

Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details, please refer to the chapter describing the GIWA methodology.

Introduction

Based on the assessment results it was decided to perform a causal chain analysis of the high priority issues overexploitation, chemical pollution, and habitat modification. Overexploitation and fish/seafood habitat modification were high priority issues in West and Southeast Greenland. Chemical pollution has severe impact in East Greenland and moderate impact in North and West Greenland. Habitat modifications due to climatic change in high Arctic Greenland are a high priority problem.

Climate is a key driving force for problems of overexploitation, chemical pollution and habitat modification and therefore, climate change is of

great concern for the biota and Greenland society. However, in the GIWA context, it is considered as an environmental driving force, as it is basically related to activities outside the Greenland region.

Immediate causes

Immediate causes are the direct reasons behind the environmental concerns and issues. It is important to identify the main direct causes as a scientific basis for policies and activities to achieve an improved environment.

Overexploitation and fish/seafood habitat modification in GIWA region 16, West Greenland Fishing

The main immediate causes of overfishing and the associated habitat modification are a combination of several factors: increasing fishery due to higher efficiency (new catch technology), inadequate resource management, and vulnerable resources due to climate variability. The impact of these factors is illustrated in the historically variable fishery for cod, the former most important fisheries resource.

The cod fisheries decline: The fluctuations in cod populations are well-known, as shown in Figure 12. The presence of cod in Greenland waters has a periodic character. The changes in the temperature conditions in West Greenland in the 20th century generally coincide with the change of the cod fishery, indicating the existence of a relatively strong climatic effect on the cod stock. When biological fisheries research began in West Greenland in 1908-09, only small, local fjord populations of cod were present. A climatic change in the 1920's caused ocean temperatures to rise and during the following years cod became abundant along the coast of West Greenland and they dispersed northward. The general

warming of the northern hemisphere around 1920 evidently led to the establishment of a self-sustaining and very abundant West Greenland cod population. From about 1930 to the late 1960s this stock produced good year classes at relatively short intervals. The drastic decline in the cod stock in the late 1960s was attributed to a combination of unfavorable cold climatic conditions and a too high fishing take in the offshore international fishery (Buch et al., 1994; Horsted, 2000). No good year classes were produced by the West Greenland population after the late 1960s due to generally lower and more fluctuating water temperatures in the West Greenland area (Figure 12). All important cod year classes in West Greenland from 1970 to the present time seem to have been of Icelandic origin (Buch et al., 1994). The most recent of these, the 1984 and 1985 year classes sustained relatively high catches during 1988-1990 but evidently left West Greenland thereafter (e.g., ICES, 2003). Today there are only very small local fjord populations of cod in West Greenland.

Increasing shrimp abundance: The Greenland economy, formerly being highly dependant on a rich cod fishery, is today almost entirely dependant on northern shrimp fishery. As seen from Figure 12, the decline of cod fisheries was replaced by a corresponding increase in shrimp fisheries.

In the beginning of the 1970s new deepwater fishing technology made it possible to develop an offshore West Greenland fishery for shrimp. An inshore fishery for Greenland halibut has been taking place in Northwest Greenland fjords since the beginning of the last century. This fishery developed gradually during the 1980s and 1990s and catches are at present around 20 000 tonnes annually.

During the last two decades shrimp and Greenland halibut have been the commercially most important fishery resources in West Greenland. Export of shrimp to e.g. Japan, has provided a high-value economic alternative to cod, comprising 73% of Greenland's total exports in 1995. However, new fisheries on snow crabs, started in late 1990s, and scallops, started in the mid 1980's, and other mainly coastal and local fisheries on cod, salmon, redfish, wolffish, halibut, herring and others are also important for the Greenland society.

Today's low abundance of cod and high abundance of shrimp most probably have the following main causes:

1) *A general cold climate after 1970.* Since 1970 the Greenland climate has been considerably colder than during the more stable warm period between 1920 and 1970. The cold and variable conditions after 1970 have been unfavourable for growth, reproduction and survival of cod.

- 2) *Continuing absence of the West Greenland cod spawning stock.* The spawning stock at the banks off West Greenland is virtually absent since the collapse in the 1970s.
- 3) *Reduced inflow of cod larvae from Icelandic spawning grounds.* Since the collapse of the West Greenland spawning stock in the early 1970s, cod stocks at Greenland have been entirely dependant on recruiting year-classes from Iceland. In addition to local production significant inflow of cod larvae from Iceland occurred almost every year in the 1950s and early 1960s; this inflow disappeared thereafter except for the big 1973 and 1984 year classes.
- 4) *Reduced predation on shrimp.* The low abundance of shrimp predators, mainly cod, but also other fish species has probably improved the survival success and productivity of shrimp in recent years.
- 5) *Overexploitation of cod.* Fishing mortality on cod has been too high due to by-catch in the shrimp fishery and due to unregulated fishery directed for cod in the fjords. The resource management has been unable to adequately protect the few remaining cod spawning populations during periods of cold climate and low cod productivity.

