This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 12.

**Freshwater shortage**

A fundamental characteristic of the hydrological regime in the Baltic Sea region is that regional precipitation substantially exceeds regional evaporation. In the northern parts of the Baltic Sea region, the average annual precipitation is about 400 mm and in the southern parts about 700 mm. Overall, the precipitation falling onto the Baltic Sea surface averages about 620 mm per year (Westing 1989). Taking into account this level of freshwater availability, the concern of Freshwater shortage was considered to have slight to moderate environmental impacts.

The severity of the concerns is not expected to change before 2020. Furthermore, the concern's transboundary aspects are less significant compared with the other concerns.

There have been some localised problems resulting from changes in the water table and the modification of stream flow, although overall these issues were considered to be of only slight environmental significance at present. The Pollution of existing supplies was recognised as the most severe Freshwater shortage issue in the region, which was considered to have moderate impacts.
Environmental impacts

Modification of stream flow

Most of the rivers that flow into the Baltic Sea have been regulated by hydropower dams, which significantly reduce the occurrence of flooding in springtime, but do not change the annual discharge of the rivers. Modification of stream flow and decrease in the occurrence of exceptional discharges due to the construction of dams used for hydropower is therefore not relevant for the region on an annual basis. For instance, analysis of the Narva River hydrograph since the construction of the Narva hydropower plant (Russia) in 1956, has shown that annual flow rate has not changed (Figure 6). This conclusion is also valid for other rivers regulated by dams in the Baltic Sea region.

However, the natural annual variation in flow rates has altered significantly in some rivers but it is difficult to generalise about the impact of human activities on flow regime (EEA 1995). Other indicators of changes in stream flow such as decreasing trends in annual river flows, declines in the extent of wetlands and changes in the mean salinity of estuaries or coastal lagoons have not been registered. In addition, the issue of modification of stream flow was not considered to be of transboundary relevance in the Baltic Sea region.

Pollution of existing supplies

The pollution of existing supplies was assessed having moderate impacts in the region. According to the European Environment Agency (EEA 1995), the quality of most rivers discharging into the Baltic Sea is fair (moderate organic pollution and nutrient content) or poor (heavy organic pollution, low oxygen concentration, sediment locally anaerobic). In addition, the overexploitation of groundwater in densely populated coastal areas of the Baltic Sea has caused saltwater intrusion in aquifers, which may affect drinking water quality (Figure 7).

Changes in the water table

Changes in the water table are determined by the level of exploitation of groundwater resources. This issue was assessed to be of slight environmental importance in the Baltic Sea region, as in general groundwater supplies are not overexploited. However, changes in the water table have been more noticeable in certain locations where freshwater demand is high, for example in region close to large urban areas (Figure 7) (EEA 1995).

Socio-economic impacts

The economic impacts of Freshwater shortage were considered to be slight, as although in general freshwater availability is not a limiting factor for economic activities, in some areas it may have a slight influence on municipal water supply and industrial activities. There may be increased costs from finding alternative water supplies, deepening wells, increased pumping, and from intake treatment. At the same time, however, the reduction of groundwater abstraction in some regions (Tallinn, Riga, Vilnius) has caused the water level to rise (EEA 1995), which might lead to a reduction in water supply costs.
The health impacts were also considered to be slight in the Baltic Sea region, as there is some concern for human health regarding the pollution of drinking water by point and non-point sources. The surface water does not meet WHO drinking water standards in rivers/streams draining more than 30% of the catchment area (EEA 1995). The level of chemical contamination and the quality of drinking water is dependent on many factors, including the quality of raw water, the extent and type of treatment, and the materials and integrity of the distribution system. However, there is no information available on the risks of this poor water quality on human health in the region.

Other social and community impacts were considered slight in the region. The people who are mostly affected by freshwater shortage are those who live in densely populated areas and in areas with intensive agriculture where water demand is high. In addition nitrogen compounds may contaminate the groundwater in agricultural regions. Monitoring data supplied by the countries of the region on nitrates in groundwater is very heterogeneous. The nitrate concentrations in the Baltic Sea catchment area only exceed the maximum admissible concentration (50 mg NO₃/l) of water for human consumption in specific locations (Figure 8) (EEA 1995).

Conclusions and future outlook
Freshwater shortage is not considered to be an urgent problem for the Baltic Sea region and was considered having a slight overall impact. There are some problems with the pollution of existing supplies, which justified the overall environmental impact of the concern being assessed as moderate. In the future, taking into account the implementation of the Water Framework Directive by the Baltic Sea region countries (except Russia), an improvement in the quality of freshwater is expected, or at least there will be no change in the concern’s level of impact in the future. A reduction in water consumption has been recorded in the transitional countries in recent years (Baltic Environmental Forum 2000), which will reduce the pressure on freshwater supplies. The same development was observed in the market economy countries in the mid-1970s during the energy crisis.

