chapter 6

Overall assessment

6.1 Introduction

6.1.1 The assessment process

An environmental assessment consists of an analysis of the quality status of a marine area or ecosystem and the extent of impacts from human activities. A major challenge is to distinguish effects of human activities from natural variability, due for instance to climatic forcing. A second challenge is to distinguish an effect of a given human activity from effects resulting from other human activities. A successful environmental assessment therefore depends on a good basic understanding and description of the natural processes and variability within the ecosystem together with quantitative information on the human activities and their relationships to the processes and components of the ecosystem.

Basic knowledge about the functional properties and variability of marine ecosystems is limited. This in turn limits the ability to carry out conclusive environmental assessments (EEA/IRF, 1998; EEA, 1999).

Several environmental assessments have been prepared for the Arctic region over the last few years. These have been used as major sources of information for the present quality status report:

- AMAP Assessment Report: Arctic Pollution Issues (AMAP, 1998);
- PAME Working Group on the Protection of the Arctic Marine Environment (PAME, 1996);
- Arctic environment in the Nordic Countries (Bernes, 1996);
- Status Report on the Marine Environment of the Barents Region (Lønne *et al*., 1997);
- Radionuclides in the Arctic Seas from the Former Soviet Union: Potential Health and Ecological Risks (Layton *et al*., 1997); and
- The State of the European Arctic Environment (EEA, 1998).

This chapter builds upon Chapters 2 to 5 where information was presented on the geography, hydrography and climate; human activities; chemistry; and biology and ecology of Region I. An assessment of human impacts is made in Section 6.2 for the issues identified in the Joint Assessment and Monitoring Programme (OSPAR, 1995). A simple ranking system was used in the assessment process. Section 6.4 presents an overall assessment on a sub-regional basis and Section 6.5 presents conclusions and recommendations.

6.1.2 Characteristics of the Arctic Region

The ocean climate and the climate of Region I is largely determined by inflow of relatively warm Atlantic water. The circulation system – with inflow of Atlantic water, its transformation into Arctic water, deep water formation in the Arctic and the exit of Arctic water into the North Atlantic – is probably a major mechanism for climate variability, both within Europe and globally.

The northern and western parts of the Iceland and Greenland Seas and the northern and eastern parts of the Barents Sea are ice-covered in winter. Most of the ice in the Barents and Iceland Seas is seasonal and melts during summer. The ice and ice-melt have a large influence on ecological conditions and pollutant transport. The northern seas are home to some of the largest fish stocks in the world, which in turn support large stocks of seals, whales, and seabirds.

Climatic variability causes large interannual variability in ice and hydrographic conditions, which in turn affect plankton production and fish recruitment. Strong biological interactions in relatively simple food webs, as well as many species being close to their limits of distribution, imply that large natural variability is a typical feature of the ecosystems of the area.

The high natural variability is both a problem and an advantage when it comes to environmental assessments. On the one hand, the high natural variability makes it difficult to detect changes due to anthropogenic effects (e.g. resulting from fishing activity or pollution), while on the other hand, such variability indicates the importance of the physical driving forces and the relatively short food webs, which makes it easier to understand the dynamic properties of the high latitude ecosystems.

Region I is very large and heterogeneous in both its physical and biological features, and is mostly a clean and unspoiled area, except in some local areas where pollution problems may occur. The region is sparsely populated with a total population of only 2.6 million inhabitants, which to a large degree are dependent on fishing and hunting. Ocean fisheries are very important for all countries within Region I. In addition there are some activities related to forestry, agriculture, hunting, mining, the metallurgical industry, petroleum exploration and exploitation, military activity and tourism.

6.2 Assessment of human impacts

Due to its remoteness and low population density, the general environmental conditions within Region I are quite good. It is one of the least contaminated regions of the OSPAR Convention area. Natural fluctuations in fish stocks may be intensified by large-scale commercial fishing activities on such stocks and stringent fisheries management actions over the last decades have played an important role in increasing the stock size of some fish species. There are, however, certain causes for concern within Region I such as the impact of fisheries and the ubiquitous presence of persistent organic contaminants in fish and marine mammals.