Apparently, climatic and oceanographic changes play a very important role in the modification of the habitats and in the sustainability of the fisheries sector. This is further aggravated by overfishing in the fragile and highly variable ecosystems (Rätz et al., 1999; Buch et al., 2004).

Changes in the ocean climate are probably the main cause to changes in productivity and structures of the marine ecosystems. For example, for many of Greenland's fish species, the seas off Greenland limit their dispersal, for example, cod, redfish, striped catfish, halibut and herring, which have their northern limit there. Conversely, too high sea temperatures set a southern limit for the dispersal of Arctic species, such as polar cod, and Arctic ray. Therefore, relatively small variations in the temperature of the sea could result in considerable fluctuations in the dispersal and productivity of many fish species, as also observed earlier (Jensen, 1939). The trend in cod distribution by-and-large follows the average sea temperature (Horsted, 2000).

In South Greenland many years of bottom trawling is believed to have impacted species compositions and community structures. By-catch of shrimp predators mainly cod, redfish, Greenland halibut and others in the steady growing fishery for shrimp during the last part of the 20th century has been suggested to be an important factor in the shift from cod dominated to shrimp dominated ecosystems by modifications of habitats and community structures (e.g. Buch et al., 2004).

A general characteristic of the mainly long-lived resources exploited in Greenland waters has been a population structure with many large, old individuals when the fishery begins. However due to slow reproduction and growth rate in cold and/or deep water, the population age structure shifts downwards as fishing intensifies, and the large older fish are removed. This trend has been observed not only with cod, but also with halibut, wolfish, scallops and other species. In the case of isolated stocks, even a short period of overfishing leads to a drastic reduction. For example, some Greenland halibut stocks appear resident in certain fjord complexes, although reproduction occurs elsewhere (Riget and Boje, 1989). Such stocks are particularly vulnerable to overfishing, on the offshore spawning grounds.

Sea bird hunting

The breeding populations of Brünnich's guillemot and common eider have both declined significantly in West Greenland during the 20th century. The immediate cause is ascribed to overexploitation (Kampp et al., 1994; Meltofte, 2001; Merkel et al., 2002). The life strategy of both species are characterised by a slow population turn-over making the stability of the population dependant on a high adult survival. This makes the populations particularly sensitive to exploitation in periods when adult birds are exposed (mainly in spring and summer). The present annual levels of harvest as expressed by the official bag records system is about 84 000 common eiders and 255 000 Brünnich's guillemots (maximum recorded numbers over the period 1994-2001) (Naminersornerullutik Oqartussat, 2002).

The main reasons for overexploitation in the last century is the increased human population in West Greenland and the technical development of the hunt (more efficient weapons, faster and more far-reaching boats) combined with the low productivity of the exploited species. However, besides the hunting harvest, climatic changes, as for example the extension and duration of winter sea ice, by-catch in gillnets and disturbance (mainly hunting related) at colonies and moulting sites may also have had an impact on the populations.

Since 1930 the breeding population of Brünnich's guillemot has decreased by 80 % in West Greenland, and by 35 - 50 % in Greenland as a whole (Falk and Kamp, 2001; Kampp et al., 1994). Only in the northernmost part of the breeding range (in Qaanaaq in North Greenland) the population seems stable (Falk and Kampp, 2001). The population is migratory, wintering in the open waters of Southwest Greenland and in Newfoundland waters (Kampp, 1988; Lyngs, 2003). In both areas the guillemots are exposed to hunting and significant numbers are taken. But it is difficult to assess the impact on the Greenland breeding population because the winter quarters are shared

with Brünnich's guillemot populations from other breeding areas, such as Svalbard, Northeast Canada and Iceland. However, the winter hunt primarily takes juvenile and immature birds, while hunt in spring and summer near the breeding sites mainly takes local adult birds.

In the early 1970s by-catch in salmon gill-nets took huge numbers of Brünnich guillemots in Davis Strait in autumn. This by-catch declined to insignificant levels in the late 1970s, because the salmon quota was reduced and timing and location of the fishery were changed, eliminating much of the overlap with the occurrence of the Brünnich's Guillemots (Falk and Durinck, 1991).

The part of the Brünnich guillemot breeding population wintering in Newfoundland waters is exposed to chronic oil polluting from the heavy shipping activities in these waters (Wiese and Ryan, 2003), but the impact on the population is not known.