Pollution

The marine ecosystem of the Baltic Sea is particularly vulnerable to pollution, due to the limited exchange of its water and because of the run-off from a catchment area containing 85 million people. Over the past 10 to 20 years, water pollution in the Baltic Sea region has not increased significantly and has even decreased in certain areas (HELCOM 2003a). However, pollution remains prevalent, particularly eutrophication which is depleting bottom waters of oxygen, oil spills from ships that are threatening birds and mammals, and the persistence of hazardous pollutants that are harming animals and humans alike.

The overall impact of Pollution was assessed as being moderate in the Baltic Sea region. The most alarming issues were eutrophication, which was considered to have a severe impact, and chemical pollution and spills that are having a moderate impact. Microbiological pollution, suspended solids and solid waste were considered to have a slight impact on the Baltic Sea region.

Thermal pollution was considered to have no known impact in the region and is therefore not further discussed. The discharge of cooling water from nuclear power plants and certain large industries has been observed but these were of local nature with no large-scale environmental effects. The assessment of the state of the Baltic Sea (HELCOM 2002) did not deem this issue to be of sufficient importance in the Baltic Sea to be studied.
Environmental impacts

Microbiological

Microbiological pollution was assessed as having a slight impact, as it has caused mainly local problems and only affected recreational activities. During the last decade, the construction of biological wastewater treatment plants in the coastal and catchment areas of the Baltic Sea has reduced the concentrations of microbes in wastewater. Nearly all of the beaches along southeastern coast of the Baltic Sea that were closed in the late 1980s due to the abnormal microbiological conditions were re-opened in the mid-1990s (HELCOM 1993b, HELCOM 1996a). In the older EU countries, the problem was resolved much earlier. From the late 1980s, the countries in transition began to construct biological and biochemical wastewater treatment plants, which became operational by the mid-1990s. The most important treatment plants are located in Tallinn, Riga, Vilnius, Kaunas, Gdansk and Gdynia. The treatment efficiency and the amount of treated wastewater in for example St. Petersburg increased significantly, and the discharge of untreated wastewater has been reduced from 3.2 to 1.42 million m³/day (Lääne et al. 2002). Moreover, many small coastal municipalities no longer discharge untreated wastewater into the Baltic Sea.

Eutrophication

Eutrophication was considered to have a severe impact in the Baltic Sea region. Large quantities of nutrients are entering the Sea via rivers, coastal run-off and airborne depositions. The issue will be further discussed in the Causal chain analysis.

The process of eutrophication can be explained as a state where concentrations of inorganic nutrients become so high that they lead to excessive production of plants and algae. Eutrophication caused by anthropogenic activities is particularly evident in areas with limited water exchange such as the Baltic Sea. Nitrogen and phosphorus are the predominant nutrients in the Sea causing eutrophication. Nutrient enrichment results in higher primary production of algae in the surface layers and on the shore, followed by higher secondary production. Excessive enrichment may result in large algal blooms. The eutrophication phenomena can affect human health and the recreational amenity of marine coastal areas.

The three main symptoms of eutrophication in the Baltic Sea region are hypoxic conditions in deepwater over widespread areas, increased occurrence of harmful algal blooms, and significant biological changes in the littoral communities (HELCOM 2002). Hypoxic conditions found in deep water between 1996 and 1998 were characterised by repeated changes in the redox regime at the seabed and the formation of hydrogen sulphide, causing an alternating distribution of nutrients. In the western Gotland Basin, oxygen concentrations have fallen since 1993 due to increased stratification of the water column, resulting in the lowest oxygen content since the mid-1980s. At the end of 1998, anoxic conditions prevailed, which initiated denitrification, thus causing nitrogen to escape from the sea into the air. It also caused phosphate to be released from the seabed causing phosphate concentrations to increase. In the Gulf of Finland, enhanced stratification during 1994-1998 caused a rapid decline in deeper-layer oxygen conditions. The mean oxygen concentration in the near-bottom layer during the period 1994-1998 was less than the mean for the previous period 1989-1993 and close to that in the period 1979-1983. In the summer of 1996, extensive anoxia occurred at the sediment-water interface in the eastern Gulf of Finland resulting in phosphate release from the sediment in quantities that almost equalled the total annual riverine load. This additional nutrient supply then became available to the phytoplankton growth cycle (HELCOM 2002).

In 1993 and 1994 the inflows of oxygen-rich salt water adversely affected the benthic communities throughout the open sea areas of the Baltic Proper and the western Gulf of Finland, manifested as short-term increases in biomass and abundance. The subsequent stagnation and hypoxic sediments resulted in considerable decimation of the macrozoobenthos, and in some cases even caused extinction. However, none of the changes in the open sea benthic conditions could be linked to changes in the prevalence of eutrophication (HELCOM 2002).