Anthropogenic inputs in Region I range in scales from local, to regional, to global. The impacts at the largest scale, such as global climate change related to the increase in atmospheric carbon dioxide and in UV-B radiation, will require wider international action. Such impacts tend to be longer, larger in scale and harder to reverse. Also, some of the heavy metal and organochlorine inputs come from sources outside the OSPAR area and to reduce them would necessitate agreement with other international bodies. This assessment mainly considers those human impacts that are predominantly internal and which fall within the OSPAR sphere of influence.

In order to assess the environmental state of Region I the effects of human activities have been ranked into three classes:

- major effects (i.e. those which have been well documented or observed and which are of great impact);
- medium effects (i.e. those with medium to small observed effects and which are of potential impact); and
- lesser effects (i.e. those with small or no observed effects and which are of low or no impact).

This ranking was based on the information presented in Chapters 2 to 5, especially the impacts considered in Sections 5.3 to 5.16. The result of the ranking is shown in *Table 6.1*. No prioritisation has been made within the three classes.

Although such an approach may be considered simple and not completely objective, an assessment of the relative importance of the different types of human impact is necessary as a basis for decision makers to take action. This classification system should not be directly compared to classification systems used for the other OSPAR Regions. Impact types and issues are discussed according to their order of appearance in *Table 6.1*.

6.2.1 Major effects

Fisheries

The effects of fisheries have been well documented in Region I. The status of several fish stocks which are assessed and for which precautionary reference points have been determined, fall outside the limit for either the spawning stock or the fishing mortality or both. In the Norwegian Sea, this is the case for cod, haddock, saithe, redfish and Greenland halibut. In Icelandic waters, similar situations occur for haddock, saithe, and Greenland

halibut. In many cases the fishing pressure is so high that the state of the stocks are beyond or close to the biological reference points, which are to be considered as warning signals. Management actions that have been in operation for some years have resulted in an improvement of the situation for some stocks, such as for Icelandic cod and the Norwegian spring-spawning herring.

Fishing mortality, stock size and the age and size composition of the stock are related. With the currently high fishing mortality for many of the stocks, fewer fish will grow to maturity. Both the total stock and the spawning stock will be reduced, and the proportion of young fish will be higher in the spawning stock as well as in the total stock. A higher proportion of small and young fish in the spawning stock may cause reductions in the reproductive potential and in the resilience towards fishing and other stresses on the stock. This has to some extent been demonstrated for the North-east Arctic cod.

In addition to direct effects, fishing can also have indirect effects on fish stocks through trophic interactions. Interactions between fish stocks can be strong through predator-prey relationships, such as has been documented for cod and capelin and for juvenile herring and capelin larvae in the Barents Sea. Reduced size of predatory fish populations will therefore have a positive effect on their prey species. Conversely, reduced size of prey populations may negatively affect predator populations. Because the effect of fishing pressure on stock size and stock interactions may coincide with climatically driven variability, the indirect effects of fishing are generally not well documented.

Table 6.1 Ranking of impacts in Region I.

Major effects
fisheries
Medium effects
PCBs
other persistent organic compounds
TBT
mariculture
oil
Lesser effects
PAHs
metals
radionuclides
eutrophication
biological introductions*
physical impacts†
shipping

* includes the impacts arising from the introduction of non-indigenous species, and microbiological pollution; † includes the impacts arising from dredging and dumping, coastal protection and land reclamation, tourism, sand and gravel extraction, and marine litter.

Discards from fisheries represent food and can cause increases in populations of scavenging species. This is likely to have contributed to population increases for some species of seabird in Region I. This is not well quantified, however, due to a lack of data on discards and limited time series data on population sizes of seabird populations.

Bottom trawling affects benthic species and habitats. There can be direct effects on organisms, i.e. they may be damaged or killed by the trawl. Organisms may also be mixed out of the sediment and made available to predators. Trawling also affects the bottom substrate. Sediments will be disturbed and resuspended. In Norway there have been investigations into the effect of trawling on deepwater corals (e.g. *Lophelia pertusa*) over the last few years. The investigations suggest that there could be extensive damage to coral reefs by fishing activities. Such investigations have not been done in other parts of Region I, but similar effects are expected due to the intensive fishing activities.

