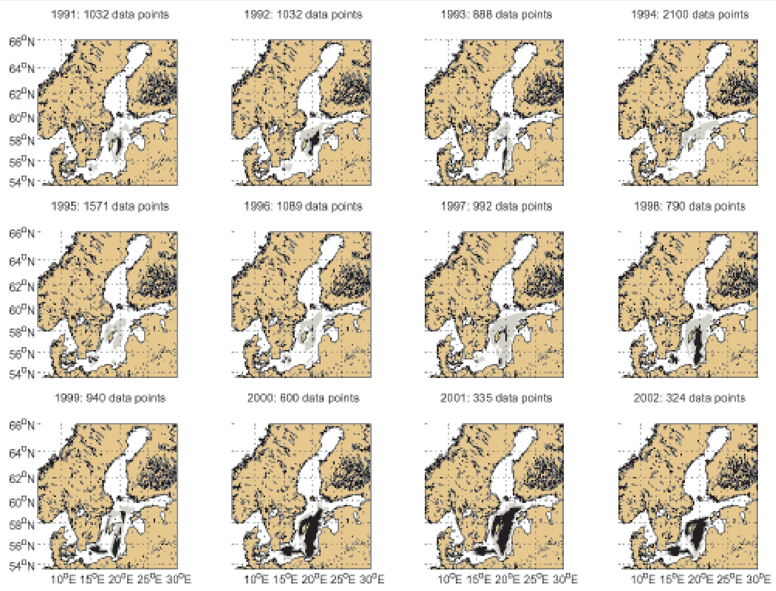


Figure 6.

Oxygen concentrations (<2 ml/l grey shading <0 ml/l dark shading) in bottom water in the Baltic Proper 1990-2002, based on annual data from August - November. (Source: SMHI).

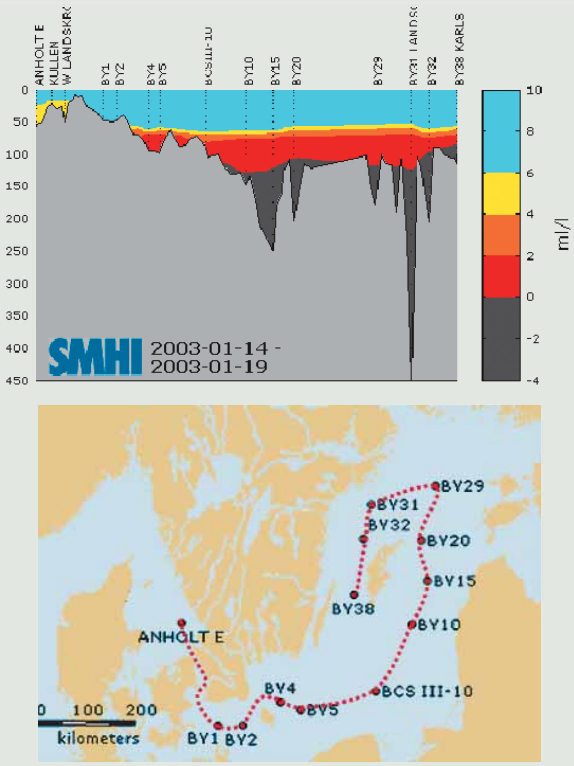


Figure 7.
The latest vertical oxygen profile from the Baltic (January 2003). The halocline at a depth of 60–80 m limits the effect pg wind mixing in deep waters. Black areas indicate the presence of hydrogen sulphide expressed as negative oxygen values (Source: SMHI).

levels in deep basins. The most recent major inflow (of around 300 km^3) occurred in 1993–1994, while a smaller inflow event occurred in January 2003, bringing over 100 km^3 of saltwater into the southern Baltic Sea. It remains to be seen whether this will improve oxygen conditions in deep waters. So far, oxygen stagnation seems to be continuing in the deep basins of the central Baltic Sea.

Salinity levels in surface waters decreased slightly during the 1990s. At the same time, salinity levels in deeper waters increased, due to the inflow event of 1993–1994. This made the halocline more pronounced, in turn reducing vertical wind-driven mixing in some waters.

Oxygen depletion still a serious problem

For fish in the open water and animals living on the sea floor, oxygen deficiency causes stress at oxygen levels below 3 ml/l, and at levels below 2 mg/l the situation becomes critical. To make matters worse, highly toxic hydrogen sulphide (H_2S) is commonly produced by chemical reactions in anaerobic conditions.

Oxygen concentrations in bottom waters are controlled by vertical mixing, water exchange and oxygen consumption by aquatic organisms. This oxygen consumption is in turn dependent on the amounts of organic matter available for decomposition. Oxygen levels are good indicators of the indirect effects of eutrophication, especially in shallow waters, because they clearly reflect the amounts of organic matter being produced and decomposed. The lowest oxygen concentrations are typically measured at the end of the summer, when the decomposition of sinking organic material uses up oxygen reserves.

Deep basins suffer most

In the deep basins of the Baltic Proper and Gulf of Finland, fluctuations in oxygen concentrations in the bottom water are mainly related to saltwater inflows (Figure 5). Oxygen concentrations in the Baltic's deeper basins have decreased since the last major saltwater inflow ended in 1994. Increasing quantities of hydrogen sulphide have again been formed in the deep basins since 1997 and the total area of sea-floor suffering from oxygen depletion has also increased. By the end of 2001, hydrogen sulphide was present in all the basins of the Baltic Proper (Figure 6). The most recent surveys of deep-water oxygen conditions (Figure 7) show no signs of improvement. The Gulf of Bothnia is only weakly if at all stratified by a halocline and there is no hypoxia in its deeper basins.

Evidence of problems even in shallow coastal waters

In August 2002, exceptionally serious oxygen depletion was observed in large areas of the Kattegat, the Belt Sea, the Sound and the Western Baltic Sea (Figure 8) leading to the widespread death of benthic animals and fish. These events were triggered by excessive runoff from the land as a result of heavy precipitation during the previous winter, in combination with excellent growth conditions for algae during a long, warm and calm summer.

Oxygen deficiency accelerates internal loading in the Gulf of Finland

Oxygen depletion is a widespread problem in the Kattegat, the Belt Sea, the Sound, the Western Baltic Sea, the Gulf of Finland and the Archipelago Sea. Eutrophication has increased primary production in marine ecosystems, and when large quantities of plankton die and sink to the sea floor, large amounts of oxygen are used up during their decomposition.

In the Gulf of Finland, the near-bottom oxygen conditions are affected by both inflows of saline water from the Baltic Proper and local conditions, especially in the heavily loaded eastern Gulf and in the semi-enclosed basins of the northern archipelago.

Extensive bottom areas in the Gulf of Finland have suffered from oxygen deficiency since the mid 1990s, exacerbating internal phosphorus loading and counteracting the decrease in external loading.

During summer 2002, deep bottom oxygen conditions in the Gulf of Finland were generally better than during the previous summer, especially in the northern part of the Gulf. However, a large area of the sea-bed stretching from the westernmost end of the Gulf to the Narva Bay was found to be suffering from serious oxygen depletion. Salinity stratification in this area was pronounced, with unusually high deep water salinity values. Low oxygen concentrations were also observed in several coastal basins along the southern Finnish coast (Figure 9).

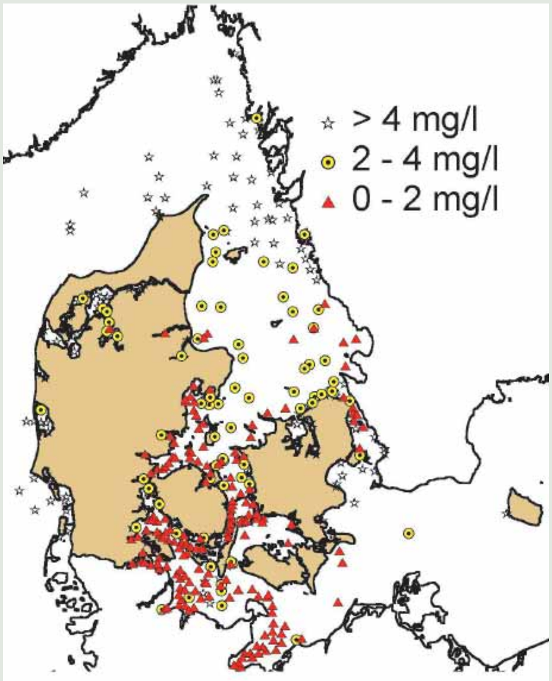
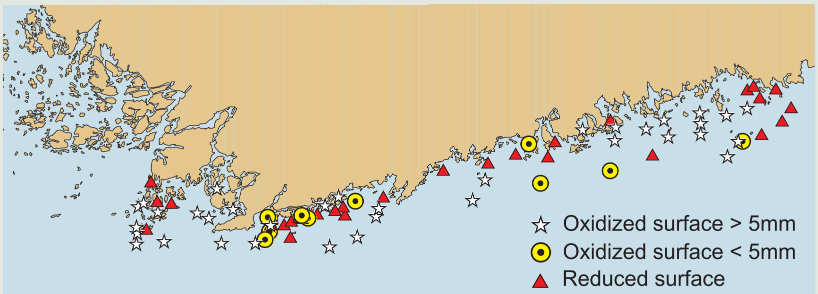


Figure 8. **Bottom water oxygen concentrations in September 2002 in the Kattegat, the Sound and the Western Baltic (Source: DMU, LANU, LUNG and SMHI).**



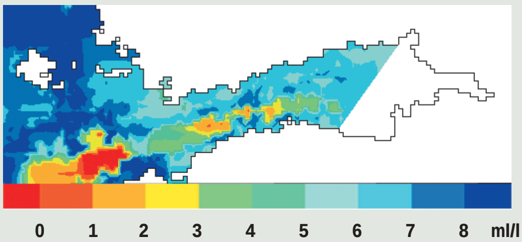


Figure 9. **Oxidation state of the bottom sediment surface (upper figure) and bottom water oxygen concentrations (lower figure) in August 2002 in the northern Gulf of Finland (Source: SYKE and FIMR).**

Nutrient pollution and eutrophication

Riku Lumiaro / FIMR

Nitrogen and phosphorus are the main nutrients at the bottom of all food chains. The smallest marine plants, known in ecological terms as primary producers, fix these nutrients into their biomass through primary production. When excessive amounts of nutrients enter the sea, this primary production increases rapidly, and the natural ecological balance of marine ecosystems is disturbed. Secondary production will also increase, as secondary producers such as zooplankton and fish feed on the increasing numbers of primary producers. This whole phenomenon of the excessive nutrient-enrichment of an ecosystem is known as eutrophication.

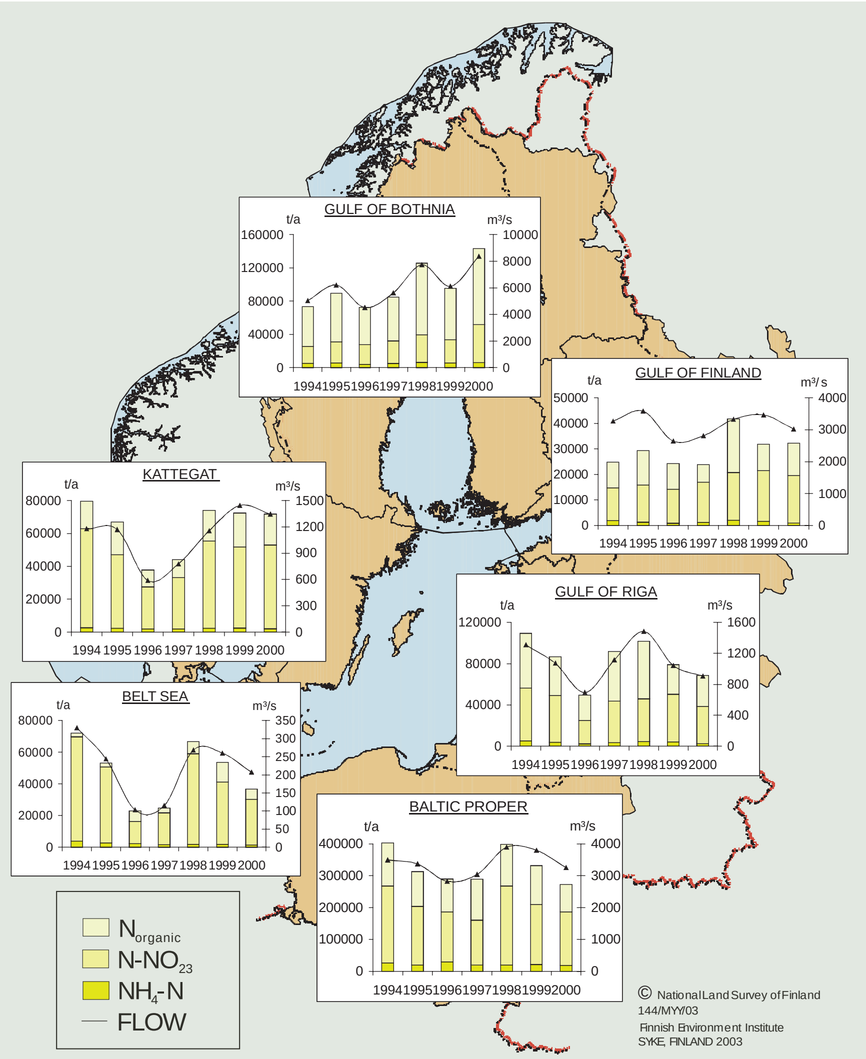


Figure 10.

Annual average riverine runoff (m^3/s) and riverine inputs of nitrogen (N_{total}) in t/a into the different sub-basins of the Baltic Sea 1994–2000. Different scales have been used in the graphs for the various sub-basins (Source: HELCOM).

Marine life can be suffocated by eutrophication

In the Baltic Sea, the excess biomass of primary producers accumulates on the sea-bed, and the decomposition of this organic material consumes oxygen from the water. This leads to oxygen depletion, especially in areas where water mixing is restricted, such as in deeper waters below the halocline, or in shallower waters affected by thermal stratification during the summer.

Oxygen depletion and internal nutrient loads – a vicious circle

A vicious circle can develop where anoxic conditions affect the nutrient cycle in the bottom water and sediments, intensifying eutrophication and accelerating oxygen depletion. This is because in anoxic conditions phosphorus is released from sediments back into the water, while nitrogen accumulates as ammonium because of a lack of denitrification and nitrogen release from sediments. These nutrients are then further utilised by more primary producers, compounding eutrophication through a factor known as internal nutrient load.

Where do the excess nutrients come from?

Nutrients enter the Baltic Sea via rivers, via atmospheric deposition, or via direct discharges from pollution sources located on the coastline. Nutrient discharges may originate from point sources, such as industrial or municipal wastewater outlets, or from diffuse sources, such as farmland, homes in rural areas and atmospheric deposition within the Baltic Sea catchment area.

Nutrients washed into the sea via rivers

In 2000, about 660,000 tonnes of nitrogen and 28,000 tonnes of phosphorus entered the Baltic Sea via rivers. Four large rivers – the Neva, Nemunas, Vistula, and Oder – together accounted for the majority of the nutrient loads entering the Baltic Sea. More than half of the total waterborne phosphorus load and nearly one third of the total waterborne nitrogen load originated from Poland (Figures 10 and 11).

During the period 1994–2000, riverine loads of nitrogen and phosphorus closely followed variations in freshwater runoff (Figures 10 and 11). In years with high precipitation and high runoff, more nitrogen leached from cultivated areas than during dry years, resulting in higher riverine nitrogen loads.

Riverine nutrient loads in 2000

In 2000, anthropogenic point and diffuse sources comprised the main part of the total riverine nitrogen and phosphorus loads entering the Baltic Sea. In most of the HELCOM countries 50–80% of the riverine nitrogen originated from diffuse sources. Diffuse loads were also the most important source of phosphorus in all areas except the Gulf of Finland, where point sources are more significant. The only area relatively unaffected by human activity was the catchment area around the Gulf of Bothnia (Figure 12).

Due to incomplete data sets for the whole time period, Russian nutrient data for the Baltic Proper (Kaliningrad Region) and the Gulf of Finland has been omitted from Figures 10 and 11. However, the total Russian nutrient riverine load in 2000 is estimated as 8,566 t/a nitrogen in the monitored part of the Baltic Proper catchment area, and 61,105 t/a nitrogen and 5,807 t/a phosphorus in the monitored part of the Gulf of Finland catchment area.

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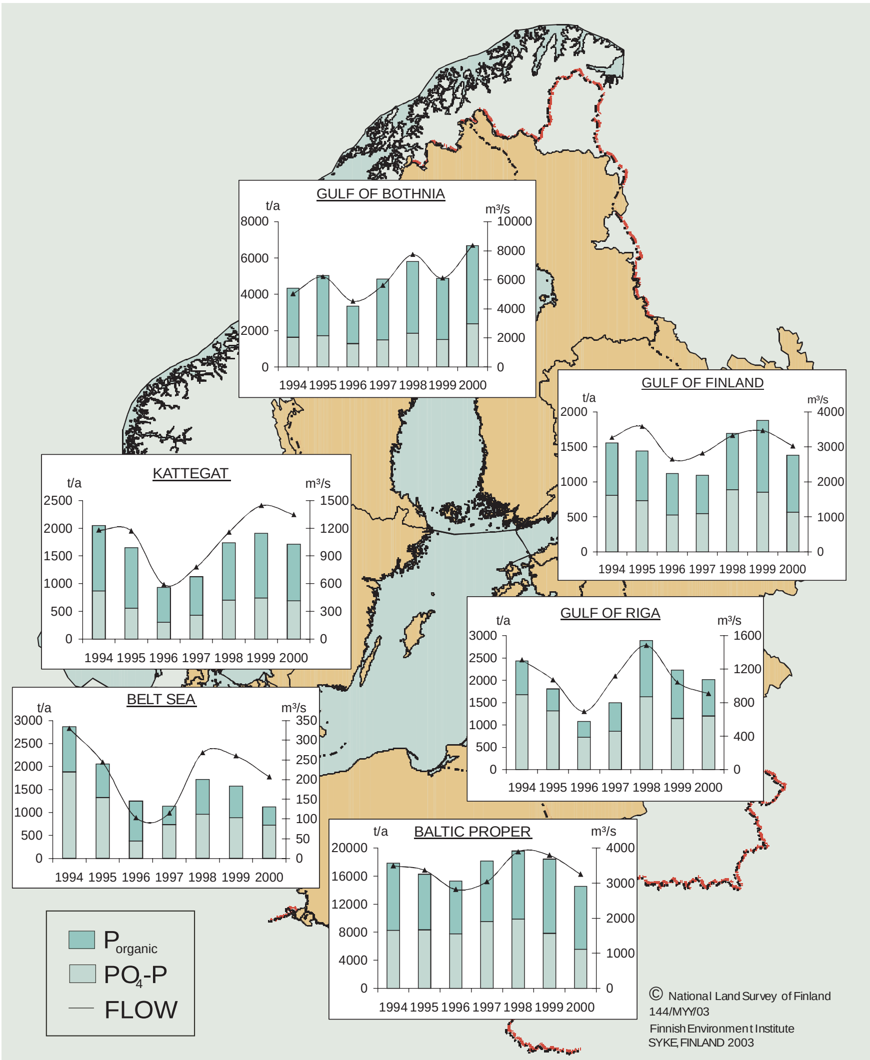


Figure 11:

Annual average riverine runoff (m^3/s) and riverine inputs of phosphorus(P_{total}) in t/a into the different sub-basins of the Baltic Sea 1994-2000. Different scales have been used in the graphs for the various sub-basins (Source: HELCOM).