The second feature is increased occurrence of harmful algal blooms. Algal blooms are naturally occurring phenomena. Due to eutrophication, however, mass occurrences of microscopic algae have increased both in frequency and intensity (HELCOM 2002). These included not only cyanobacterial blooms, but also blooms of dinoflagellates such as Scrippsiella hangoei, Heterocapsa triquetra, Prorocentrum minimum and Gymnodinium mikimotoi, which caused reddish discoloration of the water. Dinoflagellate blooms were usually relatively short in duration and occurred in all parts of the Baltic Sea region in summer and early autumn. The algal blooms, especially those formed by cyanobacteria like Nodularia spumigena, can also be toxic, and thus represent a potential health risk for humans and animals. High biomass blooms also form an aesthetic problem with possible effects on tourism (HELCOM 2003a). A secondary effect of a bloom is that it causes mortality of benthic fauna and depletes oxygen concentrations when a bloom collapses.

Chemical

Chemical pollution was considered to have a moderate impact instead of severe, based on findings that indicate a steady decrease in the
concentrations of organochlorine compounds throughout the Baltic Sea region over the past 30 years.

The concentration of metals and organic pollutants has been investigated in sediment and biota samples throughout the Baltic Sea. Of the metals studied in the biota (cadmium, copper, lead, arsenic, mercury and zinc), only cadmium exhibited systematic spatial variation, with the highest concentrations being found in the southern Bothnia Sea and in the Baltic Proper (HELCOM 2002). With the other metals, local variation is observed that is probably related to urban activities, but this is generally less than one order of magnitude. Sediment concentrations of mercury were highest in the Bay of Bothnia and the eastern Gulf of Finland, while concentrations of cadmium, zinc and copper were highest in the central basin of the Baltic Sea. High concentrations of metals in sediments were only recorded in the Bay of Bothnia. Lead seems to be evenly distributed throughout the region (HELCOM 2002).

Concentrations of dioxins in herring and salmon vary regionally. The most contaminated fish are found in the northern part of the Baltic, including herring in the Bothnian Sea, and salmon in the Bothnian Bay (HELCOM 2004b). Transfer of dioxins up the marine food chain can be observed in fish eating birds and their eggs. The concentrations of dioxins in guillemots eggs have decreased to one third of their 1970-levels. These concentrations decreased rapidly until the mid-1980s, but have since remained at roughly the same level. Dioxin concentrations in sediments peaked in the 1970s, but have begun to decrease recently (HELCOM 2004b).

The health conditions for many birds of prey and mammals have improved but some species still struggle with reproductive problems. The concentrations of dioxins and PCBs seem to have remained stable during the 1990s, indicating that the substances are still released to the Baltic Sea. The concentrations of most heavy metals monitored in mussels, fish and bird eggs have decreased or remained stable (HELCOM 2001). An exception is cadmium where the concentration has increased in fish from the Baltic Sea during the 1990s. The reason for this increase is unclear (HELCOM 2001). Despite of the implementation of the HELCOM Recommendations to reduce discharges of pollutants into the Baltic Sea, there are indications that chlorinated compounds and other toxicants such as pesticides and PCB/PCT are still released into the environment.

Data about water-borne discharges and atmospheric deposition of heavy metals is not as reliable as that for nutrients, and may be considered as only rough estimates. Reasonable deposition calculations are only available for lead, and only tentatively for cadmium. Between 1991 and 1994, the yearly mean deposition of lead and cadmium to the Baltic Sea was 600 and 25 tonnes per year, respectively (HELCOM 2003a). Due to the lack of data, an accurate assessment of the impacts from heavy metals and persistent organic matter could not be undertaken.

**Suspended solids**

The impact of suspended solids was considered slight. The quantity of suspended sediments has increased due to a proliferation of phytoplankton in eutrophicated areas and increased coastal erosion in the southern and eastern Baltic Sea. Since hydropower plants have moderated the annual peaks in stream flow, the annual cycle in the supply of suspended solids to the sea has also been affected. However, this issue was considered to be of minor importance in the region, and as a consequence, it has been given little attention in previous reports (Melvasalo et al. 1981, HELCOM 1987a, HELCOM 1990, HELCOM 1996b, HELCOM 2002).

**Solid wastes**

The amount of litter on beaches and the damage caused to fishing nets by solid waste were used as indicators when making this assessment. The litter comes from a variety of sources. For example, litter from ships and vessels includes normal household waste, cargo holds, discarded fishing equipment, and medical and sanitary articles, while litter from tourists includes plastic bags, bottles and cans. The proportion of waste that is plastic material has increased sharply in recent decades, accounting for more than 90% of the total waste volume, causing significant environmental problems. In Poland for example, the annual coastal beach clean collected 50 to 100 m$^3$ of waste (HELCOM 2002). However, the influence of solid waste on the Baltic Sea is slight because beaches and tourists areas are regularly cleaned and the amount of litter from ships is minor.