Other benthic habitats and species could also be sensitive to and affected by bottom trawling. Sponge communities are widely distributed in some areas, like the Barents Sea, and are affected by trawling. To what extent this results in lasting damage with the risk of losing species and habitats, has not yet been investigated.

Seabird populations can be indirectly affected by fisheries through effects on the fish species on which they prey. During the late 1980s there were large mortalities and sharp declines in several seabird colonies in the Barents Sea. This was due to the lack of food caused by the collapse of the capelin stock. While fishing contributed to and aggravated the situation, the collapse was mainly a natural event caused by climatic variability and biological interactions.

The former days of whaling lead to the decimation of several whale species in the Arctic region. The recovery of some overexploited species, such as the Greenland whale and blue whale, has been very slow, while the fin whale has recovered well. The Greenland whale feeds primarily on copepods in Arctic water, while the blue whale feeds on aggregations of krill during summer. It is likely that the pattern of energy flow and the dynamic properties of the ecosystems in Region I have been altered permanently by the previous whaling activities, but the extent of this situation has not yet been quantified.

The minke whale has been important in modern Norwegian whaling. Although Norwegian minke whaling resumed in 1993, the current level of whaling is not considered a threat to the minke whale population. There is a traditional catch of pilot whales by the local population of the Faroe Islands. The scale of this activity is limited and it is not considered to be a threat to the pilot whale population. Except for minke whales and pilot whales, all other whale species are protected and not subject to hunting.

The harp seals in the Barents Sea and the Greenland Sea and the hooded seals in the Greenland Sea are hunted commercially. The populations are presently at high levels and the catches are considered to be well within the limits of sustainable utilisation. Small cetaceans and seals may be entangled and killed in gillnets. The magnitude of such incidental catches is limited and does not appear to represent a threat to these populations in Region I.

6.2.2 Medium effects

PCBs

Assessing the ecosystem and human health effects of exposure to PCBs is very difficult. Organisms are always exposed to mixtures of contaminants within the ecosystem, never to single compounds. Hence, toxicological risk assessments that make use of animal test data on individual chemicals rather than mixtures of chemicals will only give indications of risk, not definite answers.

No quantitative estimates of the total input of PCBs to Region I are available. A few local sources close to urban settlements are known. The levels of PCBs cannot be explained by known use or releases from sources within Region I. This implies that long range transport from lower latitudes is important. Levels of PCBs seem to be higher in both biotic and abiotic media around Svalbard, the southern Barents Sea, and eastern Greenland, than in the Canadian Arctic. Causes and mechanisms for this are not fully understood. Very high levels of PCBs have been reported in polar bears from Svalbard.

Long-term time trends for PCBs in Region I are few. It is therefore difficult to judge to what extent agreed measures and the ban on the use of PCBs have resulted in decreased concentration levels in the environment. Data for 1991 to 1996 indicate a decreasing trend in concentrations in fish from Icelandic waters. Data from the subarctic indicate decreasing trends in PCB concentrations between the 1970s and 1990s.

Very few studies have been carried out on the biological effects of PCBs within Region I. Recent studies on glaucous gulls from Bear Island showed high PCB concentrations and indications of biological effects. In a study on polar bears no correlation could be found between PCB concentrations and reproductive success. A few studies on marine mammals from other parts of the Arctic have shown correlations between the body burden of PCBs and microsomal enzymatic activities. These studies indicate that PCBs can cause biological effects in animals living within Region I. However, scientific proof is presently very limited.

A small group of PCBs, the non-*ortho* and mono-*ortho* PCBs (planar PCBs), have dioxin-like toxicity. Intake of contaminated seafood is a major exposure route to planar PCBs for humans living in the Arctic. The question has been raised as to whether high concentrations of planar PCBs in seafood pose a risk to human health. Information on PCB levels in the tissues of residents living in Region I shows significantly elevated levels in the tissues of some ethnic groups. However, epidemiological studies on the effects of PCBs on people living within the region are not available. A study undertaken outside Region I (Michigan) suggests links between PCB exposure and neurobiological effects, low birth weight and small head circumference in newborn children. Another study found that birth size among male Inuit infants was inversely related to PCB concentrations in the breast milk of the mother.