Area-specific loads for the sub-basins of the Baltic Sea

The highest catchment-area-specific nitrogen loads were recorded for the catchment areas of the Sound (1,535 kg/km^2 N), the Belt Sea (1,349 kg/km^2 N) and the Archipelago Sea (1,053 kg/km^2 N) (Figure 13). The highest country-specific loads were for Denmark (1,862 kg/km^2 N) and Germany (581 kg/km^2 N). High area-specific nitrogen loads are related to high rates of agricultural activity, such as large livestock densities and the use of large quantities of manure and fertiliser, as in Denmark, Germany and southern Sweden.

The highest catchment-area-specific phosphorus loads were recorded in the catchment areas of the Sound (220 kg/km^2 P), the Western Baltic (63 kg/km^2 P) and the Archipelago Sea (54 kg/km^2 P). The highest corresponding national figures are for Denmark (83 kg/km^2 P), Poland (43 kg/km^2 P) and Germany (35 kg/km^2 P). High area-specific phosphorus loads are related to high population densities (as around the Western Baltic and the Sound), high rates of industrial activity, and to some extent to the intensity of agricultural activity (as around the Archipelago Sea).

Figure 12. Source apportionment results for total riverine nitrogen (N_{total}) and phosphorus (P_{total}) loads in 2000 (Source: HELCOM).

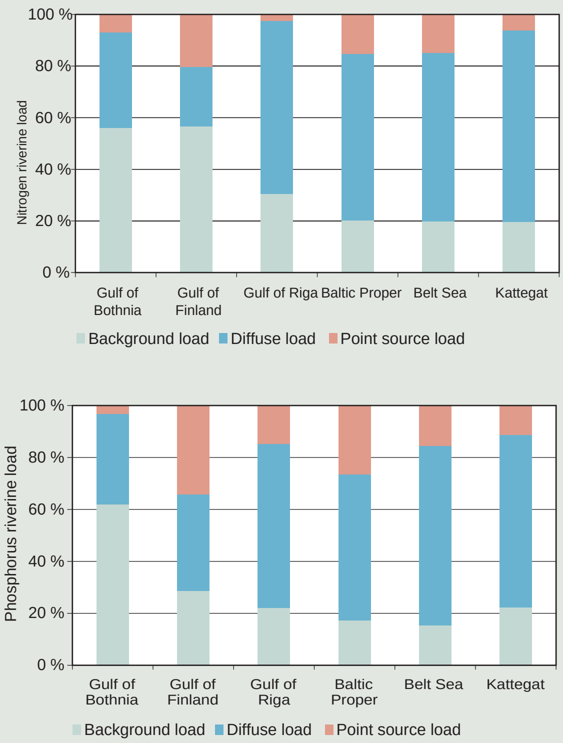
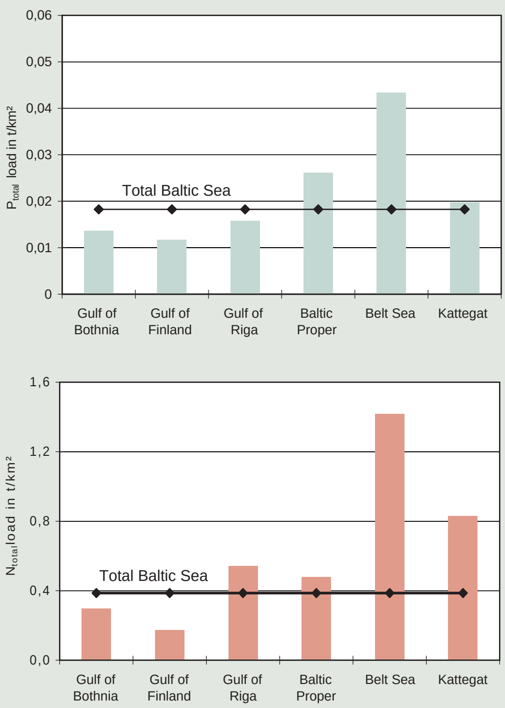


Figure 13. Drainage basin-specific riverine loads of nitrogen and phosphorus entering the different sub-basins of the Baltic Sea in 2000. These figures have been derived by dividing the load figures with the corresponding area of the drainage/catchment area (tonnes/km^2*year) (Source: HELCOM).

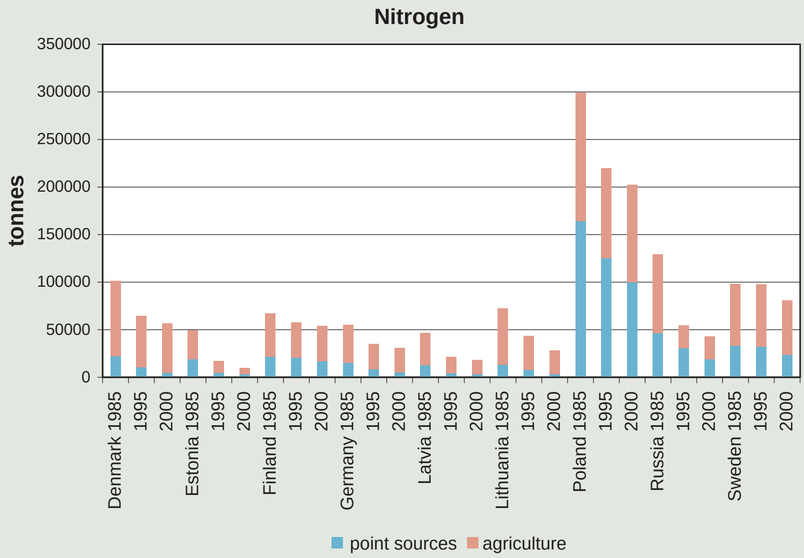


Progress in cutting nutrient pollution

Total discharges from point sources and losses from diffuse sources into surface waters within the Baltic Sea catchment area decreased for phosphorus between 1985 and 2000. The 50% reduction goal set by the 1988/1998 Ministerial Declaration has in general almost been achieved for phosphorus. Reductions in nitrogen discharges/losses over this period were lower, however, and the 50% reduction target was not reached (Figure 14).

Where point sources are concerned, the 50% reduction target has been achieved for phosphorus discharges by all the HELCOM countries, except for Poland, where reductions amounted to around 40%.

Although diffuse nutrient losses from agricultural areas show smaller decreases than point source discharges, clear reductions could be seen in some countries. This is mainly due to dramatic changes in the numbers of livestock units, a proportional reduction in the use of manure, and reductions in the use of mineral fertilisers – especially in eastern Germany, Poland and the Baltic Countries. However, these reductions at source could not yet been seen in lower loads in rivers. This is because nutrients remain in farmland soils for long periods, and are only gradually released through leaching and groundwater transport into rivers and ultimately the sea.



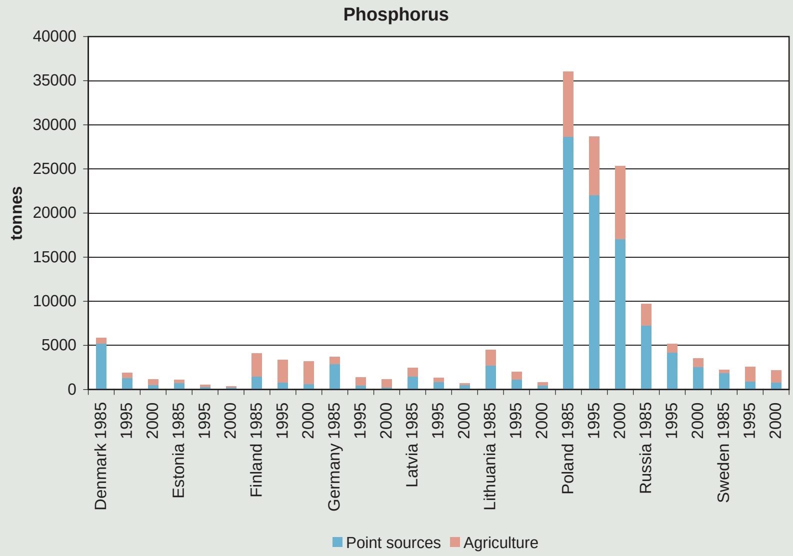


Figure 14:
Point source discharges and agricultural losses of nitrogen and phosphorus into surface waters 1985, 1995 and 2000 (Source: HELCOM).

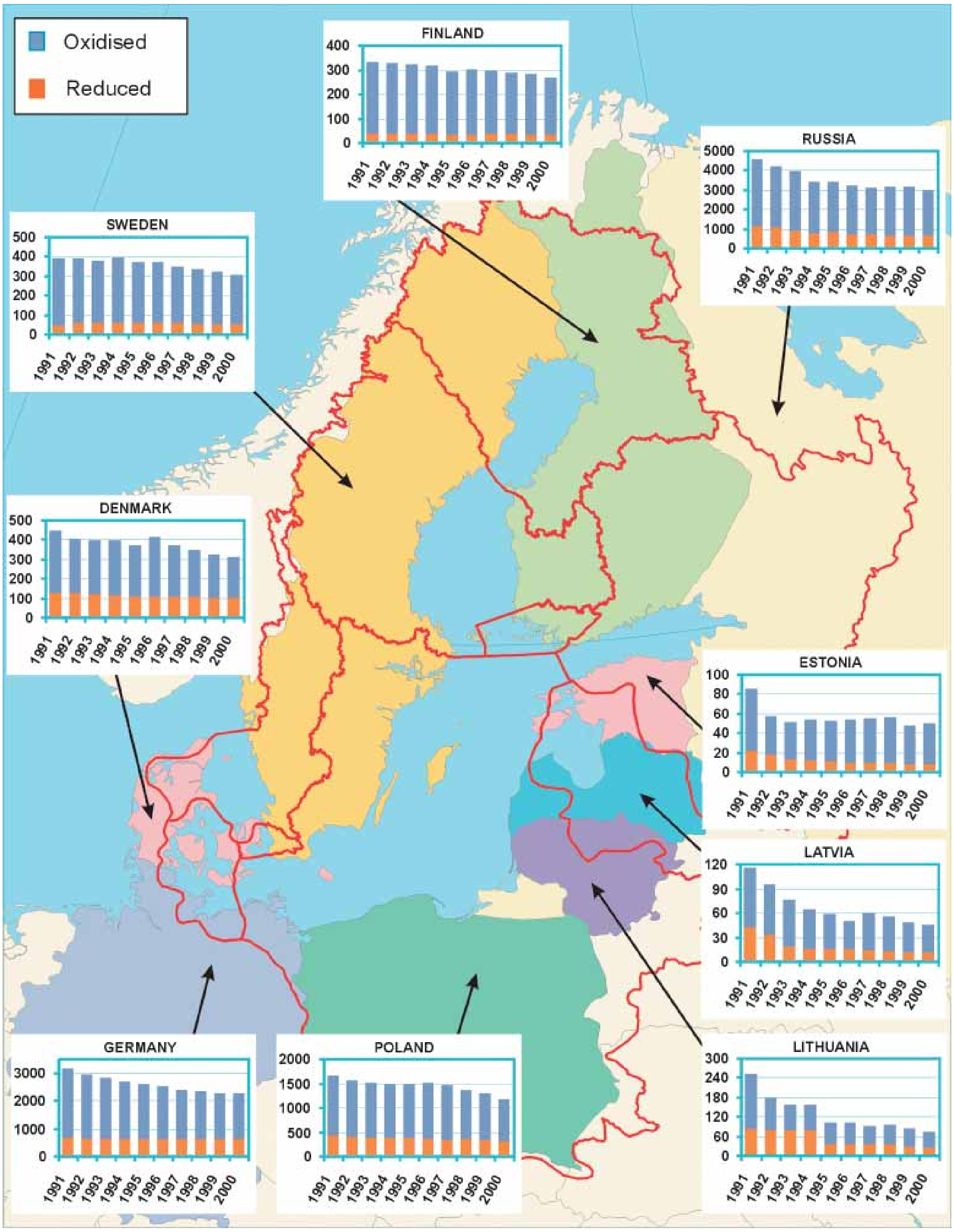


Figure 15.

Annual atmospheric emissions of nitrogen oxides and ammonium from individual HELCOM Contracting Parties 1991–2000 in kt/year. Different scales have been used in the graphs for the various sub-basins. The data covers emissions from all countries, except for Russia, where only emissions from regions covered by EMEP are included (Source: EMEP).

Nutrient pollution from the air still a problem despite emission cuts

Almost 35% of the total nitrogen load entering the whole Baltic Sea originates from airborne inputs.

Atmospheric emissions of nitrogen oxides and ammonia from the HELCOM countries were slightly lower in 2000 than in 1991 (Figure 15).

Emissions from outside the Baltic Sea region add to the nitrogen loads entering the Baltic, as do emissions from ships. In 1990, emissions of nitrogen oxides (NO_x) from international shipping traffic were estimated to account for approximately 10–20% of the total nitrogen deposition entering the Baltic Sea. No estimates are currently available for trends in these emissions.

The atmospheric deposition of nitrogen into the Baltic Sea in 2000 has been calculated with the EMEP acidification model. This annual load varies across different parts of the Baltic Sea: from 200 mg/m^2 N in the northern Gulf of Bothnia up to 1,500 mg/m^2 N in the Belt Sea.

Annual atmospheric nitrogen deposition into the Baltic Sea fluctuated at around 300 kt over the period 1996–2000. This total nitrogen deposition consisted of almost equal proportions of reduced nitrogen and oxidised nitrogen (Figure 16).

No significant trends could be determined for nitrogen loads entering the Baltic Sea or its various sub-basins.

In order to pick out longer-term trends in total nitrogen deposition, 5-year average values for 1991–1995 and 1996–2000 were compared (Table 3). In the Gulf of Bothnia and Baltic Proper, modelled deposition increased by about 25%, while in the Gulf of Riga there was a decrease of almost 50%. The changes predicted for the other sub-basins were relatively insignificant.

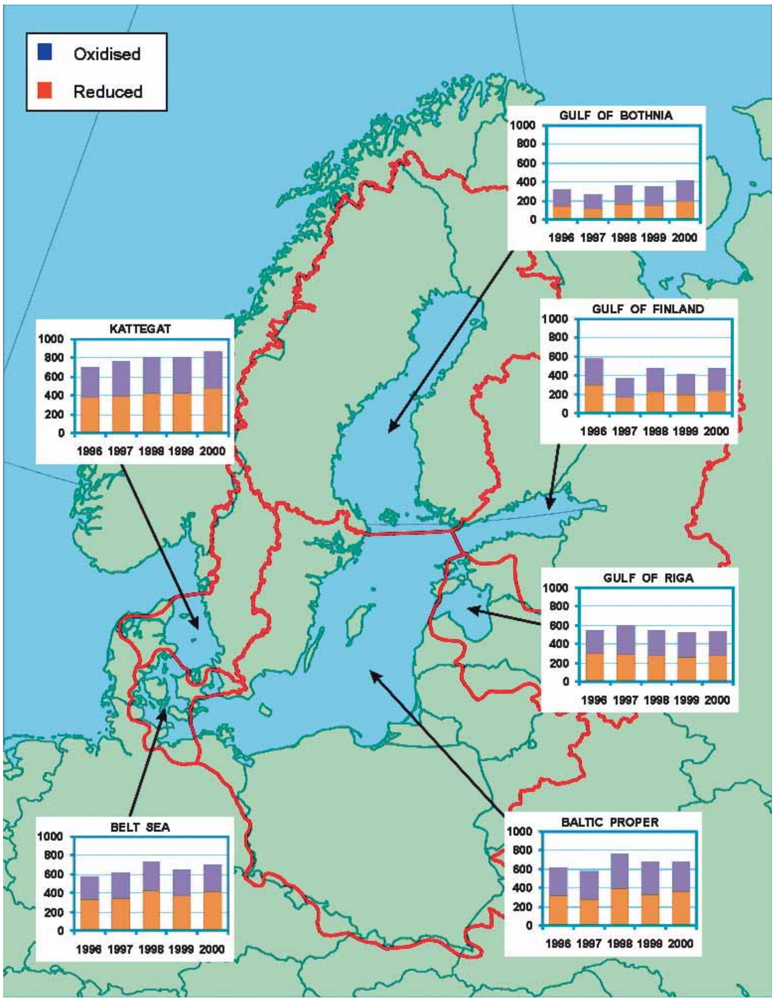


Figure 16.
Atmospheric deposition of total (oxidized and reduced) nitrogen into the six sub-basins of the Baltic Sea 1996–2000 (kt/year) (Source: HELCOM).

Table 3.
Changes in total nitrogen deposition between the periods 1991–1995 and 1996–2000.