**Radionuclides**

Minor releases of radionuclides were recorded in the region, but under well-regulated conditions and in compliance with the Radiological Basic Safety Standards. However, the impact of radionuclide pollution is considered slight, because there remains a small element of risk that an accident may occur. The majority of artificial radionuclides found in the Baltic Sea originate from the fallout following the Chernobyl accident in Ukraine, April 1986. The second most important source of radionuclides is the fallout from atmospheric weapon tests during the 1960s. The least significant source of artificial radionuclides is the operational discharges from the eight nuclear power plants within the drainage area of the Baltic Sea region (HELCOM 1995, HELCOM 2002).
Oil spills

The impact of oil spills was considered moderate due to the amount of illegal spills and accidents at irregular intervals. Oil spills may occasionally cause high mortality of sea birds, as well as contaminate the coastal zone. Oil spills pose a serious threat due to the vulnerability of the Baltic Sea, which has a long residence time of water and has a high risk of an accident due to intensity of sea transportation.

More than 500 million tonnes of cargo is transported across the Baltic Sea each year. Approximately 50 ferries have fixed routes between the Baltic ports, and more than 2 000 larger ships, including cargo carriers, oil tankers and ferries, are transiting the Baltic Sea at any given time. Moreover, the amount of maritime traffic is steadily growing (Figure 9). The risk of an accident, and subsequently a spill occurring, may increase due to the high traffic volume.

Despite the designation of the Baltic Sea as a “Special Area” under MARPOL 73/78, which prohibits the discharge of oil/oily mixtures from all ships, many illegal oil discharges are observed in the Baltic Sea. In addition, accidental oil spills occur, although more rarely but with considerable impact. These oil spills have immediate impacts such as contamination of beaches and seabird mortality, and have also had

<table>
<thead>
<tr>
<th>Point</th>
<th>Number of ships crossing in 2000</th>
<th>Number of ships expected to cross in 2015</th>
</tr>
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<tr>
<td>1</td>
<td>23 388</td>
<td>31 600</td>
</tr>
<tr>
<td>2</td>
<td>34 692</td>
<td>70 100</td>
</tr>
<tr>
<td>3</td>
<td>46 476</td>
<td>83 700</td>
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<tr>
<td>4</td>
<td>58 500</td>
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<td>75 696</td>
<td>121 100</td>
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<tr>
<td>6</td>
<td>85 296</td>
<td>136 500</td>
</tr>
</tbody>
</table>

Figure 9  Number of ships, excluding ferry traffic, in the Baltic Sea 2000.
(Source: Rytkönen et al. 2002)
long-term effects, for example, increased concentrations of petroleum hydrocarbons (PHC) in sediments. Statistically, the number of oil spill accidents in the Baltic Sea is estimated to be 2.9 per year (HELCOM 1996b). A risk assessment indicates that the statistical number of oil spill accidents will rise to 3.2 if the present oil terminal capacities are fully utilised, and to 4.9 accidents per year if plans to construct new terminals and to enlarge existing terminals are implemented, and the terminals are fully utilised. As a consequence, the predicted amount of oil spilled annually will increase to 775 tonnes and 1 475 tonnes, respectively (HELCOM 2002). Between 1969 to 1995, about 40 major oil spills of more than 100 tonnes were registered in the Baltic Sea region. However, this is not entirely surprising for an area where 7 000 voyages involving the transport of oil take place annually. The number of accidents may rise during the next decade as the sea-borne oil transport is expected to increase from its current level of 77 to 177 million tonnes per year (HELCOM 2002). Figure 10 shows the St. Petersburg commercial seaport, which following the collapse of the Soviet Union became one of the busiest among the newly independent countries and Baltic states.

**Socio-economic impacts**

Pollution was considered to have a moderate economic impact in the region. This is attributed to the higher transportation costs of raw water and additional expenses for water treatment. Moreover, the costs of preventive measures and of cleaning intakes were considered to increase moderately, while costs regarding tourism and recreational values were expected to fall moderately. Eutrophication, chemical pollution and spills have some effect on fish mortality but it is difficult to accurately assess the economic impact on the fisheries associated with pollution.

Health impacts of pollution in the Baltic Sea region were assessed as moderate. Pollution such as hazardous substances, heavy metals and nitrogen compounds cause different health problems such as allergies, poisonings, chronic inflammations, infectious diseases. Due to the advanced water treatment processes, epidemics or infectious diseases are no longer a problem in the Baltic Sea catchment area. Discharges of untreated wastewater in the market economy countries are practically non-existent, whereas in the countries in transition the
percentage is between 7 to 19% except in certain areas in Russia where the figure can be as high as 37% (Lääne et al. 2002). Some problems have also been recorded in the countryside where the nitrogen concentration or microbiological pollution in local shallow wells sometimes exceeds the maximum admissible concentrations (see Figure 8 above). The influence of the toxic algal blooms to the public is local and very limited. Possible health risks arise from consuming contaminated fish. However, the implementation of the EU Directives will limit the use of fish with high dioxin levels, which will reduce the potential health impacts.

Pollution was considered to have only a slight effect on other social and community Impacts. The point and diffuse (agriculture) sources were considered to affect the water quality, which in turn affects the use of water for different purposes. Furthermore, the use of nature for recreational value may be affected as a consequence of pollution such as oil spills and eutrophication.