Other persistent organic compounds

All persistent organic compounds, organochlorines as well as brominated organics, that have been detected in temperate waters have also been detected in Region I, showing the global distribution of such compounds. Organochlorine pesticides such as HCHs, HCB, DDTs, chlordanes and toxaphene are widespread in marine biota from Region I. These compounds are also found in sea ice and surface sediments, but generally at very low concentrations. In surface sediments from offshore sites no apparent geographical trend for persistent organic compounds seems apparent.

Results generally indicate slightly higher levels of DDTs, PCBs and dioxins and furanes in biota from eastern compared to western parts of Region I, at all trophic levels. For HCHs the opposite occurs with the highest concentrations found in animals from western parts of the region. This may be due to the combined influence of long-range atmospheric transport from North America and Europe. Another possible factor is the transport of contaminants in sea ice and the overlying snow or in association with sediment particles embedded in sea ice derived from the Russian continental shelf.

Very few biological effect studies have been carried out on persistent organic compounds in Region I. Reports from other areas indicate the potential for biological effects and negative impacts on the environment.

TBT

Exposure to antifouling paints containing TBT is responsible for the development of imposex in female snails. Development of imposex has been documented in dogwhelk and common whelk in and outside numerous harbour areas in Region I. Recent data show some signs of recovery, due to the decreased use of antifouling paint containing TBT and the ban on the of use of TBT on smaller boats.

Mariculture

The wild salmon stocks appear to have been decreasing over the last few decades while salmon farming has

shown a marked increase. Genetic effects of mariculture on wild stocks are mainly an issue for Atlantic salmon. Escaped salmon have been found to make up more than 50% of the individuals in several rivers in Norway where the natural stocks are low. The amount of escaped salmon makes it likely that there are effects on the genetic composition of wild stocks. This may contribute to a loss of genetic diversity in the wild salmon stocks and to their ability to adapt to local environmental conditions. The extent of such effects on genetic composition is not well documented.

The spreading of salmon lice from farmed to wild stocks of salmon is an issue of concern in Region I, especially in Norway. Heavy infection may cause large mortality. The problem with salmon lice appears to have increased. The extent to which cultured salmon contribute lice to wild salmon is not well documented, however. A lack of information on the role of natural factors and on natural variability makes a quantitative assessment very difficult.

Bacterial and viral diseases may also spread from farmed to wild stocks. Bacterial diseases in fish farms are presently almost absent due to the use of effective vaccines and vaccination strategies. The most serious disease problem at present, besides salmon lice, is caused by the IPN virus which affects cultured salmon. There is a potential risk of the spread of this disease to wild stocks but there is at present no evidence that this has occurred.

The use of pesticides and antibiotics in mariculture has decreased during recent years due to increased environmental awareness and improved hygiene. Apart from very locally, pesticides and antibiotics are not considered to cause significant effects on marine biota.

Oil

The most oil contaminated areas in Region I are estuaries and harbours close to human settlements, and industrial or military sites. Hydrocarbon levels in the region associated with anthropogenic inputs are generally relatively low and of low ecological significance. Local problems have occurred in connection with accidental releases of oil.

Anthropogenic sources of oil include offshore production platforms, shipping and the transport of oil, local discharges from human settlements, and long range atmospheric transport from temperate and subarctic areas. New projects for the development of oil and gas resources are presently underway or planned for the near future on the mid Norwegian Shelf, the Faroe Islands and the Barents Sea. These developments will increase the potential for accidental releases of oil.

The environmental risks associated with oil and gas development, production and transport in Region I are primary local and/or regional. Potentially, a large impact may occur if there is overlap in time and space between an oil spill and migratory animals such as seabirds, which congregate at certain times within relatively small areas. Primary concerns associated with the major new oil and gas developments involve the risks of accidents and the difficulties of taking remedial actions in such cold environments. Drilling at greater water depths will take place and the effects of a potential deep water blowout are not presently known.