Sub-basin	Change (%) in nitrogen deposition
Gulf of Bothnia	+25%
Gulf of Finland	-9%
Gulf of Riga	-51%
Baltic Proper	+24%
Belt Sea	-5%
Kattegat	-12%

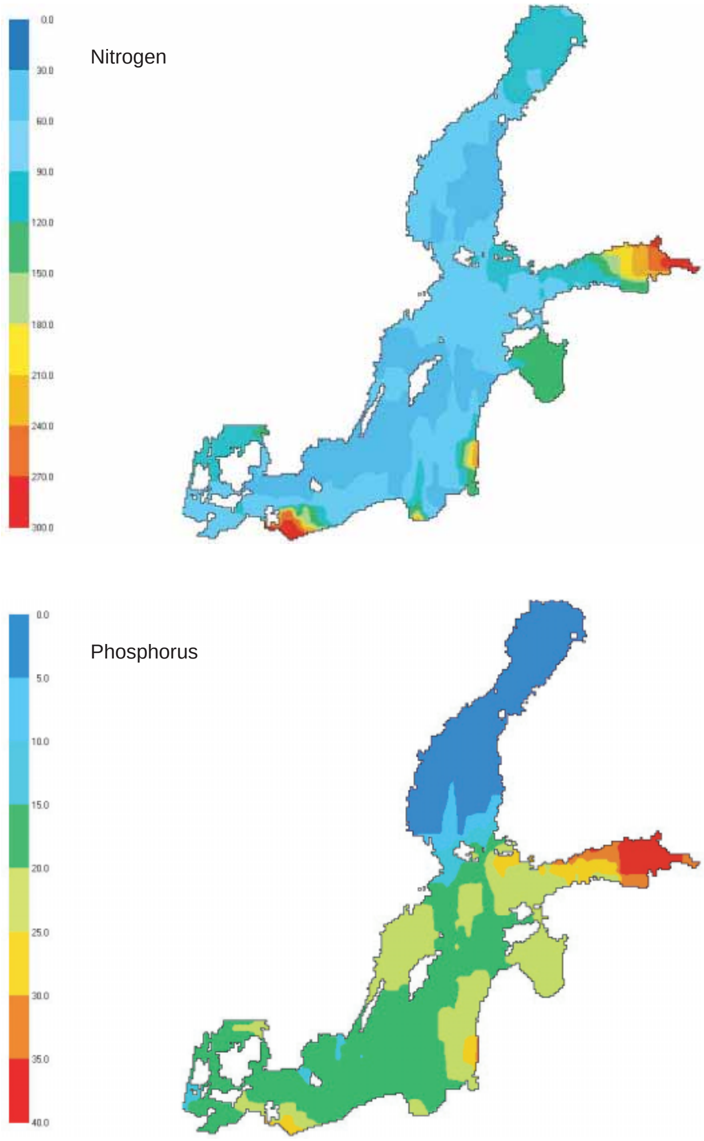


Figure 17.
Regional distribution of nitrate nitrogen and phosphate phosphorus concentrations (µg/l) in the surface water, January–February 2000 (Source: SYKE).

Nutrient concentrations in the Baltic remain high

High nitrate concentrations are still prevalent in the Bothnian Bay, the Gulf of Finland, the Gulf of Riga, the Pomeranian Bay, the Belt Sea and the Kattegat. Concentrations of both nitrogen and phosphorus have increased in deep waters.

Concentrations of inorganic nutrients in surface water layers are highest during the winter when no primary production can incorporate them into organic matter. Winter surface concentrations of these nutrients therefore provide a good indication of regional differences. Variations in these concentrations from year to year are high, but generally the highest concentrations are found near the mouths of large rivers (Figure 17). Winter concentrations of phosphates follow a similar pattern to nitrate concentrations, although concentrations in the Bothnian Bay are always low.

In general, nutrient concentrations in the Baltic Sea have not decreased since the assessment period 1994–1998, and remain persistently high. But from a longer-term perspective different trends can be seen. Since 1980, winter surface concentrations of dissolved inorganic nitrogen compounds (nitrate + nitrite) have decreased significantly only in the northern Baltic Proper (Figure 18). The statistical trend analysis of phosphate concentrations revealed a decreasing trend at 7 out of the 12 stations where analysis was carried out. The trends illustrated in Figure 18 imply that most of the nutrients are bound up in marine biota. This may reflect general changes in weather conditions over the last two decades.

Low oxygen conditions in deep water affect the amounts of nutrients in the water. Phosphorus is easily released from sediments under anoxic conditions, for instance. Nitrogen cycles in deep water layers also change in anoxic conditions: mineralization eventually produces ammonium, and no oxidation occurs to form nitrates. Consequently, the process of denitrification, which needs oxygen from nitrates, will not occur. The resulting nutrient surplus in deep water layers is a potential source of nutrients for the surface layers, where primary production may be further increased.

Phytoplankton blooms

Phytoplanktonic algae are primary producers in ecological terms, since they represent the first link between inorganic nutrients and the food web. The availability of nutrients regulates this primary production and biomass, while the ratio between the main nutrients – phosphorus and nitrogen – largely determines which species can proliferate.

Planktonic algae are an important part of marine ecosystems, and algal blooms at sea are naturally occurring phenomena. However, these mass occurrences of microscopic algae have become more frequent and intense due to the eutrophication of the sea, which is caused by various types of human activity. Harmful and toxic algal blooms have occurred annually in the Baltic Sea in recent years. Extensive and dense blooms disrupt marine ecosystems, and limit the recreational and economic use of marine resources. Algal blooms can also be toxic, and thus represent a real health risk for humans and animals, as well as an aesthetic problem.

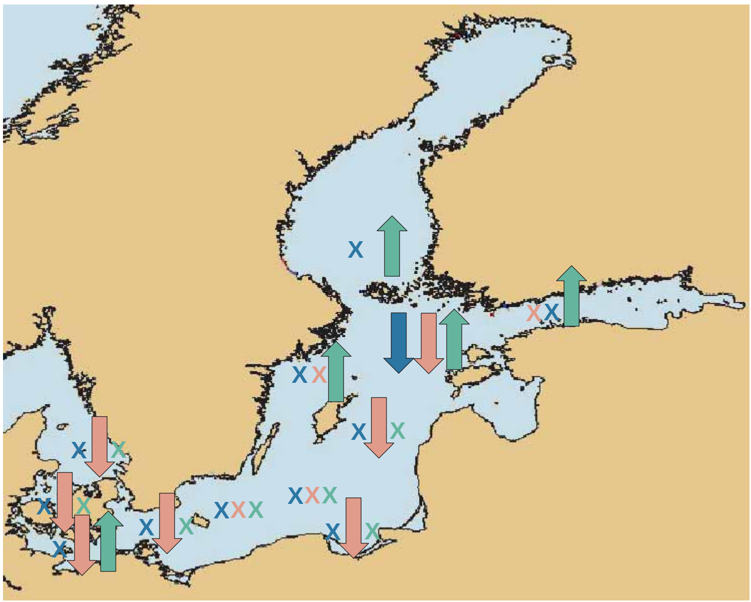


Figure 18.

Temporal trends in dissolved inorganic nitrogen (nitrate+nitrite), phosphorus and chlorophyll since 1980. Values used in the analysis are averages from surface layers down to 10 m. Blue=nitrogen, red=phosphorus, green= chlorophyll a; x = no trend, ⇑=increasing trend, ⇓=decreasing trend. Nutrient values are surface winter concentrations and chlorophyll a values are July-August means (Source: HELCOM).

Riku Lumiaro / FIMR

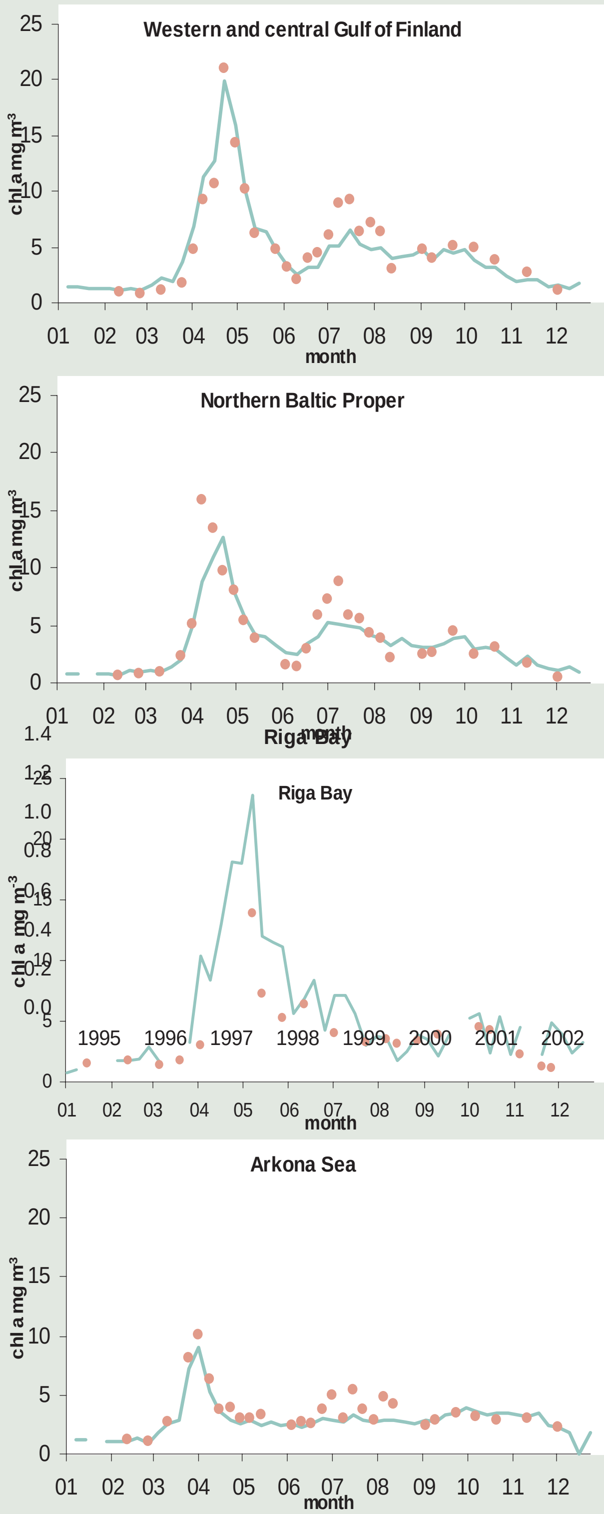


Figure 19.
Monthly variations in surface layer phytoplankton biomass (measured as chlorophyll a mg m^{-3}) in four parts of the Baltic Sea, showing the spring bloom in March-April and the blue-green algal bloom in late summer. The green curve represents the average for the years 1992–2001, while the dots show measurements from 2002. The map shows the route follower by the ship from which measurements were taken (Source: FIMR/Alg@line, for Riga Bay: Institute of Aquatic Ecology, Marine Monitoring centre, University of Latvia).

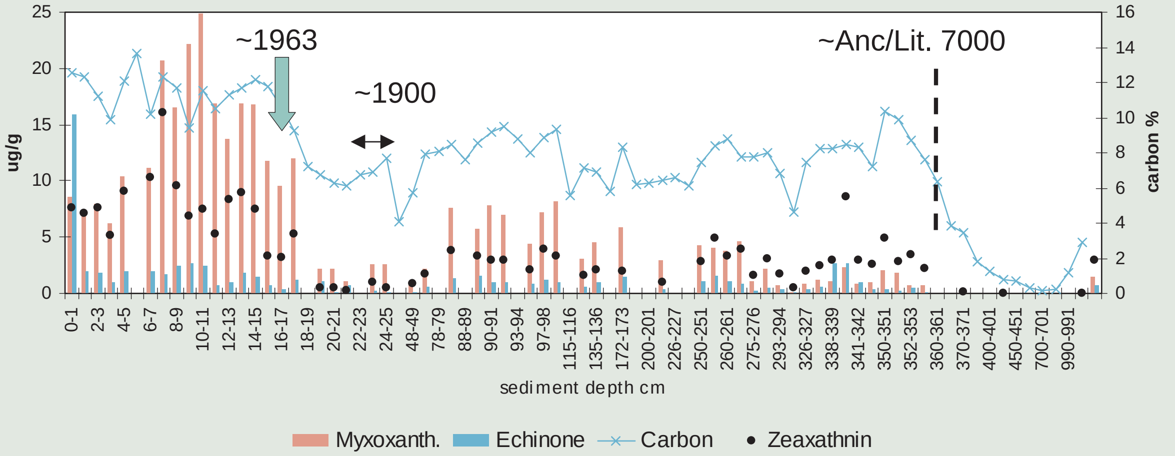


Figure 20.
Blue-green algal pigments (myxoxanthine and echinone) in sediment cores from the Gotland Deep (Source: Poutanen & Nikkilä 2001).

Two blooming seasons a year

There are essentially two annual algal blooms in the Baltic Sea. The spring bloom takes place from early March to May, depending on the area and the conditions in any year; while the blue-green algal (cyanobacterial) blooms occur mainly in late summer, from July to September (Figure 19). There can also be other regional algal blooms earlier or later in the summer, depending on the weather and the nutrients available in the water. The phytoplankton spring bloom is based on the nutrients built up over the previous winter, and its intensity reflects the scale of the nutrient reserves.

The spring bloom mainly consists of diatoms and dinoflagellates. These early phytoplankton blooms consume most of the nitrogen and the phosphorus in the water, and thus determine how much of these nutrients are left for the later blue-green algal blooms.

Blue-green algal blooms can be highly visible phenomena in the open seas during summer. Their growth is triggered by excessive levels of phosphorus. Pigment analysis of sediment cores extracted from the sea-bed indicates that blue-green algal blooms have occurred in the Baltic Sea for at least 7,000 years, but that their frequency and intensity seems to have increased since the 1960s (Figure 20).

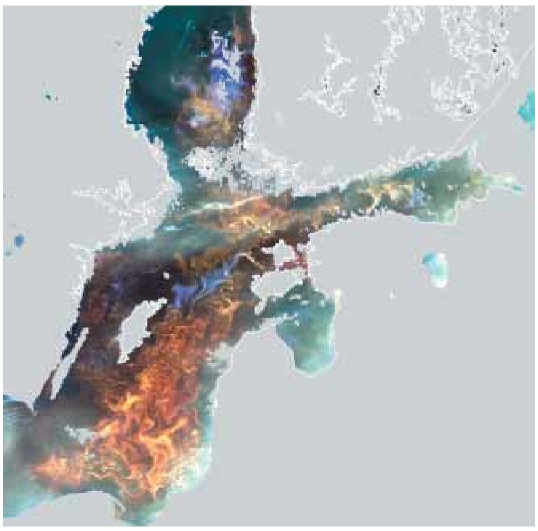


Figure 21.
This SeaWiFS satellite image from August 1999 shows the extent of the surface accumulations of blue-green algae (yellow and red areas) in the Gulf of Bothnia, the Gulf of Finland and the Baltic Proper (Source: SYKE).

Some algae summers are worse than others

The occurrence of blue-green algal blooms in surface waters is associated with particular patterns of nutrient availability and weather conditions. Prerequisites for the formation of these blooms include a lack of inorganic nitrogen, and the presence of phosphorus in the water. Blue-green algae also thrive better in warm water, and their filaments can accumulate most easily on the surface during calm weather. In summer 2002, large areas were covered by surface accumulations and the blooms were almost as intense as in 1997, widely described as the worst blue-green algae summer ever recorded. There were also pronounced surface accumulations of blue-green algae in 1999 (Figure 21).

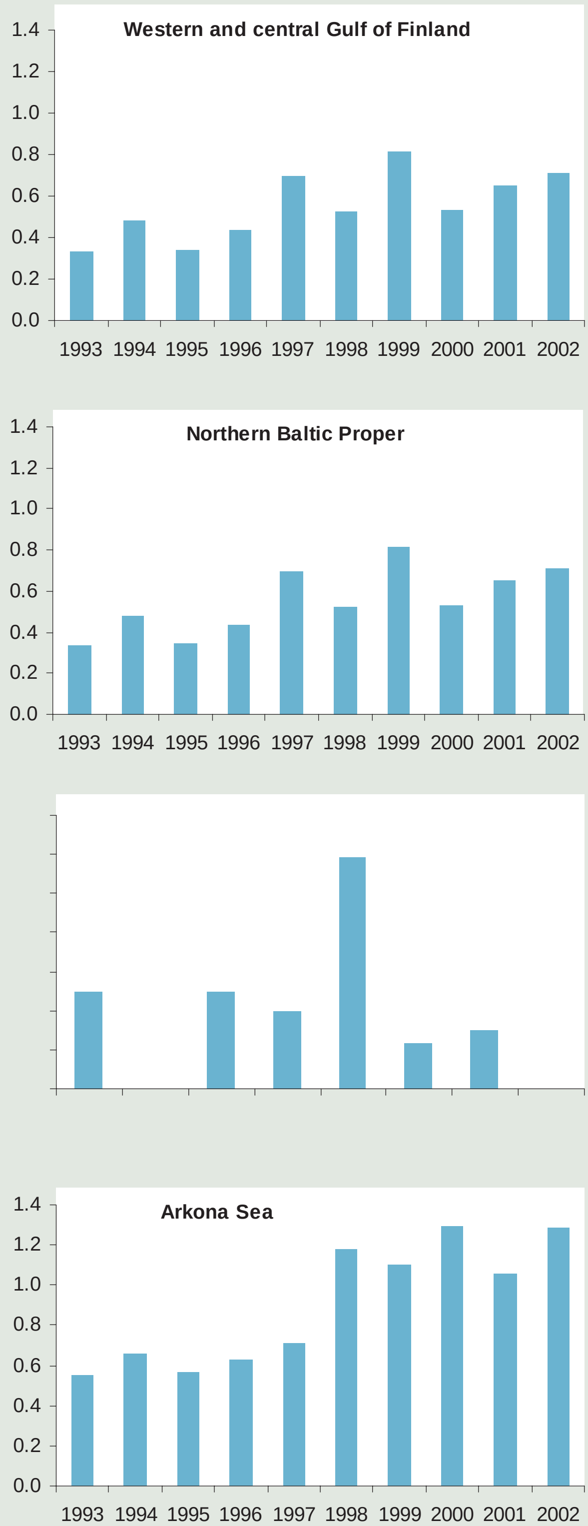
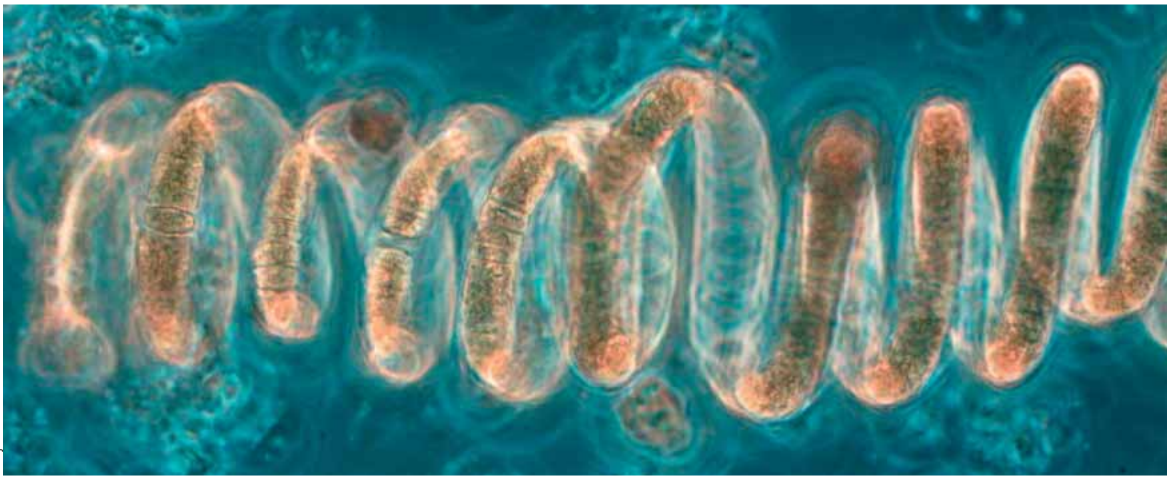


Figure 22.