Conclusions and future outlook
The overall environmental impact of Pollution is presently severe. Over the next 20 years, environmental impacts from pollution were predicted to reduce only to moderate despite improved regulations and the implementation of internationally adopted environmental protection measures such as the EU Water Framework Directives and HELCOM Recommendations. The significant reduction in the discharge of hazardous and biogenic substances at the end of the 20th century was an important step towards reducing the pollution load of the Baltic Sea. However, significant improvements in water quality may take a long time, due to the slow water exchange and the accumulation of large quantities of pollutants in the Baltic Sea.

Environmental impacts
Modification of ecosystems or ecotones
Approximately 90% of the marine and coastal biotopes in the Baltic Sea are to some degree threatened, either by loss of area or reduction in quality (HELCOM 2001, 1998c). According to HELCOM (1998c), 88% of the identified 133 marine biotopes and 13 biotope complexes are exposed to some kind of threat (e.g. eutrophication, contamination, fishery or settlements) and are regarded as endangered or heavily endangered. In 1998, HELCOM compiled a status report on biotopes and biotope complexes in the HELCOM area (HELCOM 1998c), including a classification system for Baltic coastal and marine biotopes. Of the 66 pelagic and benthic marine biotopes described in the report, 2 biotopes were classified as heavily endangered, 58 as endangered, 4 as potentially endangered, and 2 had no data available. This indicates a considerable pressure on the Baltic Sea habitats. Marine habitats are mainly affected by human settlements, pollution and construction along the coastline. The main reasons for the modification of ecosystems were considered to be related to agricultural, municipal and industrial discharges, dredging and excavation of peat and gravel, construction of ports, as well as tourism.

Wetlands, the peat bogs and marshlands were considered to be the most affected habitats with a moderate degree of impact. The peat bogs have been subject to extraction and drainage especially in the northern and eastern Baltic Sea. The marshlands on the other hand have been affected mostly in the southern parts of the Baltic Sea, despite attempts to restore these habitats. Other habitats have been impacted to varying degrees. Littoral belts alongside lakes and ponds are severely affected in the southern Baltic, but only slightly in the northern regions. In running water wetlands (tidal rivers are excluded), drainage and agricultural activity have been the predominant causes of habitat modification. The impact on them was considered slight, although impacts were greatest in the southern regions. There are no known impacts on saline wetlands.

Open or running waters (fast flowing, stony bottomed, and sandy/ muddy flood plain rivers) have been affected by pollution and the construction of dams. Standing waters have also been affected to a certain extent, as lakes and ponds have been enriched with nutrients from agricultural activities (diffused discharges) and discharges from point sources (municipal and industrial discharges). The subsequent changes in the trophic status affect the flora and fauna of the impacted areas. The damming of rivers has changed the hydrological regime necessary for salmon to reproduce and caused a decline in their populations (HELCOM 2001). In compensation for these losses, hatcheries have been built to sustain wild salmon stocks. This has

Habitat and community modification
The GIWA concern of Habitat and community modification consists of two environmental issues: loss of ecosystems or ecotones and the modification of ecosystems or ecotones, including community structure and/or species composition. Loss of ecosystem or ecotones was considered to be slight in the Baltic Sea region and as the two issues are closely connected, the assessment of this concern will only focus on the modification of ecosystems or ecotones, which was considered to be of moderate impact.
led to the loss of distinct populations and a decline in overall genetic variability. Recent estimates indicate that wild salmon reproduction has increased, although yields of juvenile wild salmon in certain rivers are still alarmingly low (HELCOM 2003a).

The coastal marine ecotones have experienced slight to moderate impacts. Sandy foreshores (including dunes) are comparatively sensitive to anthropogenic influences and have been moderately affected by tourism, pollution and construction. Lagoons and estuaries were also considered to have had moderate impacts. Lagoons are threatened by pollution, urbanisation, industry, agriculture and dredging, while estuaries suffer from land-based pollution and construction activities, e.g. harbours. Other habitats considered to be under slight impact in the Baltic Sea region were muddy foreshores and rocky foreshores. Muddy foreshores have been affected by dredging, whereas the rocky foreshores have been impacted by the construction of harbours (for example in Sweden and Finland).

Other benthic marine habitats that have been seriously affected are seagrass and fucus meadows, which have experienced moderate impacts from pollution. Sandy and gravel extraction has had a slight impact on nearby ecosystems. There are no known impacts on mud bottoms, as they suffered from oxygen depletion even before industrialisation. Pelagic habitats (above and below the halocline) have been slightly impacted by changes in light above the halocline and from oxygen depletion below the halocline.

Socio-economic impacts
Generally, the economic impacts of habitat and community modification were considered slight in relation to human needs for aesthetic and recreational values. The loss and modification of ecosystems and ecotones will have serious economic impacts in the future, and considerable investment is needed in order to rehabilitate modified habitats. The economic impact of this concern will therefore increase from slight to moderate in the future.