6.2.3 Lesser effects

PAHs

PAHs are present in petroleum, and can have pyrogenic or biogenic sources. Anthropogenic activities are generally the most important source of PAHs released into the environment. Estimates of total inputs of PAHs to the Arctic are not available. Industry and urban settlements within Region I are considered important local sources. Long-range atmospheric transport is probably of some importance.

PAHs are less prone to biomagnification than most of the other persistent organic contaminants and there is less concern about disperse, long range inputs from atmospheric sources. PAHs are most likely to have a local impact in regions where direct inputs occur, such as near oil wells, metallurgical plants and urban settlements.

PAHs accumulate in and are usually found at highest concentrations in sediments. Sediments in deep parts of the Greenland, Iceland and Norwegian Seas show low background concentrations of PAHs. Areas of the Barents Sea near Svalbard contain elevated concentrations of PAHs, probably due to contamination by petroleum. It is not known whether this is a natural phenomenon (seepage) or partly caused by human activities. Levels of PAHs in other parts of the Barents Sea are generally low. Low concentrations of PAHs have been detected in mussels in coastal areas. However, elevated levels of PAHs have been found locally in mussels and shellfish affected by direct discharges.

There has been limited attention given to studies on the biological effects of PAHs on fish and shellfish from Region I. Most of the data for acute and sublethal toxicity have been acquired from studies on acute oil spills from places outside Region I. Biomagnification has not been observed for PAHs. Due to the generally low levels of PAHs in Region I, it is unlikely that significant biological effects occur.

Metals

Background levels of metals in sea water from Region I generally fall within the global range for ocean areas. The concentrations of lead, cadmium, mercury and copper in Arctic marine sediments are mainly dependent on local

geology. An anthropogenic influence is only apparent in areas close to point sources. Mercury concentrations in Arctic sediments show an increase over time, even though anthropogenic discharges of mercury have not increased in recent years. This indicates a regional or global process that is not fully understood.

Cadmium levels in marine organisms from large parts of the Arctic exceed common global background concentrations, mainly due to natural processes. Mercury (and selenium) levels in some marine mammals are high, while lead levels in large parts of the Arctic are relatively low. Traces of metals have been found in fish, with few large scale geographical differences. For seabirds and marine mammals including polar bears, cadmium and mercury levels have been shown to be highest in western parts of Region I. Geology, food and growth processes linked to temperature are most likely explanations for these differences.

Temporal trend data are scarce for biota from Region I. There is some evidence of mercury increasing by a factor of 2 to 3 in some marine mammals over the last two decades. Only liver, and in certain cases kidney, shows such an increase. It remains unclear, however, whether this is a real increase or reflects year to year variation.

Biological effects of metals have so far not been investigated in biota from Region I. Cadmium and mercury are probably the most important metals because they occur in some seabirds or marine mammals at concentrations that may have health implications both for individual animals and for human consumers. It is unclear whether mercury poses a health threat to the most highly exposed marine mammals such as pilot whales from the Faroe Islands. However, there are indications that selenium is present in concentrations that can protect against mercury poisoning. Lead levels in marine organisms from the Arctic are well below food standard limits.

Radionuclides

Contamination of the Arctic by artificial radionuclides derives primarily from two historical sources – global fallout from past atmospheric nuclear weapons testing and fallout from the Chernobyl reactor accident – and one ongoing activity – releases from European nuclear fuel reprocessing plants.

The additional contamination of the Arctic by radionuclides from local sources, such as spent fuel storage sites and radioactive wastes dumped at sea, is at present of negligible radiological significance. The greatest future threats to human health and the environment in the Arctic are associated with the potential release from dumpsites and accidents in the civilian and military nuclear sectors.

Levels of artificial radionuclides in Region I are generally very low. The maximum values were recorded during 1950 to 1970 as a consequence of atmospheric nuclear weapons testing. Following the cessation of widespread atmospheric weapons testing in the early 1960s, the relative importance of other sources, such as releases from European nuclear fuel reprocessing plants, increased. A second, but lower, peak in fission product radionuclides occurred in the early 1980s as a consequence of increasing radionuclide discharge from Sellafield in the mid 1970s. Fallout from the Chernobyl accident in 1986 made an additional contribution to radionuclide contamination in the Arctic. Since then, the levels of artificial radionuclides have been decreasing.