Ratios between the mean abundance of bloom forming blue-green algae, toxic Nodularia and non-toxic Aphanizomenon in three sea areas, in samples taken in July–August. The map shows the route follower by the ship from which measurements were taken (Source: FIMR/Alg@line, for Riga Bay: Institute of Aquatic Ecology, Marine Monitoring centre, University of Latvia).



Maija Huttunen / FIMR

Monitoring the toxic threat

Mass occurrences of blue-green algae are often made up of several species of blue-green algae. Since 1992 the relative abundance of the most common species has shown a clear trend in the Arkona Basin and in the northern Baltic Sea. The toxin-producing species *Nodularia spumigena* has become more abundant in relation to the non-toxic *Aphanizomenon flos-aquae* (Figure 22). In the Gulf of Finland, the change in this ratio is less clear.

Regional distributions of phytoplankton can be monitored by satellites (Figure 23). The mean July-August concentrations of chlorophyll-like pigments show clear regional differences, with the highest concentrations detected in the Gulf of Finland and off the mouths of large rivers, and the lowest concentrations in the Gulf of Bothnia.

The algorithms currently used to interpret satellite data have not yet been fully developed for conditions in the Baltic Sea. For example, dissolved humic substances which can be yellowish in colour, may affect the assessment of chlorophyll concentrations.

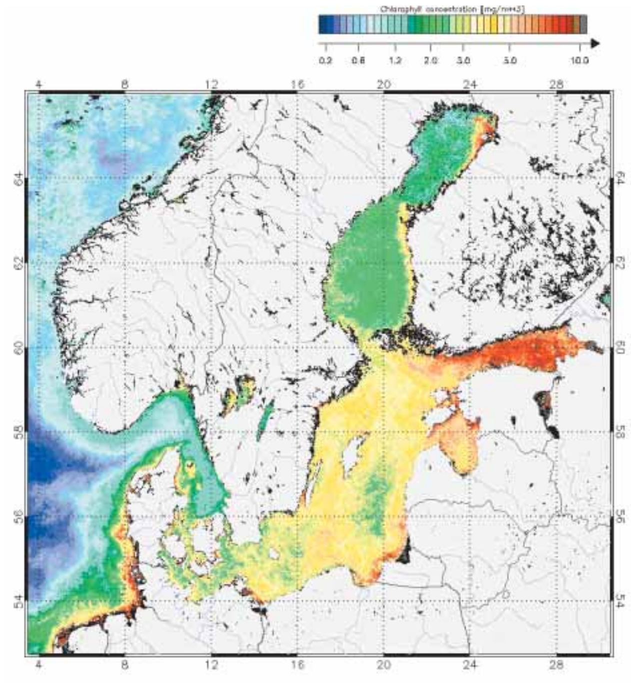
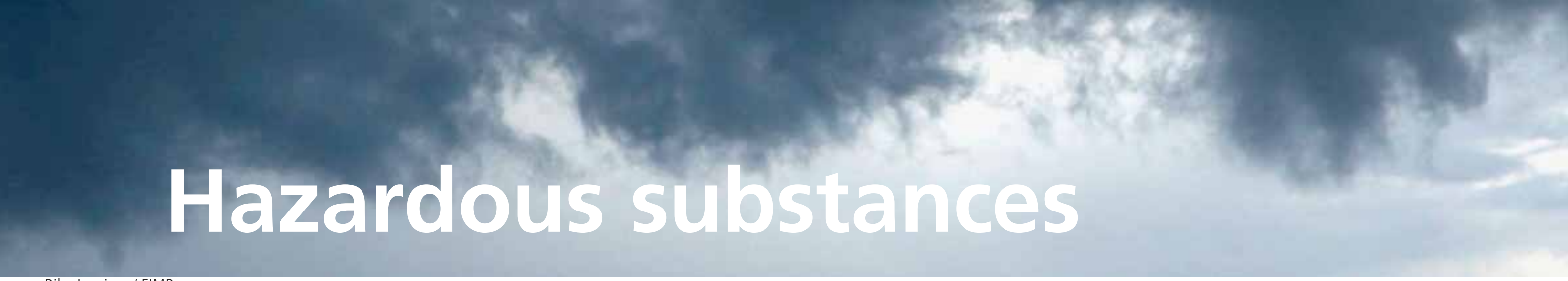


Figure 23.
July–August mean concentrations of chlorophyll-like pigments in the Baltic Sea, obtained by the SeaWiFS satellite (Source: EC/JRC).

Hazardous substances



Riku Lumiaro / FIMR

Riku Lumiaro / FIMR

Contaminants in the Baltic Sea include:
- substances that do not occur naturally in the environment, such as PCBs, DDTs, dioxins, TBT, nonylphenolethoxylates (NP/NPE), short-chained chlorinated paraffins (SCCP), brominated flame retardants (PBDEs) and certain nitromusks;
- substances occurring at concentrations exceeding natural levels, including heavy metals like lead, copper, cadmium and mercury.

Contaminants that are ecologically harmful are also referred to as pollutants or hazardous substances.

Hazardous substances can accumulate in the marine food web up to levels which are toxic to marine organisms, particularly predators, and they may also represent a health risk for people. Once released into the Baltic Sea, hazardous substances can remain in the water for very long periods. Certain contaminants may be hazardous because of their effects on hormone and immune systems, as well as their toxicity, persistence and bio-accumulating properties.

A dilute marine cocktail of contaminants

The gradual pollution of the Baltic marine environment by hazardous substances has caused a serious threat to the environment, and may even threaten the health of future generations. Although monitoring indicates that the loads of some hazardous substances have been reduced considerably over the past 20–30 years, problems still persist. There is still too little comprehensive knowledge about the impact of the most widely used chemicals and their cocktail-like combinations on human health and the environment. Relatively few organic pollutants are fully understood or even identified today. Another problem is that the degradation and transformation of these substances in the marine environment may change their structure and reactive properties. These unknown substances could pose a considerable threat to the environment.

Heavy metal hazards

Heavy metals from the air

Annual emissions of heavy metals in the HELCOM countries decreased during the period 1996–2000, by 26% for cadmium, 15% for mercury and 10% for lead. These figures should be considered with some caution, however, because emission trends over this period were far from clear for most countries. Although the overall decline in cadmium emissions was mostly due to a 50% reduction in emissions in Poland (Figure 24) it remained the largest source of cadmium emissions among the HELCOM countries, followed by Russia and Germany.

Figures for atmospheric deposition rates are also only rough estimates, since they are dependent on either uncertain emission inventories or measurement series taken at just a few coastal stations whose data is difficult to extrapolate to cover the whole sea.

Lead deposition evidently decreased by more than 50% during the 1990s, mostly due to the increased use of unleaded gasoline.

It is estimated that about 9 tonnes of cadmium was deposited in the Baltic Sea during the year 2000. The mean cadmium deposition rates for the period 1996–2000 are on average 30% lower for all the sub-basins of the Baltic Sea in comparison with the preceding period 1991–1995 (Table 4).

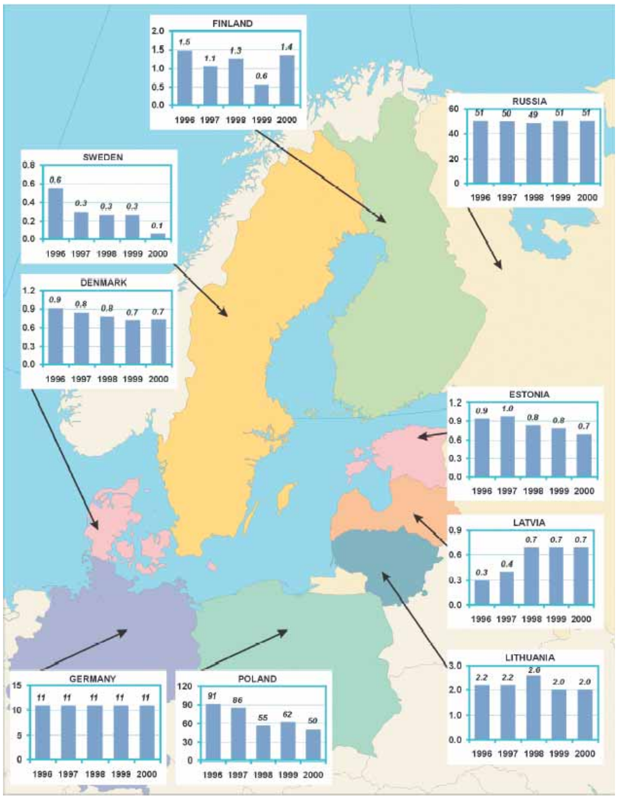
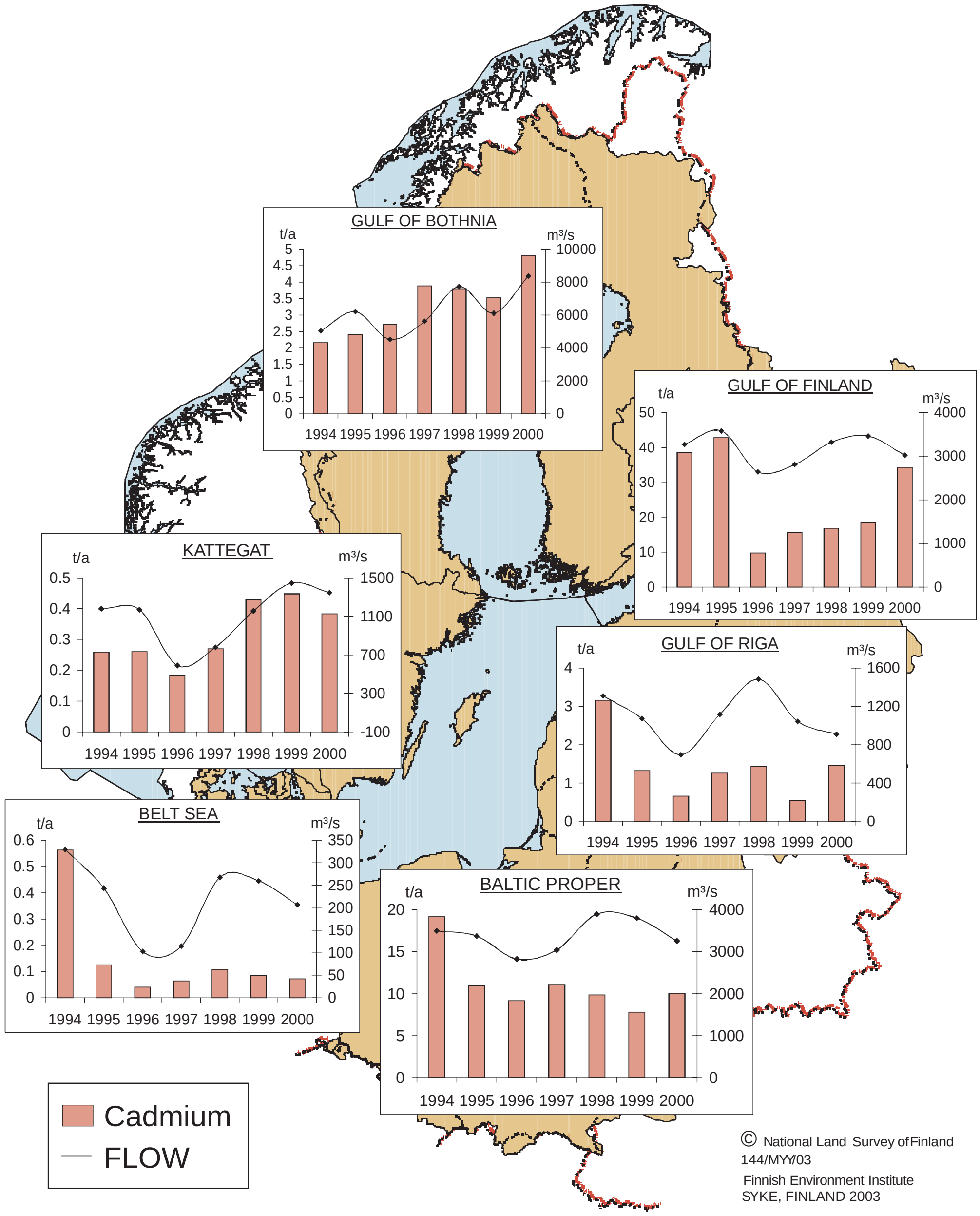


Figure 24.
Atmospheric cadmium emissions from the HELCOM Contracting Parties (CPs) in t/year for the period 1996–2000. Different scales have been used in the graphs for the various countries. The data covers emissions from all countries, except for Russia, where only emissions from regions covered by EMEP are included (Source: EMEP).

Table 4.
Changes in average annual cadmium and lead deposition rates between 1991–1995 and 1996–2000

Sub-basin	Cd	Pb
Gulf of Bothnia	-35	-57
Gulf of Finland	-38	-61
Gulf of Riga	-31	-61
Baltic Proper	-16	-52
Belt Sea	-39	-66
Kattegat	-23	-60

Figure 25a.
Annual average riverine runoff (m^3/s) and riverine inputs of cadmium in t/year into the different sub-basins of the Baltic Sea, 1994–2000. Different scales have been used in the graphs for the various sub-basins



Heavy metals via rivers

The Gulf of Finland and the Baltic Proper receive the lion's share of the riverine heavy metal loads entering the Baltic Sea. Riverine loads of lead and cadmium vary according to runoff to some extent (Figure 25a and b), but not as clearly as nutrient loads (Figures 10 and 11). During the period 1994–2000 discharges of heavy metals (mostly cadmium and lead) decreased in most of the sub-regions.

Due to lack of data, the riverine heavy metal loads for cadmium and lead shown in Figures do not cover the total input into the Baltic Sea. Measurements were no carried out in all of the smaller Danish rivers. Since no comparable data sets for the whole time period were presented by Russia and Estonia, the data from these countries has been omitted from Figures. The riverine loads of cadmium and lead for 2000 were omitted from Figures, but amounted to about 800 kg/year and 288 t/year for the Gulf of Finland, and 36 kg/year and 0.3 t/year for the Gulf of Riga.

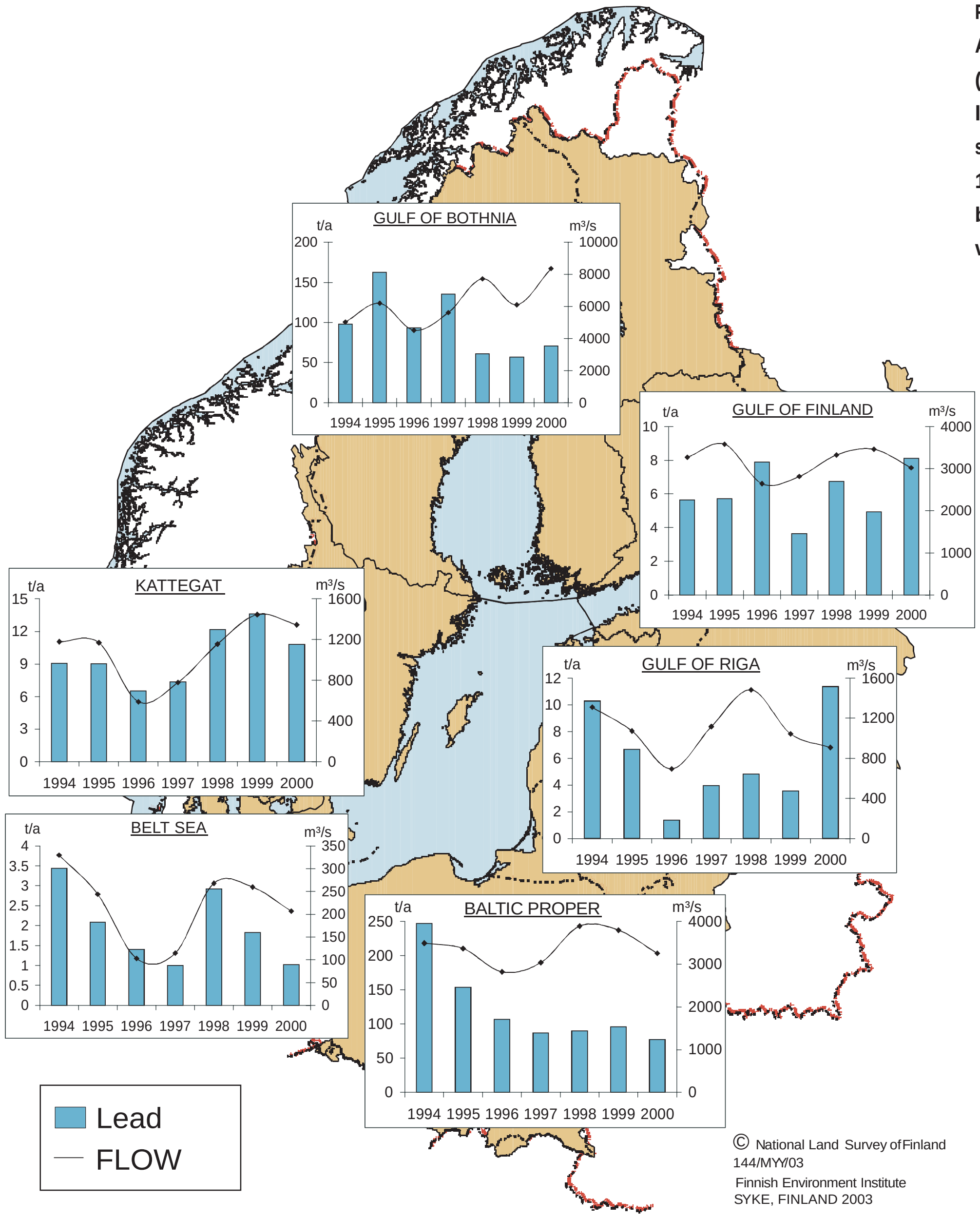


Figure 25b.
Annual average riverine runoff (m^3/s) and riverine inputs of lead in t/year into the different sub-basins of the Baltic Sea, 1994–2000. Different scales have been used in the graphs for the various sub-basins