The common eider breeding population was very large in West Greenland late in the 1800s, documented by eider down trade figures. As early as in the beginning of the 1900s concern was expressed for the status of the population due to overexploitation (Boertmann et al., 2004). Locally the population has been reduced by 80% since 1960, when the population already was reduced compared to earlier in the century (Merkel and Nielsen, 2002). Exploitation is mainly hunting, and as much as 32% of the hunting bag has been taken in the spring months when the population is particularly vulnerable. The open hunting season has been reduced since 2002. The high hunting pressure is documented by the fact that a high proportion of the common eiders carry embedded lead shots in their tissues (Falk and Merkel, unpubl.). Egg collection and previously also down collection also impact the population as well. Preliminary studies indicate that by-catch in gill-nets (mainly for lumpsucker) also contribute to the mortality (Merkel, 2002b), but the impact is not known. King eiders at moulting sites also show population declines (Mosbech and Boertmann, 1999).

Marine mammals: Beluga, narwhal and walrus hunting

A number of marine mammals have been exploited commercially in Greenland in recent times, either by whalers or by organised hunting cooperations that have sold their products on the national and international market. Subsequently, several species were and are exploited by local hunters whose hunting techniques and economic motivations resemble those of commercial whalers. This has been particularly obvious in cases where the hunting of marine mammals has been part of an overall pattern of exploitation that included fishing. Examples of this are belugas, narwhals, and walruses (Born et al., 1994; Heide-Jørgensen, 2001).

The hunting of walrus in West Greenland during the 20th century is an example of how increasingly efficient hunting methods and lack of regulation may rapidly lead to overexploitation of a group of marine mammals in which the innate capacity of increase is relatively low.

Beginning in 1911, hunting expeditions using government schooners were sent to the walrus haul-outs in West Greenland. Private motorboats soon began to participate in the hunt. The most obvious result of this intensified and uncontrolled hunting pressure was the complete disappearance after about 30 years of walrus from their haul-outs in West Greenland. They have not since returned to these haul-outs.

Since 1932, walrus have also been hunted during the spring in the West Ice off Sisimiut/Holsteinsborg to Aasiaat/Egedesminde and west of Qeqertarsuaq/Disko. The vessels used were likewise partially financed by public funds. The walrus hunt thus had the character of a commercial activity that was subsidised by the government. Great amounts of hides, tusks, and blubber were sold to the Royal Greenland Trade Company, which continued to buy these products long after it became difficult to sell them on the international market. For a number of years catches were very large; in West Greenland alone at least 12 000 walrus were landed between 1900 and 1987. The actual number of animals killed was probably much higher, because not all catches were reported and because many animals sank and were lost during hunting. Furthermore, mainly females with young were hunted in the West Ice because they were more accessible than males. The males preferred to stay in the dense pack ice further offshore. Moreover, during spring females have a relatively greater content of blubber, making them a more attractive commodity.

Even though the decrease of the walrus population in these areas was obvious relatively early, hunting regulations were not introduced until around 1950, finally affording the walrus a certain degree of protection.

The population is still far below earlier levels. Aerial surveys between 1981 and 1994 indicated that during the spring there are less than 1 000 animals in the West Ice between Sisimiut/Holsteinsborg and Qeqertarsuaq/Hare Island. During this period, in which hunting continued, there have been no signs of growth in the stock.

In a "traditional" hunting community without the mechanisms of a market economy, the hunting effort is reduced as soon as the number of animals decreases, allowing the population to recover. This "feedback" regulation mechanism was put out of operation in the case of the walrus of West Greenland, because public funds were used

to increase hunting effort and maintain it at a high level, even though there were signs that the population was being overexploited. Today hunting is not self-regulating mainly do to efficient transportation and hunting equipment.

The above historic example emphasises the necessity of monitoring and regulating hunting efforts; this is especially true when it becomes technically and economically feasible to intensify the hunt on a population of marine mammals.

Chemical pollution

Long range transport and climate

The vast majority of chemical pollution in Greenland is due to long-transported contaminants from outside Greenland (AMAP, 2002; Macdonald et al., 2003).

Main sources of marine pollution are the industrialised areas in Europe, Russia and USA (AMAP, 1998, 2002; Christensen et al., 2003). Pollutants are transported to Greenland by the atmosphere and by the marine currents, however, transportation by ice may also play a role. The prevailing patterns of wind direction, especially in winter, transport air masses from industrialised areas to the Arctic (Figure 13). The cold Arctic climate seems to create a sink for e.g. Hg and POPs (AMAP, 1998, 2002; Macdonald et al., 2003; Christensen et al., 2003).

Three major mines have been in production in Greenland, and elevated heavy metal levels have been observed in fjord areas within approximately 40 km from the mine sites (Riget et al., 2000). However, local sources of pollutants in the marine environment around Greenland play a minor role, except for lead pollution from the use of lead shot (Johansen et al., 2004).

Heavy metals

The heavy metals assessment in AMAP focuses on mercury, lead, and cadmium. Of the metals, mercury (Hg) pollution generate the greatest concern because levels in the Arctic are already high, and are not declining despite significant emissions reductions in Europe and North America (Macdonald et al., 2003).