Eutrophication

The population density of the land areas bordering Region I is very low and therefore the inputs of nutrients are generally low. The aquaculture industry contributes about 10 000 t of nitrogen and 2000 t of phosphorus annually, the main part being from Norwegian salmon farming. This production is spread along a long coastline and the nutrient input constitutes an insignificant component (less than 1%) of the nutrient budgets in fjords and coastal waters. In fjords with shallow sills and restricted water exchange, the discharges of nutrients and organic material from feeds and faeces may cause local problems. As the location of aquaculture plants is regulated by the authorities according to the conditions and capacity of local areas, such problems are generally avoided.

Transboundary inputs of nutrients via the atmosphere or ocean currents, such as from the North Sea, have no detectable influence on nutrient concentrations in Region I. It is concluded that eutrophication is not an issue of concern and that the whole of Region I can be regarded as a non-problem area in terms of the negative effects of nutrients.

Impact of biological introductions

Impacts of biological pollution include both the introduction of non-indigenous species and the effects of microbiological pollution. The only observed impact that could have a possible effect on the ecosystem of Region I is the introduction of the Kamchatka crab.

Impact of physical disturbance

Physical disturbances include the impact of dredging and dumping, coastal protection and land reclamation, tourism, sand and gravel extraction and marine litter. All these impacts are regarded as minor problems in the region and are therefore not further discussed in this chapter.

6.3 Gaps in knowledge

The lack of data and limitations in information that were demonstrated in Chapters 2 to 5 hampered the assessment process and prevented definitive conclusions. Information from the ice-covered Arctic Ocean is

very limited. Information on human activities and data from environmental monitoring in the Russian Federation was not easily available.

Natural fluctuations in the physical properties of the ocean are the main factor influencing variability in the marine ecosystems. There is consequently a need to improve the scientific basis for linking the physical processes with the chemical and biological processes. Key factors are how the ecosystems will respond to changes in ocean climate and how to extend the predictability of the ocean conditions, including climatological forecasting. The physical numerical models are now close to operational development and should be generalised to incorporate both chemical and biological parameters.

Fisheries

There is a lack of knowledge about several fish stocks, since only the most important fish stocks are assessed on a regular basis. The effects of fisheries on non-commercial fish species are not well known. The effect of fishing pressure may coincide with climatically-driven variability, and the information required to separate these processes is limited, making it difficult to quantify the effects of fisheries on the size and composition of total fish stocks.

Data on discards from fisheries are not available, making an assessment of the effects on the size of fish stocks difficult. Discards can be linked to increases in seabird populations. However, due to a lack of data on discards and limited time series on population sizes of seabirds, the effects have not been quantified, although discards are likely to have contributed to population increases for seabirds in Region I.

The effects of different types of fishing gear on benthic habitats have not been sufficiently investigated. There is a lack of information on the fishing intensity by trawls in different parts of Region I. Whether trawling causes lasting damage with the risk of losing species and habitats is therefore not well known.

There is insufficient information to quantify the effects of the previous whaling activities on the energy flow and dynamic properties of the marine ecosystems.

Contaminants

There is a general lack of knowledge concerning the total inputs of the different groups of contaminants from their various sources to Region I and concerning the influence of Arctic conditions on the transformation and fate of these contaminants. It is very difficult to quantify the inputs, for example those via the atmosphere, rivers and ocean currents. Current understanding of the importance of the different transport processes is limited. This results in a poor understanding of contaminant focusing zones. One element that is not fully understood is the role played by ice in contaminant transport.

Information on contaminant levels is lacking both for certain contaminants and for different media in some areas. Time series data sets for detecting long-term trends in levels of contaminants in different media are very limited. This results in a very limited ability to judge to what extent measures for the reduction of contaminant inputs have been effective.