Table 5.
Concentrations of dissolved trace metals (ng/kg) in the North Atlantic and the Baltic Sea. Source: Kremling, K. & Streu, P. (submitted); Pohl, C. et al. (1993); Pohl, C. & Hennings, U. (1999); Dalziel, J. A. (1995)

Metal	North Atlantic	Baltic Sea
Mercury (Hg)	0.10 – 0.3	5 – 6
Cadmium (Cd)	4 ± 2	12 – 16
Lead (Pb)	7 ± 2	12 – 20
Copper (Cu)	75 ± 10	500 – 700
Zinc (Zn)	10 – 75	600 – 1000

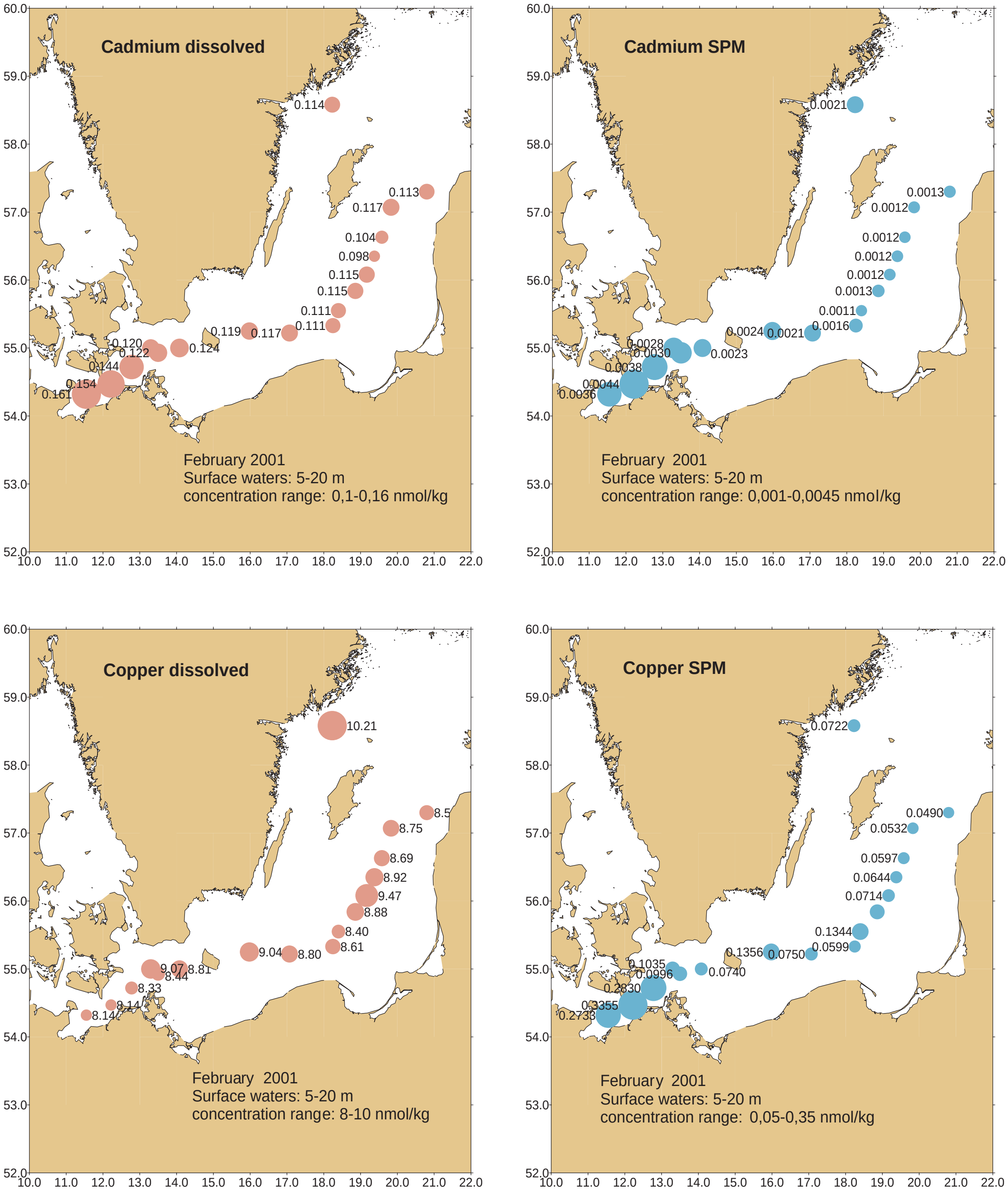


Figure 26a. Distribution of cadmium (Cd) and copper (Cu) in the dissolved phase and in particulate phase (SPM) in the Baltic Sea surface waters (Source: IOW).

Heavy metal concentrations in the water still high

Heavy metal concentrations in the Baltic Sea are many times higher than in the northern Atlantic, and have not decreased since the 1990s (Table 5).

Concentrations of cadmium and copper declined by about 6% per year between the 1980s and the mid-1990's. Since 1993, concentrations of trace metals in seawater have generally remained stable.

Concentrations of cadmium, lead and zinc are on average higher in the south-western parts of the Baltic Sea (Figure 26a and b), where atmospheric deposition of heavy metals is greater and waste containing high levels of heavy metals has been dumped.

Heavy metals may be either dissolved in the water or bound to particles. This affects the chances of organisms absorbing them from their surroundings.

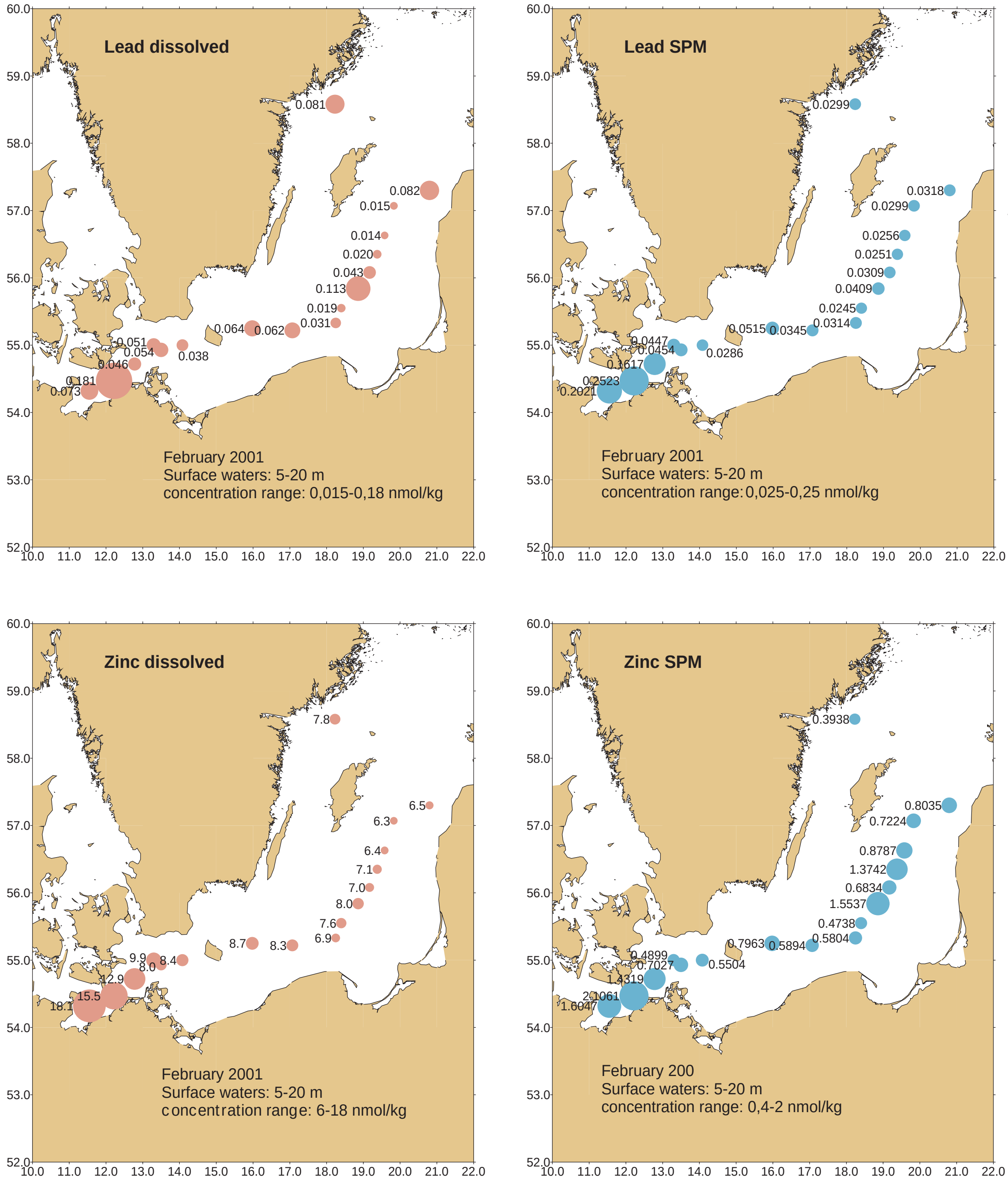


Figure 26b. Distribution of lead (Pb) and zinc (Zn) in the dissolved phase and in particulate phase (SPM) in the Baltic Sea surface waters (Source: IOW).

The chemistry of heavy metals is also influenced by oxygen concentrations in the water. A shortage of oxygen makes cadmium and copper precipitate as sulphide compounds, and they will subsequently be deposited in sediments in this form. This means the amounts of heavy metals in the water are directly linked to the oxygen depletion associated with eutrophication.

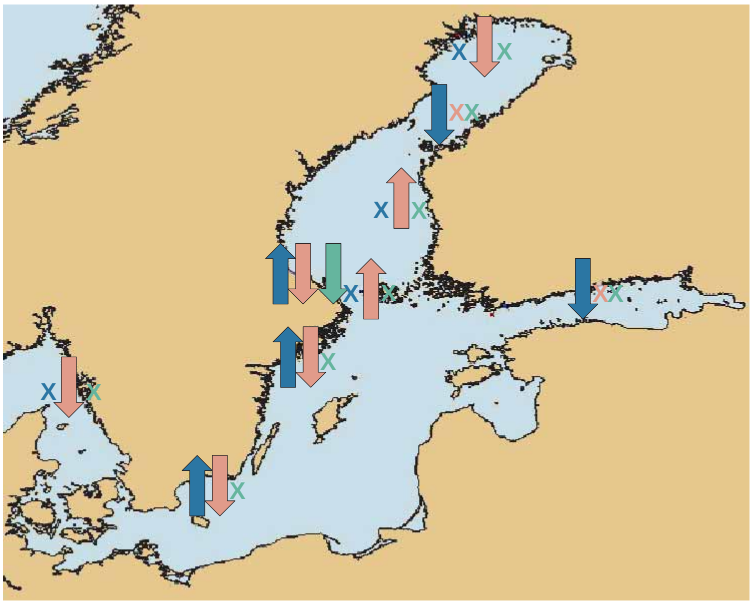


Figure 27.
Trends in metal concentrations in herring: cadmium (blue), lead (red) and mercury (green) during the period 1980-2001 in different parts of the Baltic Sea. X: no significant trend; ⇑: Significant upward trend; ⇓: significant downward trend (Source: HELCOM).

Heavy metals in marine organisms

Even though the concentrations of some heavy metals have decreased in many parts of the Baltic Sea, high concentrations can still be found in certain marine organisms, notably in Baltic herring.

Since the 1980s, lead concentrations in herring have generally decreased (Figure 27, red arrows). These declining trends are probably caused by the reduced atmospheric input of lead pollution, due in turn to the removal of lead from petrol.

Cadmium concentrations in Baltic herring have increased significantly (Figure 27, blue arrows), despite a general declining trend in concentrations in the waters of the Baltic Proper and the Western Baltic Sea.

Mercury concentrations in herring have remained at roughly the same level since the 1980s (Figure 27, green arrows).

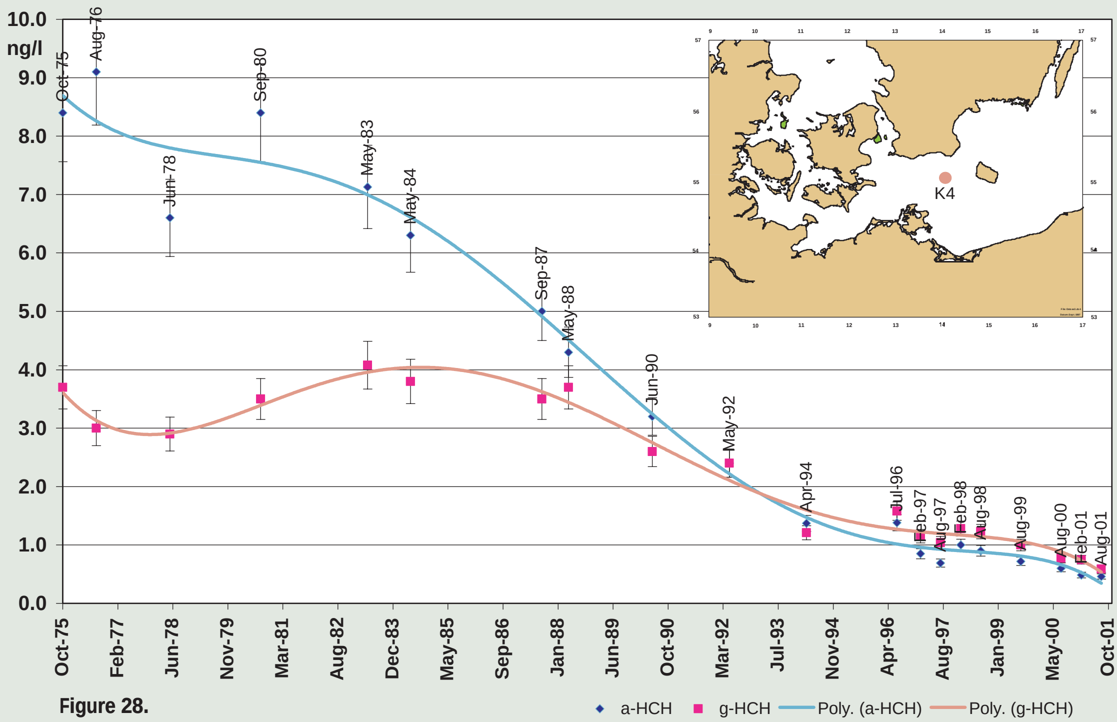


Figure 28.
Temporal trends in concentrations of HCH-isomers (-HCH, -HCH (Lindane) in the surface water of the Arkona Basin (Source: BSH).

Persistent organic pollutants (POPs)

Vast amounts of persistent organic pollutants have been released into the environment around the world. Due to long distance transportation by winds, POPs have spread and become a global contamination problem. Like heavy metals, POPs tend to accumulate in living organisms.

There have been substantial inputs of POPs into the Baltic Sea from numerous sources over the past 50 years. These sources include industrial discharges, such as the organochlorines in effluent from pulp and paper mills, runoff from farmland, the special paints used on ships and boats, and dumped wastes.

Several POPs, notably certain organochlorine pesticides such as DDT and technical grade HCH, have been completely banned since the 1980s. Subsequently, concentrations of HCH-isomers have considerably decreased in the waters of the Baltic Sea (Figure 28). After a sharp decrease over the period 1983–1993 a levelling off was observed until 1999, when a downward trend began, leading to a further decrease of more than 30% by 2001.

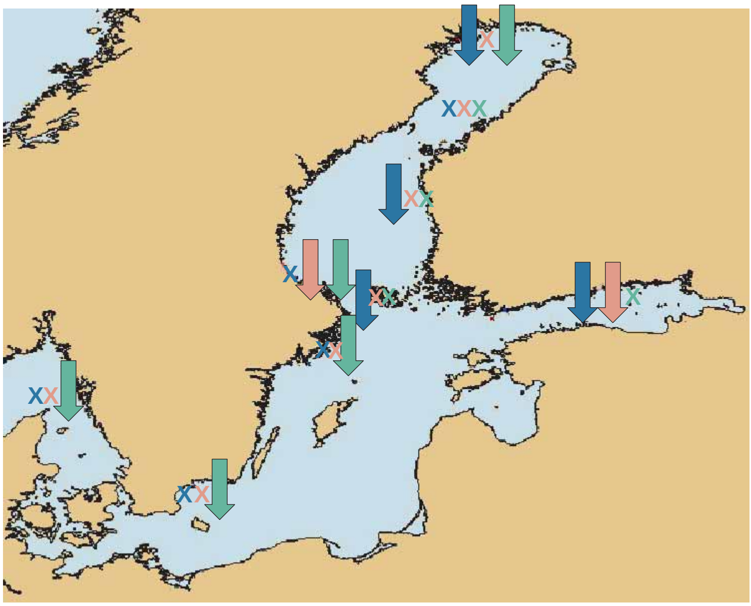


Figure 29.
Temporal trends in concentrations in herring of persistent organic pollutants CB180 (blue), sum of the 7 CB's (red), and lindane (green) during the period 1980–2001 from different areas in the Baltic Sea. X: no significant trend; ⇑: Significant upward trend; ⇓: significant downward trend (Source: HELCOM).

Concentrations of polychlorinated biphenyls (Figure 29, blue and red arrows) and lindane (green arrows) in herring have both decreased significantly, probably due to the effect on emissions of stricter regulations and bans in the HELCOM countries.

Measurements taken in 2001 in marine snails show relatively high concentrations of TBT in the Danish estuaries, the Kattegat, the Sound and the Belt Sea and the Western Baltic Sea. Imposex and intersex reproductive and gender disorders induced by TBT are consequently widespread in the Danish Straits and coastal areas.