There have been slight health as well as other social and community impacts associated with the loss and modification of habitats. The capacity for the ecosystems to meet human food demand has been reduced and the degraded environment has caused health risks for the local population. In the future, the situation will improve slightly but because of a low level of confidence, there are no reasons to lower the assessed impact degree.

Conclusions and future outlook
Improvements are occurring due to EU, HELCOM, and NGO activities and the implementation of environmental protection legislation as well as different projects, for example the Baltic Sea Regional project (HELCOM 2003b). Freshwater habitats are generally believed to react more quickly to changes than the larger marine habitats, as they are smaller water bodies and have faster water turnover times. Greater public awareness of the impact of human activities on sensitive habitats is needed, although in many instances it may be too late to rehabilitate the modified ecosystems.

Unsustainable exploitation of fish and other living resources
The overall environmental impact of unsustainable exploitation of fish and other living resources in the Baltic Sea region was assessed as moderate. Overexploitation was considered severe; average annual landings of the most important commercial species (for example cod Figure 11) have decreased two-fold, between the 1980s and 1990s. Since the mid-1800s close to 100 non-indigenous species have been introduced to the Sea as well as escapes from fish farms and the uncontrolled restocking of salmon have altered the composition of ecosystems and affected genetic biodiversity. There has also been decreased viability of stocks in the region due to pollution and diseases, for example the recently discovered mouth disease on pike, crayfish disease in Sweden and salmon M-74 disease. There is expected to be a slight improvement in the future due to the implementation of fishing regulations.

Environmental impacts
Overexploitation
The impact of overexploitation in the Baltic Sea region was considered severe and was chosen for further analysis by the GIWA Task team. For more information and data please refer to the causal chain analysis section.
Total average annual landings of the most important commercial species in the Baltic Sea region have decreased two-fold between the 1980s and 1990s. Cod landings have become 3.5 times smaller over the same period (ICES 1994, 1999, Baltic 21 1998b). Figure 12 shows the changes in landings and mortality of cod, and Figure 13 represents recruitment and spawning stock biomass. Major inflows of saline North Sea water before 1976 led to the highest cod spawning stock biomass in 1980-1985 (Baltic 21 2000). Total lack of inflow in 1980-1992 and only one major inflow in 1993 caused a stagnation period in Baltic deep water and poor recruitment. A minor decrease in eastern cod landings in 1994-1996 (when the salinity increased) was followed by a general water and poor recruitment. A minor decrease in eastern cod landings in 1980-1985 (Baltic 21 2000). Total lack of inflow in 1980-1992 and only one major inflow in 1993 caused a stagnation period in Baltic deep sea water before 1976 led to the highest cod spawning stock biomass in 1980-1985 (Baltic 21 2000). Total lack of inflow in 1980-1992 and only one major inflow in 1993 caused a stagnation period in Baltic deep water and poor recruitment. A minor decrease in eastern cod landings in 1994-1996 (when the salinity increased) was followed by a general decline since 1997. Total landings of cod in 2000 were estimated to be 66 000 tonnes (Walday & Kroglund 2002). The stocks have been highly exploited beyond the levels advised by the ICES. There has not been a reduction in fleet capacity or fishing effort in response to the overexploitation, and fish mortality has increased as stocks have declined (Baltic 21 1998b).

The lack of accurate data for fish landings and an overassessment of resources has led to exploitation beyond the region’s biological limits. This was recognised in the Agenda 21 for the Baltic Sea Region, as the main cause for the overfishing of cod, and is also considered a major factor in the depletion of other commercial fish stocks in the Baltic Sea region.

**Excessive by-catch and discards**
The total by-catch of fish in the Baltic Sea is unknown, as no quantitative estimates are currently available. However, in some coastal fisheries there may be very high rates of by-catch, such as in the roe fishery (Vendace, *Coregonus alba*). As a result of these discards, the abundance of organic matter may increase, which in turn may contribute to the depletion of oxygen in bottom waters (HELCOM 2002).

By-catch of Harbour porpoises (*Phocoena phocoena*) has been estimated to amount to a few percentages of the population in the Danish and German waters, although this figure is believed to be underestimated. Seals mortality as a result of being caught as by-catches does not seem to have threatened their populations since their numbers are increasing (HELCOM 2002). Based on these findings the influence of this issue was assessed to be slight in the region.

**Destructive fishing practices**
Some seabeds in the region exposed to trawling recover quickly while some have a longer recovery time (Baltic 21 1998b). Trawling in shallow areas is prohibited, but it is unknown to what extent it does continue. However, relatively few fishers employ illegal fishing techniques and beam trawling, so this issue was considered to have a slight impact.