There is a need for a better understanding of biological effects of contaminants on humans and on species identified as being at highest risk. In particular, it is important to undertake further studies on the effects of persistent organic compounds on the development of offspring and/or immunosuppression and on endocrine disrupting properties. Knowledge about the combined effects of contaminants on biota and humans, both at the individual and the ecosystem level, is also very limited.

Mariculture

The effects of escaped salmon on the genetic composition of wild salmon stocks are not well documented. This is also the case as to the extent to which cultured salmon contribute lice to wild salmon. Lack of information on the role of natural factors and on natural variability makes a quantitative assessment very difficult. There is also limited information concerning the risk of diseases spreading from mariculture to wild stocks.

6.4 Overall assessment

6.4.1 Introduction

Region I was subdivided into sub-regions based on ecological characteristics, namely: the Barents Sea, the Norwegian Sea, the Iceland Sea and shelf area and the south-east Greenland shelf, and the Greenland Sea. These subregions were used as the basis for the overall assessment in which priorities have been given to the various issues. No overall assessment has been made for the sector of the Arctic Ocean in Region I due to a lack of information.

6.4.2 The Barents Sea

The following issues of concern have been identified:

- high fishing pressure on targeted fish stocks and possible indirect ecological effects and effects on benthic habitats;
- high concentrations of persistent organic contaminants and possible biological effects at high trophic levels;
- the risk of pollution and disturbances from oil exploration and development;
- the spread of radioactive substances from dumpsites, storage sites and accidents; and
- possible ecological effects of the non-indigenous species Kamchatka crab.

Fisheries

The main concern in the Barents Sea is the risk of overfishing targeted stocks and the associated indirect effects on other parts of the ecosystem. Heavily fished stocks are likely to be more variable, reducing the resilience of the ecosystem. The effect of trawling on benthic habitats and species is also a cause for concern although quantitative studies to indicate the magnitude of such effects are lacking.

Persistent organic contaminants

High levels of PCBs and some other persistent organic contaminants have been found in polar bear and some species of seabird from the Svalbard area and Bear Island. Some biological effects are indicated and the persistent organic contaminants could potentially have negative effects on organisms in the Arctic marine environment, particularly those at the top of the marine food chains. Persistent organic contaminants are transported via the atmosphere to the Arctic region. Deposition over the Arctic Ocean may be transported with the transpolar ice drift to enter the sea as the ice melts in the northern Barents Sea. It is important to quantify this transport and to establish temporal trends. In addition to classical contaminants such as PCBs and DDT, there are new and possibly as yet unknown substances that may also be important.

Oil exploration

Norwegian and Russian oil exploration and development of the petroleum industry in the Barents Sea pose future risks for the environment. Low temperatures and ice may make the consequences of accidental or routine discharges of oil and chemicals more severe than in more temperate environments.

Radionuclides

The Barents Sea contains very low levels of radioactive substances from anthropogenic sources. The spread of radioactive substances from dumpsites or storage facilities and from routine or accidental releases from nuclear power plants and atomic weapons, however, pose a long-term threat to the marine environment.

Non-indigenous species

The Kamchatka crab has been introduced to the Barents Sea. It is now increasing in abundance and spreading westwards. It could possibly have ecological effects on other species in the Barents Sea ecosystem.

6.4.3 The Norwegian Sea

The following issues of concern have been identified:

- the impact of fisheries on deepwater coral reefs and other benthic habitats and the impact of high fishing pressure on targeted fish stocks;
- pollution and the impact of oil and gas exploration and production in deep water on benthic habitats and the effects of produced water discharges on marine organisms;
- potential biological effects of persistent organic contaminants; and
- effects on the genetic composition and survival of wild salmon stocks by escapees and salmon lice from salmon farms.

Fisheries

Extensive damage and destruction of deepwater coral reefs have been indicated. Several fish stocks are close to or outside the biological reference points and it likely that they are or may become overfished. There are also many commercial fish species for which no reference points and no assessment of stock size are made.

Oil industry

The oil industry is expanding its activities into deep water along the slope to the Norwegian Sea. There is a risk of deep sea blowouts, from which large amounts of oil may remain in the water column and affect pelagic and benthic organisms. There are also discharges of toxic compounds in produced water from oil and gas exploration. These represent chronic exposure to low concentrations of toxic compounds. It is of concern that the consequences of these regular discharges have not been adequately assessed due to insufficient scientific information.