Juha Flinkman / FIMR

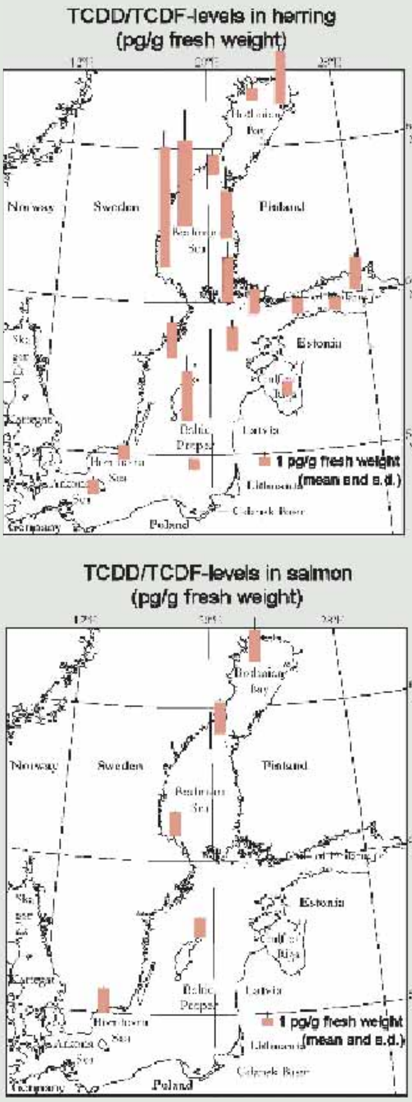


Figure 30.
Dioxin concentrations in Baltic herring and salmon (Source: Swedish EPA).

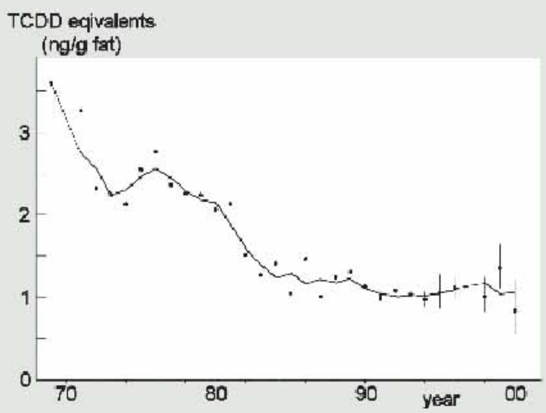


Figure 31.
Dioxin concentrations in guillemot eggs (Source: Swedish EPA).

The dioxin threat

Some of the fish caught in the Baltic Sea exceed the new EU limits on concentrations of dioxin in food and livestock feed. Finland and Sweden have been granted exceptional permission to allow the domestic sale and consumption of Baltic Sea fish until 2006 although the dioxin levels are still expected to exceed the new EU limits even then.

Concentrations of dioxins in herring and salmon vary regionally (Figure 30). The most contaminated fish are found in the Gulf of Bothnia, including herring in the Bothnian Sea, and salmon in the Bothnian Bay.

Transfers of dioxins up marine food chains can be observed in fish-eating birds and their eggs. The concentrations of dioxins in guillemots eggs have now decreased to one third of their 1970-levels (Figure 31). These concentrations decreased rapidly until the mid 1980s, but have subsequently remained at roughly the same level.

Dioxin concentrations in sediments peaked in the 1970s, but have more recently started to decrease.

Eliminating pollution hot spots

Riku Lumiaro / FIMR

Due to investment and remediation projects carried out at pollution hot spots around the Baltic Sea, HELCOM's official list of pollution hot spots has been radically shortened.

This list of the most significant pollution source "hot spots" around the Baltic Sea was first drawn up under the Baltic Sea Joint Comprehensive Environmental Action Programme (JCP) in 1992. Today 95 hot spots or sub-hot spots remain on the list, following the deletion of 54 of the 149 hot spots/ sub-hot spots by the end of 2002.

Increasing numbers of pollution hot spots have been deleted from the HELCOM list over the last three years (Figures 32 and 34).

Reported investments at hot spots have amounted to a total sum of around 1,114 million euros. This figure is certainly an underestimate, as information on investments was missing from 20 hot spots.

Estimated pollution load reductions for selected parameters are shown in Figure 33. This elimination of pollution hot spots has contributed substantially towards overall pollution load reductions in the Baltic Sea catchment area.

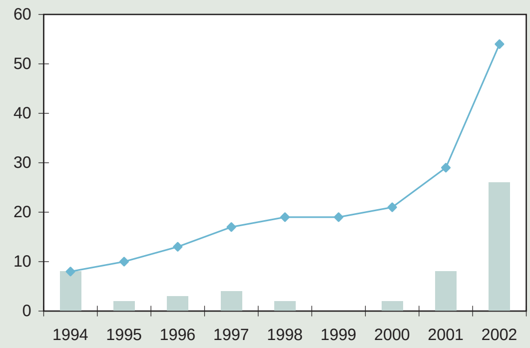


Figure 32.
Pollution hot spots and sub-hot-spots deleted from the HELCOM list by 2002. The bars indicate the numbers of deletions each year, and the line shows the cumulative number of deletions (source: HELCOM).

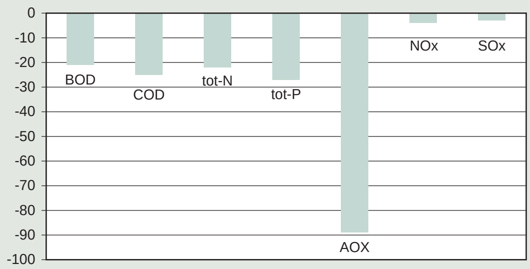


Figure 33.
Pollution load reductions (%) obtained at the hot spots deleted from the HELCOM list. Loads recorded in November 2002 are compared here to the loads recorded when the JCP was initiated in 1991 (Source: HELCOM).

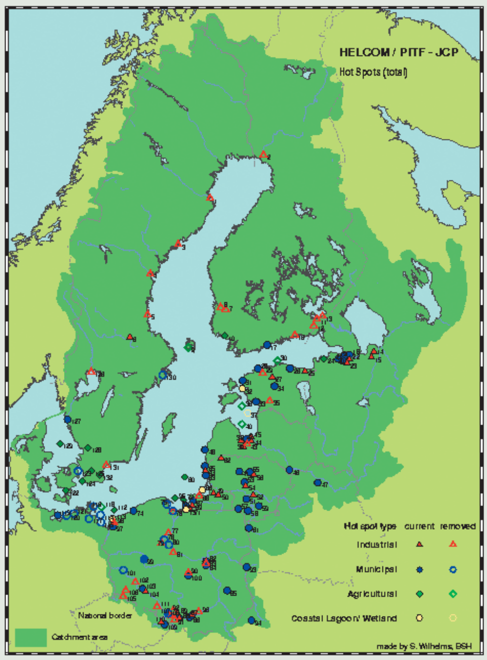


Figure 34.
Location of current and deleted (removed) HELCOM pollution hot spots.

Oil pollution and shipping

Riku Lumiaro / FIMR

Oil is a serious threat to Baltic ecosystems and wildlife. Oil spills contaminate the water by creating an oily layer on the surface or by mixing and dissolving into the water – depending on the quality of the oil. The most visible effects of oil-spills are caused by the oil on the surface: birds and seals are smothered, and their chances of survival are hampered by problems with their mobility or the insulating properties of their feathers or skin. Oil pollution also destroys habitats for many plants and animals, including the spawning areas of fish. Moreover, many of the chemicals in oil-spills are toxic, and can have serious effects on plankton, fish and animals living on the sea floor.

Oil decomposes slowly in the cold waters of the Baltic, where the average water temperature is only about 10 degrees. Coastal areas contaminated by oil-spills need to be actively cleaned up, which is a very slow and laborious task, especially during the winter. The necessary clean-up operations may themselves unavoidably harm marine life and coastal habitats. Oil-spills can also have serious repercussions for tourism and commercial fisheries.

Illegal oil discharges

About 10% of all the oil hydrocarbons in the Baltic Sea originate from deliberate, illegal discharges from the machinery spaces or cargo tanks of vessels sailing in the Baltic. Surveillance aircraft detect about 400 illegal oil discharges a year in the Baltic Sea (Figure 35). Not all spillages can be observed, however, so the actual number of illegal discharges is probably much higher than this figure. In most cases the amount of oil discharged is less than one cubic metre.

Increasing oil transportation

The intense shipping in the Baltic Sea accounts for approximately 15% of all maritime traffic around the world. In 2000, 80 million tons of oil were transported in the Baltic. Forecasts indicate that by 2015 the total amount of oil transported in the Baltic will amount to more than 130 million tonnes a year. It is estimated that this increasing oil transportation will raise the risk of a large oil-spill involving over 10,000 tonnes of oil by 35% for the whole of the Baltic Sea, and by 100% for the Gulf of Finland.

Figure 35. Number of detected oil discharges in the Baltic Sea, 1988–2001 (Source: HELCOM).

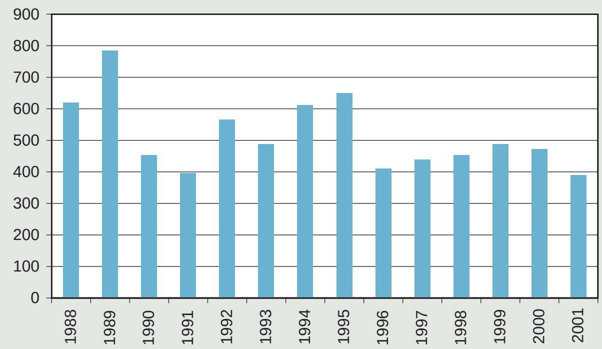
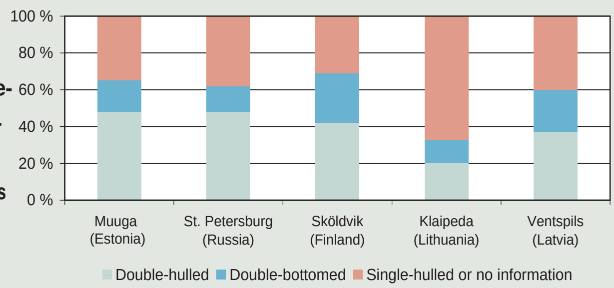


Figure 36. The percentage of double-hulled, double-bottomed and single-hulled oil tankers at the main oil terminals around the Baltic Sea, May/June 2001 (Source: Rytkönen et al. 2002).



Oil-spills from collisions at sea

Shipping accidents in the Baltic are mainly caused by groundings and collisions. Over the last 11 years, 251 shipping accidents occurred in the Baltic Sea, with about one in five resulting in oil pollution. Out of 119 accidents during the period 2000–2001, including 19 accidents involving oil tankers, 9 accidents resulted in oil pollution entering the sea. The total amount of oil spilled into the Baltic in 2000 and 2001 was 2,756 m^3, of which around 2,500 m^3 was spilled in a single accident.

Double hulls reduce risks

The risk of an oil accident depends greatly on the type of vessel. Single-hulled tankers are much more likely to spill oil in an accident than modern double-hulled or double-bottomed ships. In 2000 and 2001 accidents involving single-hulled tankers resulted in oil pollution in one of every four cases, while the same ratio for double-hulled tankers was 1 in 6.

Many of the oil tankers operating in the Baltic Sea are still only single-hulled (Figure 36).

Chemical munitions

Janne Broon / FIMR

Chemical weapons dumps in the Baltic

About 40,000 tonnes of chemical munitions were dumped into the Baltic Sea after the Second World War. It is estimated that these chemical munitions contained some 13,000 tonnes of chemical warfare agents. No new information on these dumps has been reported in recent years.

The locations of the dumped chemical munitions are well known. The main dumping areas are south-east of Gotland, east of Bornholm and south of the Little Belt (Figure 37). It is also quite likely that munitions were jettisoned overboard while ships were en route to the dumping areas of the Bornholm and Gotland basins.

Extensive investigations carried out by Germany during the period 1994–1997 in order to detect any munitions dumped along the shipping routes to the dumping areas revealed no chemical munitions within German territorial waters.

Effects on the marine environment

Chemical warfare agents break down at varying rates into less toxic, water-soluble substances. Some compounds, however, show an extremely low solubility and slow degradability (e.g. viscous mustard gas, Clark I and II, and Adamsite). These compounds cannot occur in higher concentrations in water, so a wide-scale threat to the marine environment from these dissolved chemical warfare agents can be ruled out.

Elevated levels of slightly soluble Clark, Adamsite or mustard gas in viscous form may occur in sediments in the immediate vicinity of the dumped munitions. But because of the very limited distribution of these agents, there is evidently little likelihood of any threat to marine life.

Bearing in mind the existing information on the ecotoxicity of chemical warfare agents, recent Swedish investigations confirm that mustard gas is not likely to pose any acute toxicological threat to zooplankton organisms. However, Clark compounds do constitute a potential ecotoxicological risk to zooplankton (EC_{50}: 6 to 255µg/l). These studies also showed that Clark compounds are eliminated from the water phase by adsorption into sediments. Toxicity tests conducted on the benthic crustacean *Nitocra spinipes* showed that sediments were indeed toxic, although chemical analysis could not specifically reveal the presence of Clark I or its primary hydrolysis product.

Fishermen may be at risk

Over the period 2000–2002 about 10 incidents a year were reported where chemical munitions were netted by fishermen, showing that these chemicals are still a risk for the crews of fishing vessels operating in this part of the Baltic.

No traces of mustard gas or other chemical warfare agents have so far been found in edible fish or other types of seafood, so these chemical warfare agents do not seem at the moment to constitute a problem in terms of food toxicology.

It is very unlikely that these munitions could have been moved away from the vicinity of their dumping sites by currents, so there is little probability of any significant threat to coastal areas.

There is no new information that could weigh against the general HELCOM recommendation that attempts should not be made to recover the chemical munitions dumped in the Baltic.

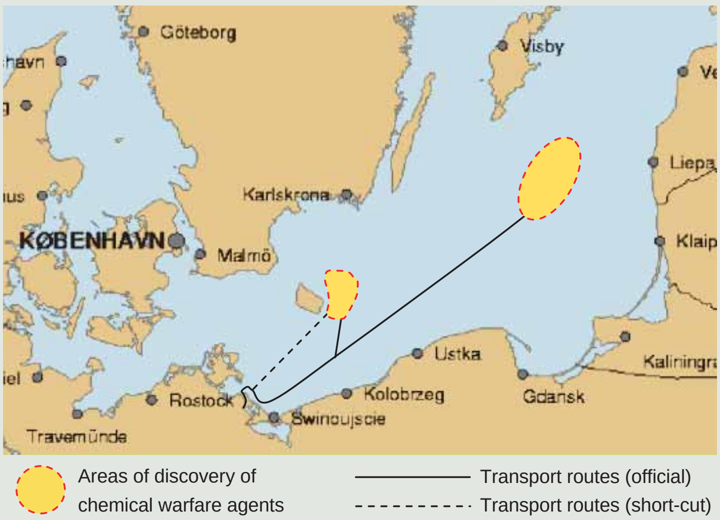


Figure 37.
Waters where of chemical munitions were dumped after the Second World War.

Fish stocks and disease

Riku Lumiaro / FIMR

Baltic fish stocks are widely overexploited

Total fish catches have increased tenfold since the early 20th century as a result of more effective open sea fishing, decreased predation by seals and increased fish production due to eutrophication. Eutrophication is a double-edged sword, however, as it also has negative impacts, particularly in spawning areas, leading to reductions in the reproductive success of many fish species. Another man-made problem affecting natural reproduction is the widespread damming of the spawning rivers of migratory fish species like salmon, migratory whitefish and brown trout, whose natural populations have suffered greatly. About 90% of the total fish catch in the Baltic consists of herring, sprat and cod. Even though salmon only accounts for about 1% of the total catch by weight, it is still a commercially important species.

Cod on the decline

Cod is a marine fish which can only spawn successfully in oxygenated waters with salinity levels of at least 12 PSU. A lack of oxygen in established spawning areas combined with overfishing has drastically reduced cod catches in the Baltic Sea since the mid 1980s (Figure 38). In 1992, the spawning stock biomass of cod in the Baltic reached a record low. Particularly in the eastern Baltic, cod stocks are seriously overexploited and their numbers are below safe biological limits (Figure 39).

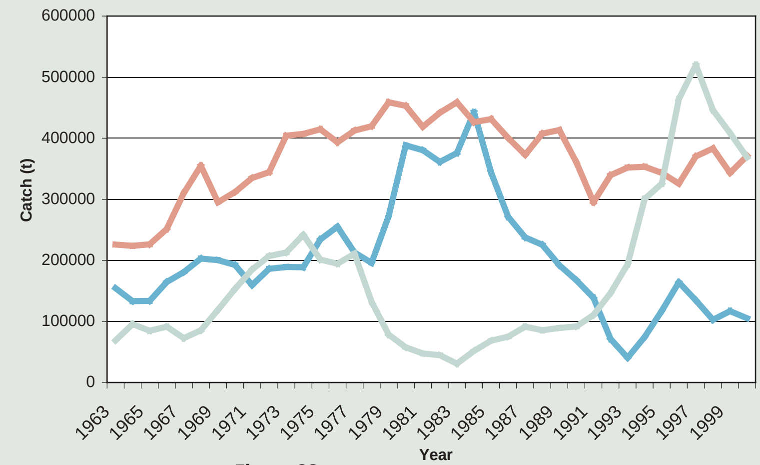


Figure 38.

Cod, herring and sprat landings 1963–2000 (Source: ICES).

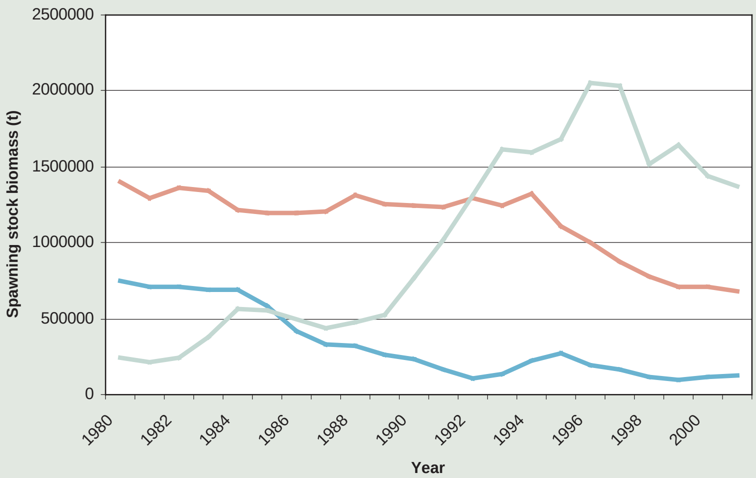


Figure 39.