**Decreased viability of stock through pollution and disease**
Evidence has been found of decreased viability of stocks in the Baltic Sea ecosystem caused by pollution and diseases (Walday & Kroglund 2002). The presence of pollution such as eutrophication and toxic contaminants may not only spread diseases but also influence species composition, reproduction biology and migratory habits. Examples of diseases include the recently discovered mouth disease on pike, crayfish disease in Sweden, salmon M-74 disease, and diseases in eel and flatfish, from which the eel is yet to recover. The stocks of the naturally spawning salmon (Figure 14) have been significantly depleted after the appearance of the M-74 syndrome in Swedish and Finnish rivers, which was first observed in 1974. In the 1970s-1980s the M-74 mortality was about 15-30 %, but it increased to 60-80% in 1992-1996 and has decreased since 1997 to levels between 15% (1998) and 40% in 1999 (Karlström n/d).

In 1996 production of wild smolt was very limited as a result of disease, with the smallest stocks at risk of extinction. However, the situation has improved considerably in recent years. The viral lymphocystis disease was prevalent in 5 to 38% of flounder larger than 20 cm, with a decreasing spatial trend from the western to eastern parts of the Baltic Sea (HELCOM 1996b). The most externally visible disease of Baltic cod is the bacterial skin ulcer, which has been found on between 15% and 40% of the cod. Its prevalence decreased from the 1980s to 1990s.
(HELCOM 1996a), but according to recent studies (HELCOM 2002), a high prevalence of acute skin ulceration in Baltic cod has been observed in the last few years. There is concern that this disease may cause mortality and thus deplete stocks, and may also reduce the fitness and reproductive potential of surviving cod. Based on these findings the GIWA Task team assessed the impact of this issue to be moderate in the Baltic Sea region.

Impact on biological and genetic diversity

Biological and genetic diversity in the Baltic Sea has been affected by a variety of activities. The uncontrolled restocking of salmon and escapes from fish farms have altered the composition of ecosystems and affected genetic diversity. Fishing is recognised to have both direct and indirect impacts on biodiversity and has caused a loss of habitats and biotopes in certain parts of the Baltic. Foremost are the direct effects caused by the removal of fish and shellfish for landings, and the capture of non-target fish and shellfish and other animals (Baltic 21 1998b). Overfishing has altered the ecological balance of many ecosystems in the region; key biotopes have been depleted, which has modified predator-prey relationships within the food chain.

The introduction of new species into the Baltic Sea ecosystem has been another major factor that has impacted on biological and genetic diversity. Over the past 20 years, a growing number of alien species have been released into the Sea, and as ship traffic increases, more and more ‘stowaway species’ have arrived (HELCOM 2001). NEMO (Non-Indigenous Estuarine and Marine Organisms) is an inventory of alien species, maintained by a group of non-governmental Baltic marine biologists, which has recorded that close to 100 non-indigenous species have been introduced since the mid-1800s, including plankton, invertebrates, fish, birds and mammals (Table 13) (NEMO 2002). Since 1990, 10 new species have been introduced into the Baltic (Walday & Kroglund 2002). However, it should be noted that these new species have been introduced relatively slowly, and to date, the Baltic system does not appear to be significantly impacted.

Socio-economic impacts

The economic and other social and community impacts of the unsustainable exploitation of fish and other living resources was considered as moderate. Although in some areas it is more severe, for example in countries where the fisheries has greater significance for the national economy like Poland (EU Enlargement 1998) and Kaliningrad, Russia (Dvornyakov 2000).

The fishing market is affected as fish landings become more variable and uncertain. The reduced landings have also increased unemployment in the fishing sector, and jeopardised income growth. An economic downturn in the fishing sector may lead to increased demand for subsidies and other governmental support. Moreover, stringent protection measures to help fish stocks recover may in the short-term exacerbate the economic impacts (Baltic 21 1998b, FAO 1997).

Increasing unemployment and the loss of fishermen’s livelihoods is a growing concern especially in the recently EU acceded countries and Russia. For example, the unemployment level in Russian fishing regions has been identified to be 1.5 to 3.5 times higher than in other sectors of the economy (Dvornyakov 2000). Increasing unemployment associated with the declining fishing resource is having social and community impacts in many communities that have traditionally depended heavily on the fishing industry.

The unsustainable exploitation of living resources was considered as having no known health impact in the region.

Conclusions and future outlook

Fishing activities are affecting the species composition and the size distribution of the main target species as well as non-commercial fish stocks in the Baltic Sea region. The fishing pressure on the stock is one reason why many young fish have been caught before they have reproduced for the first time. The number of fish in the reproductive stage is estimated to be far below the sustainable limit. At such low levels the stock is unlikely to replenish itself. Despite regulations, fishing fleets continue to overexploit the fisheries resource in the Baltic Sea. Concerning the future a slight improvement is anticipated due the implementation of fishing regulations, however, cod stocks are not expected to recover in the near future.