Persistent organic contaminants

Levels of persistent organic contaminants are relatively low compared to those in more urbanised areas. Higher levels may be found near the coasts. However, the potential for effects is still considered a matter of concern.

Mariculture

Escaped salmon from Norwegian mariculture may have an effect on the genetic composition and ability for local adaptation of wild salmon stocks. Salmon lice from farms may also infect juvenile salmon migrating from the rivers through fjords and coastal waters, resulting in increased mortality. The extent of such effects has not yet been determined.

6.4.4 The Iceland Sea and shelf area

The following issues of concern have been identified:

- the effects of fisheries on targeted stocks and on benthic habitats; and
- potential biological effects of persistent organic contaminants.

Fisheries
Some fish stocks (haddock and Greenland halibut) are at or below the biological reference points. This suggests that the stocks are or may become overfished.

Persistent organic contaminants
Levels of persistent organic contaminants are relatively low. Higher concentrations are found near the most populated areas in Iceland although they are still low compared to those in more urbanised areas. However, the potential for effects is still considered a matter of concern.

6.4.5 The Greenland Sea

The following issue of concern has been identified:

- elevated concentrations of persistent organic contaminants and possible biological effects in organisms at high trophic levels.

Persistent organic contaminants
Persistent organic contaminants may be transported to the Greenland Sea via the atmosphere and ice from the Arctic Ocean. Relatively high concentrations in seals and polar bear indicate that biological effects may occur.

6.5 Conclusions and recommendations

6.5.1 Conclusions

In general the environmental quality of the Arctic waters is good and Region I is among the least contaminated parts of the OSPAR Convention area. Several issues, such as the levels of metals and radioactivity, are not presently creating problems and others such as eutrophication are of low environmental significance in the region (see *Table 6.1*). However, there are several reasons for concern.

Fisheries
There are clear indications that fisheries have the greatest observed effects on the ecosystems in Region I.

Contaminants, oil and mariculture
The potential impacts of persistent organic contaminants, potential problems connected to the future development of offshore petroleum resources, and problems related to mariculture on the Norwegian coast are of concern.

Gaps in knowledge and lack of information
The assessment process has been difficult due to the limited availability of data on trends in inputs and systematic contaminant monitoring data on geographical and temporal trends.

A lack of data on the biological effects of contaminants has made it difficult to draw conclusions about the impacts of contaminants on the Arctic marine ecosystems.

The region is very large, with huge natural variability within the region. Processes governing inputs of contaminants to the area is not well known. Processes and activities outside the region are probably also of importance in explaining the present levels of contaminants in different parts of Region I.

Global effects
The effects of global warming have not been considered in detail in this report. However, global warming can potentially influence the hydrographical conditions in Region I. The climate in Europe is highly dependent on the physical conditions in the Nordic Seas.

6.5.2 Recommendations

Taking into account the human activities identified in the QSR, their impact on the marine environment and the evaluation of existing measures, it is recommended that the appropriate authorities consider the following :

- Management of living resources and the environment should be based on science and any management action will need to be under constant review and modified as the scientific basis improves.
- To ensure continued improvement of the quality of the region adequate resources should be made available to implement the OSPAR Strategies.
- To improve the management of fish stocks there is a need for the development of better assessment tools regarding the effects of discards and by-catch, and the effects of interactions between fish stocks.
- There is a need for more research on the effects of fishing gear on marine habitats.

- Qualitative and quantitative information about the inputs, sources and pathways of contaminants to the region should be improved.
- That research programmes into pathways and sources be initiated together with monitoring programmes to identify critical regions and temporal trends.
- There is a need to obtain more knowledge about the biological effects of in particular the low chronic exposure to persistent organic contaminants of organisms living in the region.
- More information and research is needed on the possible genetic effects and the spread of parasites and diseases from mariculture to wild stocks.
- Environmental impact studies are required in relation to oil exploitation in or near ice covered areas.
- Research is required on the implications of climate change for the marine environment.