Spawning stock biomasses of cod, herring and sprat in 1980–2001 (Source: ICES).

Herring also suffering from low salinity

The Baltic herring stock consists of several regional populations that spawn in different coastal areas and migrate to common feeding grounds in the Baltic Proper during late autumn and winter. These herring populations used to be classified as spring-spawners or autumn-spawners, according to their reproductive behaviour. Today the herring stock has become more uniform, with the autumn-spawners in the northern Baltic constituting only 2–4% of the whole herring population.

The spawning stock biomass of herring has been decreasing steadily (Figure 39), due to the unfavourable changes induced by falling salinity levels, in the zooplankton communities the herring feed on. The spawning stock biomasses of herring in the Central Baltic are currently low, whereas in the Bothnian Sea and the Gulf of Riga stocks have been thriving.

The widespread disappearance of cod has also affected herring populations, since reduced predation pressure from cod initially increased the abundance of herring, which subsequently may actually have worsened the situation for herring by adding to the competition for a diminishing food supply. The combined effect of these factors has reduced the average sizes of fish of any particular age (weight-at-age) in the Baltic Proper and the Gulf of Finland since the mid 1980s.

Sprat stocks sustainable

Sprat stocks are evidently being exploited within safe biological limits at the moment, but the situation should still be closely monitored. Sprats, like herrings, have benefited from the lower numbers of cod; and their spawning stock biomass increased from the 1980s to a peak in the mid 1990s (Figure 39) before a decline began in 1997. Between 1991 and 1997 sprat catches increased fourfold (Figure 38), but catches have subsequently decreased. The average weight of the sprats caught has been declining since 1993.

Wild salmon at risk

The wild salmon of the Baltic Sea spawn in rivers, and their populations have suffered greatly from the damming of rivers. Wild Baltic salmon smolts are nowadays only produced in 40–50 rivers. In compensation for these losses, hatcheries have been built to sustain wild salmon stocks. This has led to the loss of distinct populations and a decline in overall genetic variability.

Efforts made by HELCOM and the International Baltic Sea Fishery Commission (IBSFC) to protect and restore wild salmon populations have started to bear fruit. Estimates indicate that wild salmon production increased over the period 1995–2001 by one million individuals, raising the annual yield of juvenile wild salmon from 0.3 million to over 1.3 million (Figure 40). However, yields of juvenile wild salmon in certain rivers are still alarmingly low, particularly in smaller forest rivers around the Bothnian Bay and in Estonia.

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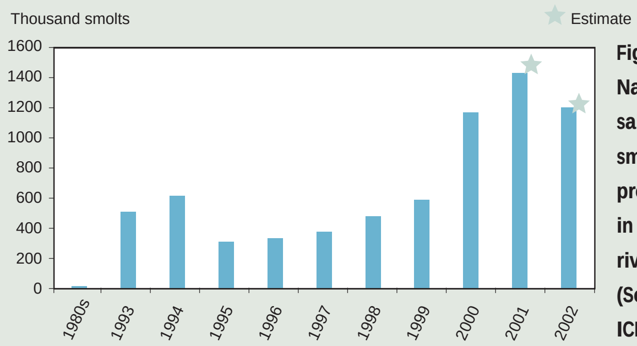

Figure 40. Natural salmon smolt production in Baltic rivers (Source: ICES).

Salmon still afflicted by the M74 syndrome

The reproduction levels of wild salmon have been reduced due to a syndrome known as M74, which leads to high mortality rates among the very young yolk-sac fry, and also causes disturbances in the gender balance and behaviour of adult fish. The syndrome has been known since 1974, but extremely high fry mortality rates have only occurred since the early 1990s. M74 has been associated with maternally-transmitted vitamin deficiency, mainly in terms of a lack of vitamin B_1 (thiamine). Correlations have also been found between M74 and concentrations of dioxin-like organic compounds which can influence the metabolism of thiamine and carotenoids. There is as yet no sign as to the ultimate cause of this syndrome. A sharp decline can be seen in the prevalence of this syndrome in the broodfish, but this is mainly due to more careful selection process before fry stripping. Recent data indicates that M74 is generally on the increase again, although surveys of salmon parr in Latvian rivers over the period 1995–2002 suggest that these populations remain unaffected by M74.

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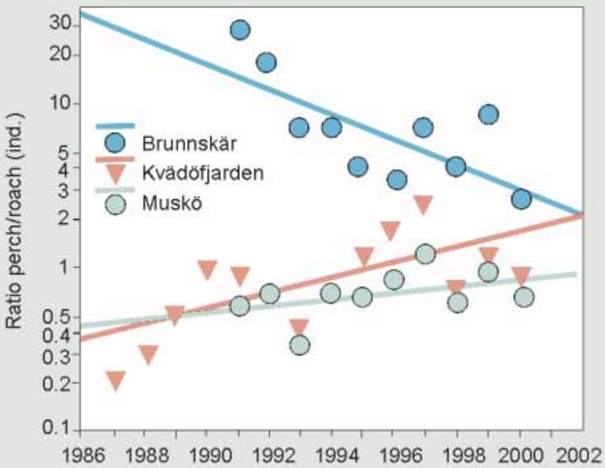
Changes in coastal fish stocks

Reproductive failures have been observed among the coastal fish stocks of the Baltic Proper and the western Gulf of Finland since the mid 1990s. While the reason for these problems is not fully understood, increasing eutrophication is widely implicated. The spawning areas of several coastal fish species are situated in the inner archipelago and coastal bays, where their reproduction may be affected by the pronounced effects of eutrophication, such as decreased water transparency, changes in the sea-bed and oxygen depletion.

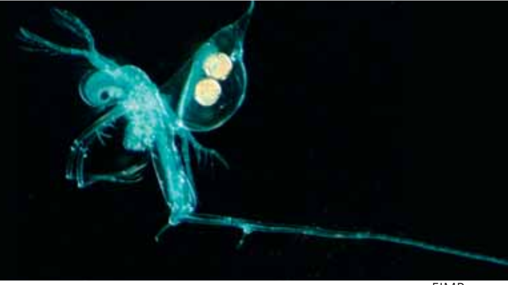
Figure 41. Changes in the ratio between perch and roach in catches in reference areas (Source: Appelberg & Ådjers 2001).



The species make-up of fish communities in coastal waters has also changed due to eutrophication. These communities have in general become more dominated by cyprinid fish, like roach *(Rutilus rutilus)* and bream *(Abramis brama)*; while perch *(Perca fluviatilis)* and pike-perch *(Stizostedion lucioperca)* have declined. The ratio between the abundance of perch and roach is a good indicator of eutrophication. The increased proportion of perch and pike-perch in Swedish coastal monitoring areas (Kvadöfjärden, Muskö) indicates a decrease in eutrophication, whereas in the Åland Archipelago (Brunnskär) the increased proportion of cyprinid fish indicates that eutrophication has worsened during the 1990s (Figure 41).

Present fishing practices cause considerable by-catches of non-commercial fish species, seabirds and marine mammals. Seabirds, harbour porpoises and seals are particularly liable to end up in drift nets, set nets, fyke nets and traps.

Invasive species



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An increasing threat

Due to increasing shipping, more alien species are finding their way into the Baltic Sea than ever before. These non-indigenous invaders can induce considerable changes in the structure and dynamics of marine ecosystems. They may also hamper the economic use of the sea or even represent a risk to human health. About 100 non-native species have been recorded in the Baltic Sea, and almost 70 of them have been able to establish viably reproducing populations. Most of these invasive species originate from freshwater or brackish-water environments, particularly from North America or the Ponto-Caspian region.

In some cases, alien species have been deliberately introduced for fishing or aquaculture, but most have been brought in accidentally by ships, which can rapidly transport marine animals, plants and algae across the world in their bilge and ballast waters.

Four invaders

Cercopagis pengoi is a predatory water flea which is native to the Ponto-Caspian region, the Caspian Sea, the Aral Sea and the Azov Sea. It was first observed in the Gulf of Riga and the Gulf of Finland in 1992, and in 1995 it was found in large quantities in samples from the eastern Gulf of Finland. This species clogs fishing nets and competes with herring for zooplankton prey. It was exceptionally numerous in the Bothnian Bay during the warm summer of 2002.

Marenzelleria viridis is a polychaete worm that lives inside bottom sediments. It was observed in the southern Baltic Sea for the first time in 1985, but has subsequently spread all the way up to the Bothnian Bay. Its distribution has mainly been restricted to shallow coastal areas, but in 2000–2002 *Marenzelleria* started to colonize the deeper waters of the Bothnian and Åland Seas, and it has also increased profusely in the Quark. Marenzelleria can out-compete the very few species that form the native benthic community in the northern Baltic Sea and thus alter the structure of the whole benthic ecosystem.

Prorocentrum minimum is a phytoplankton species of the open seas, which may originally have been brought into the Baltic Sea by currents or in ships' ballast water. It is well established as a common species in the southern Baltic Sea, but in summer 2002 it formed blooms in the Archipelago Sea along the Finnish coast, and it has also been found in the Gulf of Finland. There are no records of toxic *Prorocentrum* blooms in the Baltic Sea.

Nature conservation and biodiversity

Juha Flinkman / FIMR

There are many unique ecosystems and habitats around the Baltic Sea which serve as vital breeding grounds, nurseries, shelters and food sources for many aquatic and terrestrial species. Despite the low number of typical marine species, the Baltic Sea still hosts a unique variety of plants, animals and micro-organisms, specially adapted to the brackish-water environment.

Human activities pose a variety of threats to the ecosystems, species and biotopes around the Baltic. Such anthropogenic pressures are aggravated by the challenging natural conditions and the naturally low level of biodiversity. These circumstances make nature conservation a common concern for all the HELCOM Contracting Parties.

Protecting species

The conservation work of HELCOM has contributed to many success stories, including:

- The recovery of the white-tailed eagle around the Baltic Sea
- The return of the cormorant to the whole region
- Early signs of recovery in Baltic wild salmon populations
- Increasing numbers of seals in northern areas of the Baltic Sea

But for many species there is still cause for concern:

- Nearly all the Baltic's top predators, such as marine mammals and several bird species, still suffer from pollution, fisheries' by-catch and habitat destruction
- Baltic harbour porpoises are still endangered
- All the Baltic's seal species are still to some degree threatened
- The sturgeon is presumed to be extinct in the wild in the Baltic region
- Baltic cod stocks have been depleted to alarmingly low levels, and non-commercial fish stocks have also been seriously disrupted due to intensive fisheries activities.

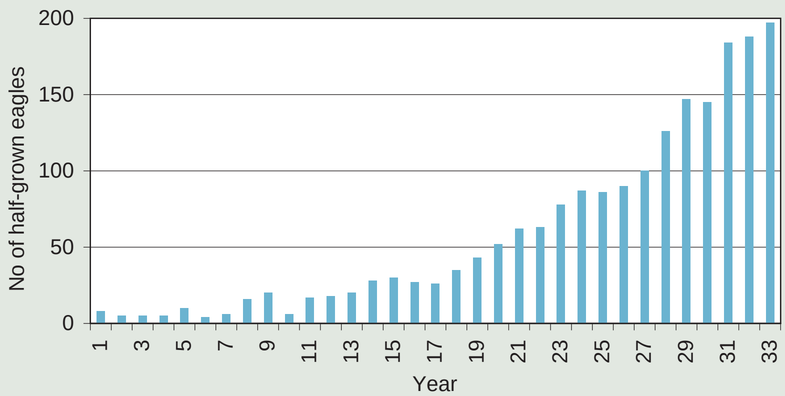


Figure 42.
Number of young white-tailed eagles hatched per year in Finland, 1970-2002 (Source: WWF Sea Eagle Working Group, Finland).

Threatened species

The white-tailed eagle

Environmental pollutants have had dramatic effects on white-tailed eagle (Haliaeetus albicilla) populations. Cumulative amounts of DDT, PCBs and other pollutants earlier led to severe reproductive problems, as indicated by the thinning of the birds' egg shells. But since these chemicals were banned through HELCOM initiative, white-tailed eagles have been able to feed on uncontaminated meat and fish, and their reproductive success rates have duly improved to almost natural levels (Figure 42 and 43). According to the WWF, white-tailed eagles bred well in Finland in 2002, when 192 eaglets were hatched. But another continuing threat to the white-tailed eagle is habitat loss as a result of the widespread adoption of modern forestry methods.

Marine mammals

Only four marine mammal species live and breed in the Baltic Sea, including three seal species and the harbour porpoise – a small whale.

Harbour porpoise populations decimated over the 20th century

The only cetacean regularly found in the Baltic is the harbour porpoise *(Phocoena phocoena)*. At the beginning of the 20^{th} century between 10,000 and 20,000 porpoises lived in the Baltic Proper, and ranging as far as the eastern Gulf of Finland and the Bothnian Bay.

Porpoise populations have decreased drastically due to hunting, periodic catastrophic mortalities associated with severe winter ice conditions, pollution, disturbances such as noise, and deaths caused by fishing equipment.

Today the population in the Baltic Proper is estimated to number only some 600 individuals, and

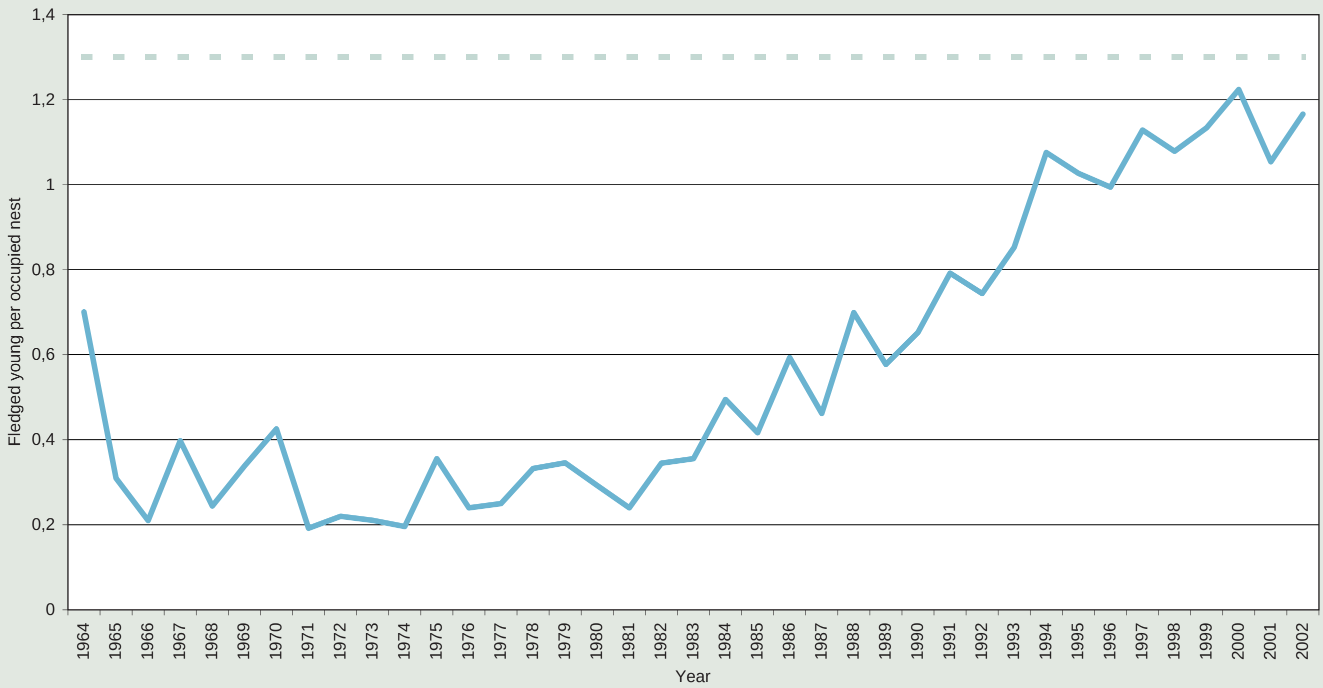


Figure 43.

Breeding rates for white-tailed eagles along the east coast of Sweden, as calculated by dividing the total number of fledged young by the total number of pairs. The dotted line indicates breeding rates observed prior to 1954. (Source: Dr. B. Helander, Swedish Society for Nature Conservation/Swedish Museum of Natural History).

the species seem to be completely absent from the northern and easternmost parts of the Baltic Sea . In the Skagerrak and Kattegat , however, there are about 36,000 individuals, and this population is important on the European scale.

Between 1999 and 2001, 206 dead harbour porpoises were reported to HELCOM from around the Baltic, including 113 caught up in fishing equipment.

Seals making a comeback in the north

Three seal species live in the Baltic Sea: the ringed seal *(Phoca hispida baltica)*, the grey seal *(Halichoerus grypus)* and the harbour seal *(Phoca vitulina)*. About a century ago it is thought that the Baltic was home to at least 200,000 ringed seals, 100,000 grey seals, and 5,000 harbour seals. All three species have been severely affected by hunting, and in the 1950s and 1960s their already depleted populations suffered further from severe reproductive, metabolic and immunological disorders, caused by the accumulation of hazardous substances in the marine environment.

But seal numbers are now increasing, as a result of bans on seal hunting, and reductions in the concentrations of hazardous substances. Reproductive failures are still a problem, however, and seals are also currently suffering from other diseases as well. Human disturbance and entanglement in fishing equipment also pose continuous threats to the Baltic seals.

International surveys estimated that there were 13,100 grey seals in the Baltic in 2002. Finnish studies have indicated that grey seals' current reproduction rates and heath conditions are close to natural levels. However, the species is still absent from the southern parts of the Baltic Sea.