Table 13  Introduced species to the Baltic Sea.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Number of introduced species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishes</td>
<td>29</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>21</td>
</tr>
<tr>
<td>Molluscs</td>
<td>13</td>
</tr>
<tr>
<td>Polychaeta/oligochaeta</td>
<td>7</td>
</tr>
<tr>
<td>Phytoplankton</td>
<td>8</td>
</tr>
<tr>
<td>Macroalgae</td>
<td>7</td>
</tr>
<tr>
<td>Mammals</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
</tr>
</tbody>
</table>

(Source: NEMO 2002)
Global change

The GIWA assessment considered that there are currently no known environmental impacts associated with global change, due to there being insufficient data available to make an accurate evaluation. However some changes in the hydrological cycle have been noticed. There are no known impacts of increased UV-B radiation as a result of ozone depletion, as there is currently a lack of information exploring how increased UV-B radiation as a result of ozone depletion has affected the Baltic Sea region. There is either no known impact from changes in ocean CO₂ source/sink function, and an assessment could not be made due to a lack of information. These issues are therefore not further discussed.

Environmental impacts
Changes in the hydrological cycle (climate change scenarios)
Only slight changes in the hydrological cycle were identified, with impacts mainly associated with changes in ice conditions. As a result of climate changes, the break-up of ice on rivers is expected to occur earlier, the frequency of saline water entering the Baltic Sea will be reduced, and there will be an increase in the frequency of heavy storms and floods. The sea surface temperature of the Baltic Sea is expected to increase by 2-4°C and ice is estimated to be 20-30 cm thinner. Climate changes are predicted to increase the water flow entering the Gulf of Finland by 2% during the next 20 years which will result in an estimated increase of the phosphorus load from non-point sources by 4% and load of total nitrogen by 4% (Pitkänen et al. 2004).

Sea level change
It is not known what extent global changes are influencing sea level in the Baltic Sea region, as it is unclear to what extent isostatic movements from the last ice age are influencing this issue. In addition the predicted 2% increase in water flow to the Baltic Sea is not expected to influence sea level (Pitkänen et al. 2004).

Socio-economic impacts
Global changes were assessed to have a slight economic impact in the Baltic Sea region under present conditions. Concerning the future, more serious impacts are expected due to changes in the hydrological cycle, but it is unclear what impact the other issues may have in the future.

Health impacts were considered to be slight. Other social and community impacts from global changes are connected to certain groups of people, who are more exposed to these changes than others. The degree of these impacts was considered slight. As the confidence level is low concerning the other social and community impacts, the same impact for the future as for the present is appropriate, albeit the situation is getting slightly worse.

Conclusions and future outlook
There is currently insufficient information on the impacts of global changes in the Baltic Sea region, and therefore it was assessed as having no known impact. In the future, the economic and health impacts may increase slightly, yet these were considered minor compared with many of the other assessed concerns.

Priority concerns for further analysis
The GIWA concerns were prioritised in the following order:
1. Pollution
2. Unsustainable exploitation of fish and other living resources
3. Habitat and community modification
4. Freshwater shortage
5. Global change

The most alarming issues were found under the two concerns; Pollution and Unsustainable exploitation of fish and other living resources. Based on the assessment results, the priority issues of eutrophication and overexploitation of fish were selected for the Causal chain analysis since these were identified as the most severe transboundary issues of the Baltic Sea.

Eutrophication has been caused by the excessive input of nutrients; namely nitrogen and phosphorus. According to the conclusions of the most recent HELCOM periodic assessment of the state of the Baltic Sea (HELCOM 2003a), eutrophication remains the most pressing environmental issue in the Baltic. None of the nine Baltic Sea countries have been able to meet the target adopted at the Helsinki Commission in 1988; to halve their total nutrient discharges to the Sea. The countries acceded to the EU in 2004 have managed to come closer to meeting this target than the other EU countries, largely due to political and economic changes. However, a substantial reduction in nutrients from the agricultural sector is still urgently needed (Lääne et al. 2002).

Although landings of commercially important species have been stable at between 0.9 to 1 million tonnes per year, this does not mean fish populations are also stable in the Baltic Sea. Closer analysis of individual species such as sprat and cod reveal wide fluctuations in landings, indicating ecological imbalances. As populations of cod
are depleted, the number of sprat increases, reflecting their predator-prey relationship. Studies of the main target species between 1994 and 1998 indicated that the cod, herring, salmon and eel fishery is unsustainable in the Baltic Sea. In order to avoid the collapse of these stocks, there is a need to allow populations to recover to safe biological limits. In accordance with HELCOM’s working group on habitats (HELCOMHABITAT) in 2001, sustainable fishery management practices need to be designed that meet the needs of the entire Baltic ecosystem. HELCOM has intensified cooperation with the International Baltic Sea Fishery Commission (IBSFC), including a joint seminar held in February 2002 in Gdynia, Poland. The parties agreed at this seminar on a sustainable fishery management strategy designed to meet the needs of the whole ecosystem, and discussed how to address concerns such as the impact of commercial fishing on the Baltic food web, excessive by-catch, and the change in abundance and distribution of non-commercial fish stocks and main targeted fish species.