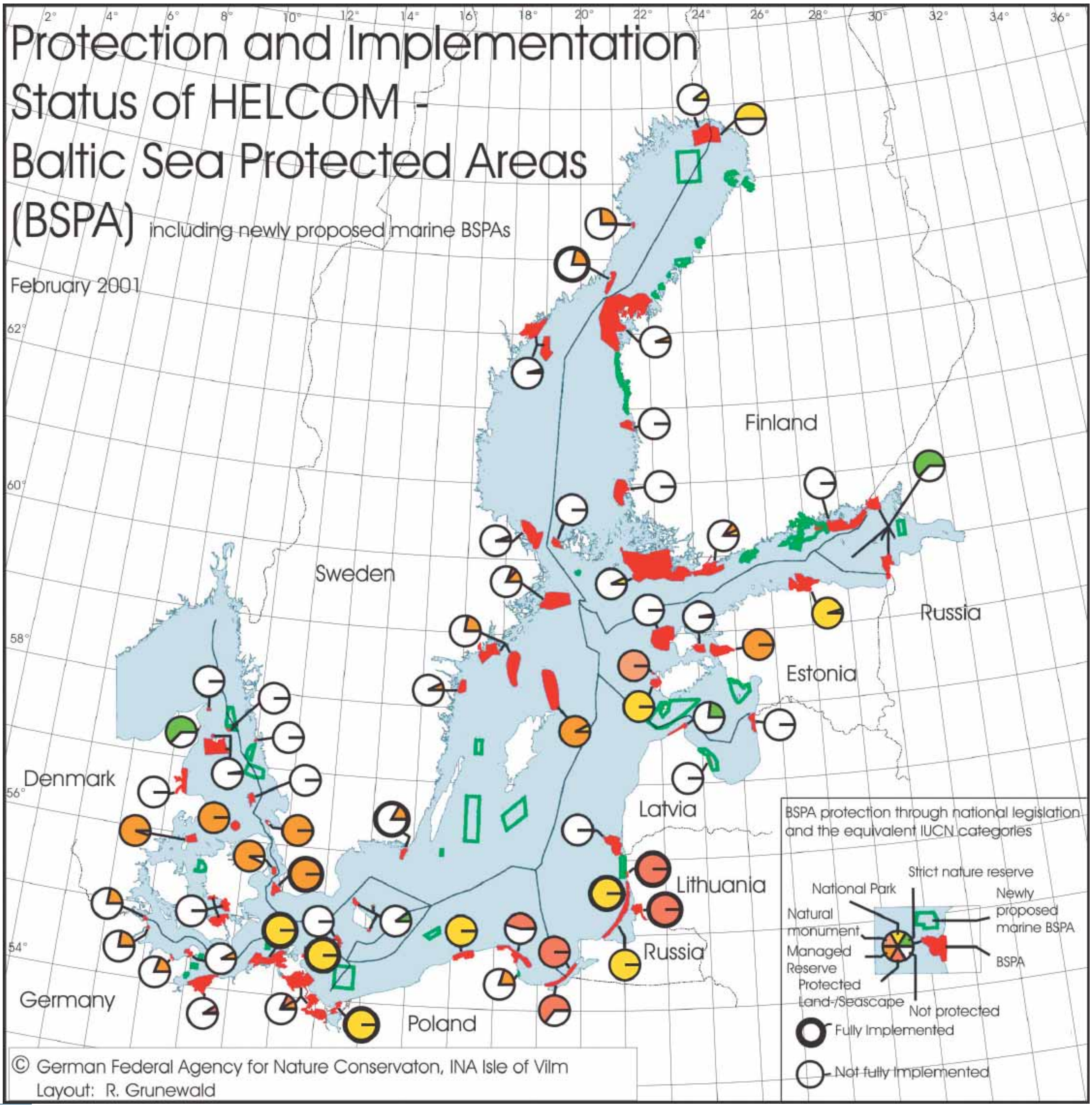
In 1996, the total Baltic ringed seal population was estimated at around 5500 individuals. Since then areal surveys have been made only in 2003, but the results are no yet available for this publication. Ringed seal reproduction rates are still thought to be lower than natural rates, but the status of the population in the Gulf of Finland is still unclear.

Rising seal populations have led to conflicts with fishermen, whose catches are reduced due to competition from seals. Some seals raid and damage fishing gear and or even raid fish farming facilities, rendering fishing virtually impossible in some areas. The need to resolve this conflict is recognised by HELCOM.

Habitat protection

As much as 90% of the marine and coastal biotopes around the Baltic Sea area are to some degree threatened today, and many of these areas are important habitats for rare or endangered species. Many coastal areas of the Baltic are being rapidly built up, increasing the fragmentation of natural habitats.

Figure 44. Protection and implementation of Baltic Sea Protected Areas in 2001 (Source: BfN).



In order to improve the alarming situation reflected in 1998 HELCOM Red List of Marine and Coastal Biotopes, HELCOM adopted a Recommendation on general biotope protection (2000, HELCOM Recommendation 21/4), where the Contracting Parties committed themselves to protect biotopes, particularly those which are endangered or deteriorating. These measures will include the banning of any activities which can damage or destroy valuable biotopes. Most of the HELCOM countries have subsequently taken important steps to give legal protection to biotopes.

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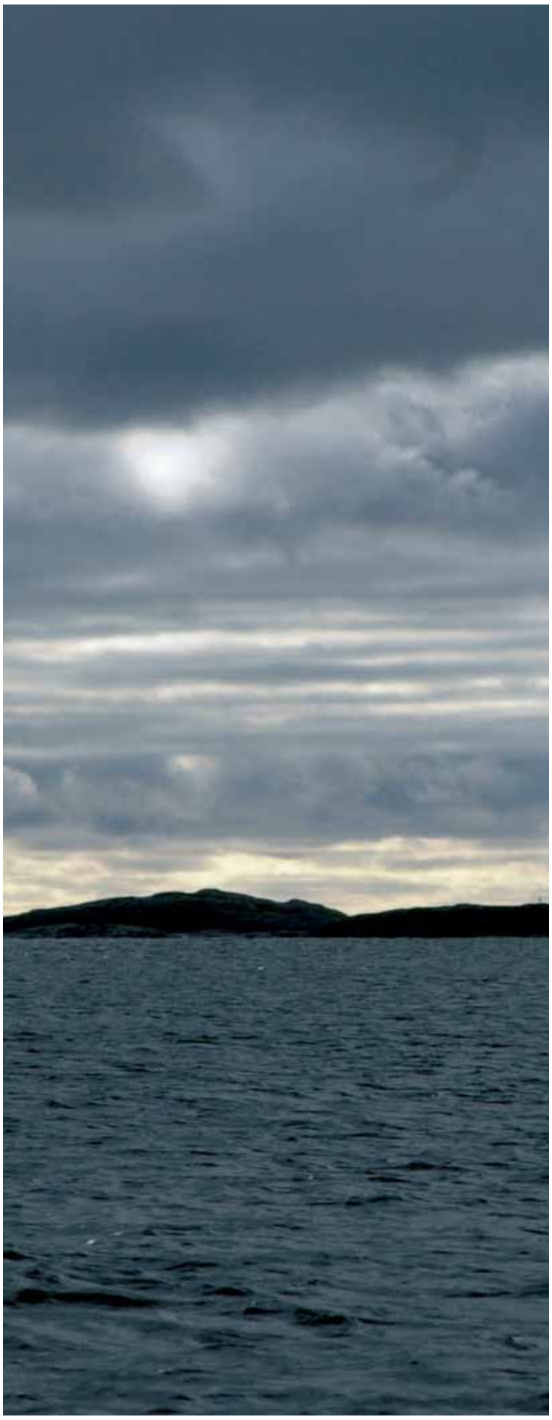

More action needed to create a network of marine and coastal Baltic Sea Protected Areas (BSPA)

In 1994, 62 BSPAs were designated under HELCOM Recommendation 15/5. Although preference was given to areas already under some form of protection, very few of the designated areas have been finally incorporated in the BSPA network yet (see Figure 44). There still remains the additional task to incorporate 24 offshore areas identified by experts in 1998 into the network.

In order to harmonise the approaches and the implementation processes for marine protected areas (MPAs) in the Northeast Atlantic and the Baltic Sea, HELCOM and OSPAR have jointly developed a detailed work programme on MPAs, including a concrete timetable for implementation until 2010. This programme will most likely be adopted and endorsed by the region's environmental ministers at the joint meeting of both Commissions in Bremen, Germany, 2003.

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Conclusions

Eutrophication still a widespread and persistent problem

The Baltic Sea is particularly vulnerable to pollution due to its unique natural conditions. Oxygen depletion is a natural problem in the Baltic, but eutrophication induced by nutrient pollution has considerably worsened this threat to marine ecosystems. Biodiversity and fish stocks have been affected as well, and exceptionally intense algal blooms have become more common.

Successes with emissions cuts

There has been considerable progress towards achieving the 50% reduction targets for nutrient emissions and discharges set in the 1988/1998 Ministerial Declaration. The target has in fact been achieved for phosphorus emissions from point sources in all the HELCOM countries except Poland, where reductions amounted to around 40%. A clear decline in riverine phosphorus loads has also been detected in the Belt Sea Area.

Nitrogen losses from agriculture have decreased less than the discharges from point sources. National estimates indicate that 50% reductions have been achieved in Estonia, Latvia, Lithuania and Russia, mainly due to the dramatic changes in the number of livestock units and reductions in the use of mineral fertilisers. Despite these reductions at source, no general decrease has yet been detected in nitrogen riverine load, entering the Baltic Sea.

Airborne nutrient inputs remain still high.

Prospects still worrying

Eutrophication remains an issue of major concern almost everywhere around the Baltic Sea area. In some areas, such as the western and northern Baltic, the Gulf of Finland and the Bothnian Sea, phytoplankton biomass has been increasing since the early 1980s.

In the Gulf of Finland, phosphorus concentrations have increased rapidly since the mid 1990s, as a result of intensified internal loads received from oxygen-deficient sediments. This has resulted in extensive algal blooms, especially in the summers of 1997 and 2002. Phosphorus concentrations in the deep basins of the Baltic Proper have started to increase as well, as the areas with oxygen deficiency have been expanding since late 1990s. These developments combined with certain weather conditions could lead to the formation of extensive blue-green algal blooms in the future.

Coastal waters are also being affected by oxygen depletion. This problem has been particularly acute in recent years in the Kattegat-Belt Sea Area, which is especially vulnerable due to pronounced stratification and shallow depths. Nutrient loads here are still so high that the annual oxygen minimum during calm weather in summer and autumn can develop into severe oxygen depletion, as occurred in 2002.

More action still needed on hazardous substances

It is not possible to draw any general conclusions from the limited changes observed in heavy metal concentrations in seawater or marine organisms. Concentrations of some metals, such as cadmium, are declining in organisms in some areas (e.g. the Gulf of Bothnia and the Gulf of Finland) but increasing in others (e.g. the western Baltic Proper). The best news is the clear decrease in lead concentrations in herring observed in most areas.

Concentrations of HCH-isomers (lindane) in water and biota have decreased considerably since the early 1980s.

Concentrations of dioxin and PCBs in marine ecosystems declined in the 1980s but this decrease levelled off in the 1990s. Dioxin levels in fish still exceed the new EU food safety limits in some areas, particularly further north.

TBT concentration levels are still so high that they have potential biological effects, at least in the Kattegat, the Belt Sea and the Sound. For other endocrine disrupting substances and new contaminants like flame retardants, a full assessment of their levels or effects is not possible due to the lack of monitoring data.

Similarly for riverine and atmospheric inputs of organic contaminants, not enough accurate data is available to allow detailed analysis. However, the pollution load from hot spots has been reduced substantially within the framework of the JCP.

The chemical weapons dumped in the deep waters of the Baltic Sea in the 1940s are not currently seen as a serious threat to marine ecosystems. Research also indicates that any attempt to recover these munitions would be more likely to cause harm than good.

Increasingly crowded shipping lanes

Increasing maritime transport in the Baltic poses an increasing threat to the marine environment. Even in the absence of any major oil spill, the many illegal oil discharges and accidents with minor oil spills already noticeably affect ecosystems. The predicted increase in shipping will multiply the risk of a serious spill if preventive measures are not strengthened.

Increasing maritime transport also means increases in NOx emissions, while more non-native species are likely also to gain a foothold in the Baltic Sea, with the potential to disrupt ecosystems.

Over-fishing a serious problem

Present commercial fishing practices have environmental impacts throughout the whole Baltic Sea, affecting species caught accidentally as by-catches, as well as the stocks of commercially fished species themselves.

Some of the commercially important fish stocks in the Baltic Sea are currently exploited in excess of "safe biological limits". This over-fishing can put entire marine ecosystems under pressure by changing their species composition and predator-prey ratios. Over-fishing of Baltic cod is currently a serious problem. Spawning stocks of herring have also decreased steadily since the 1970s, mainly due to changing environmental conditions.

Excessive fishing pressure can also harm other species such as porpoises, seals and seabirds, and even damage the physical environment, ultimately affecting the productivity of marine ecosystems and reducing biodiversity.

One positive sign is an increase in the productivity of wild salmon of one million young fish a year over the period 1995–2001.

Habitats and biodiversity at risk

One sure sign of the success of HELCOM's environmental programmes and nature conservation measures is the steady increase over recent decades in the breeding success rates of top predators such as the white-tailed eagle and the Baltic's three seal species. But these species still face health problems, with sterility levels high among young ringed seals, other pollution-related disorders evidently increasing in grey seals, and harbour seal population again suffering from the Seal Distemper Epidemic in 2002.

The vast majority of the marine and coastal biotopes around the Baltic Sea are to some degree threatened, and many of them are important for rare or endangered species.

Invasive species pose an increasing threat to ecosystems and the region's biodiversity.

The network of marine and coastal Baltic Sea Protected Areas is still not fully implemented. In many cases the Contracting Parties have not yet managed to demarcate BSPAs or prepare management plans, and few concrete steps have been taken to include the 24 proposed offshore BSPAs in the network.

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Riku Lumiaro / FIMR

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- HELCOM Pollution Load Compilation Programmes
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  - HELCOM PLC-4: PLC-Water, Fourth Pollution Load Compilation
- HELCOM COMBINE Programme
- BOING: Baltic On-Line Interactive Geographical and Environmental Information Service (http://boing.fimr.fi/index.html)
- BSH: Bundesamt für Seeschiffahrt und Hydrographie (Federal Maritime and Hydrographic Agency of Germany)
- DMU: Danmarks Miljøundersøgelser (National Environmental Research Institute, Denmark)
- EC/JRC: European Commission, Joint Research Centre
- EMI: Estonian Marine Institute
- FIMR: Finnish Institute of Marine Research
- GRID-Arendal: UNEP-affiliated environmental data and information centre within two EU-projects, BOING and BALANS.
- Swedish EPA: Swedish Environmental Protection Agency
- IOW: Institut für Ostseeforschung (Baltic Sea Research Institute,Warnemünde)
- RKTL: Riista- ja kalatalouden tutkimuslaitos (Finnish Game and Fisheries Research Institute)
- SMHI: Swedish Meteorological and Hydrological Institute
- SYKE: Suomen ympäristökeskus (Finnish Environment Institute)
- Swedish Museum of Natural History
- WWF Finland
- LANU: Landesamt für Natur und Umwelt Schleswig-Holstein, Germany
- LUNG: Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern
- BfN: Bundensamt für Naturschutz, Germany

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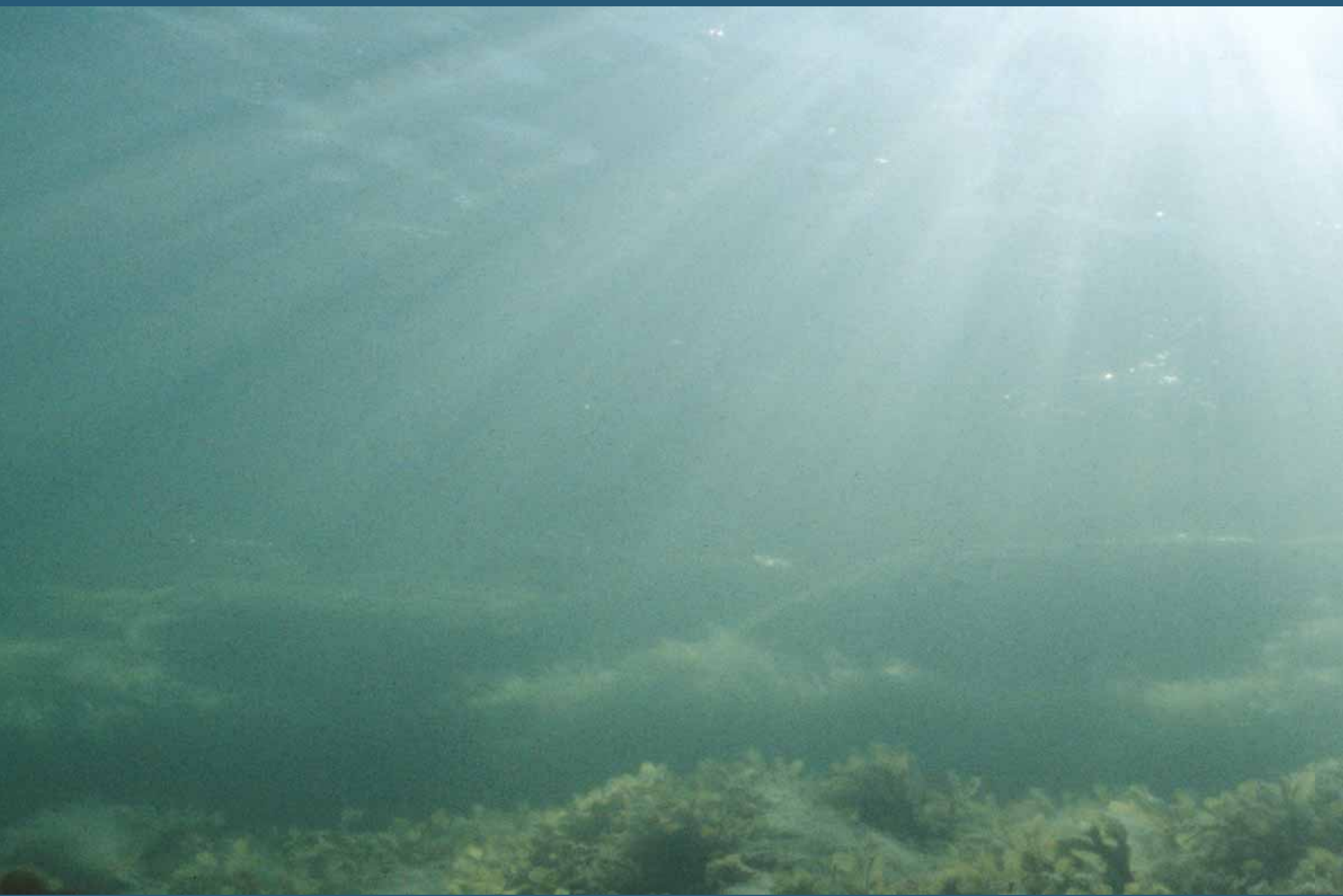

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