Coal burning, waste incineration, and industrial processes around the world emit Hg to the atmosphere, where natural processes transport the metal. The Arctic is vulnerable because unique pathways appear to concentrate Hg in forms that are available to the food web. Environmental changes may have made these pathways more efficient in recent years. In the Arctic, Hg is removed from the atmosphere and deposits on snow in a form that can become bioavailable. A recently

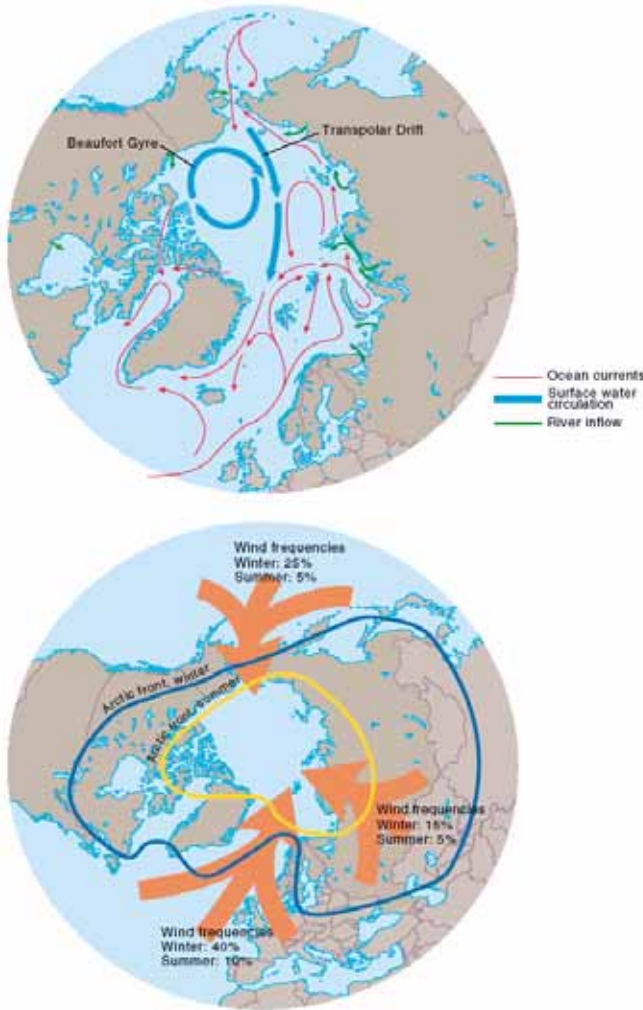


Figure 13 Pathways for pollutants transported to Greenland.

Upper map: Rivers and ocean currents are important pathways for water-soluble contaminants and those that are attached to particles in water.
 Lower map: Winds provide a fast route for contaminants from industrial areas to the Arctic, especially in the winter.
 (Source: AMAP, 2002)

discovered process links enhanced deposition of Hg to the polar sunrise, which is unique to high latitude areas. The resulting enhanced deposition may mean that the Arctic plays a previously unrecognised role as an important sink in the global Hg cycle (AMAP, 2002). Some of the deposited Hg is released to the environment at snowmelt, becoming bioavailable at the onset of animal and plant reproduction and rapid growth. Although poorly understood, this process may be the chief mechanism for transferring atmospheric Hg to Arctic food webs.

Despite declining anthropogenic emissions, at least in the period between the 1980s and the 1990s, the Arctic ecosystem appears to be increasingly exposed to Hg (Macdonald et al., 2003). It is unclear why this is so because the complete Hg pathway has not been adequately

studied. The connection between atmospheric transport and deposition to Arctic surfaces (Hg depletion events) shows the Arctic to possess a unique, climate-sensitive process that may explain much of its susceptibility to Hg contamination. However, the pathway for Hg between its deposition to surfaces, especially following polar sunrise, and its concentration in apex aquatic feeders is very poorly known. AMAP recommends that studies continue on the Hg cycle in the Arctic with emphasis on the processes implicated in Hg depletion events and in the biogeochemical cycling of Hg in ice-covered environments (Macdonald et al., 2003).

POPs

Most of the total quantity of POPs found in the Arctic environment is derived from distant sources (Figure 14). Most POPs are semi-volatile and their transport is complex.

In temperate and tropical regions, they are picked up by the winds as gases. When temperatures drop, they condense onto atmospheric particles and other surfaces, reaching the ground via rain, snow, or direct deposition onto land and water. The role of atmospheric transport varies with the seasons. Generally, atmospheric long range transport to the Arctic from source areas in North America and Eurasia is much higher in winter and early spring than in summer (Macdonald et al., 2003).

The precise importance of ocean transport for each compound depends on the physical properties of the substance (AMAP, 2002; Macdonald et al., 2003). The role of ocean currents in transport is

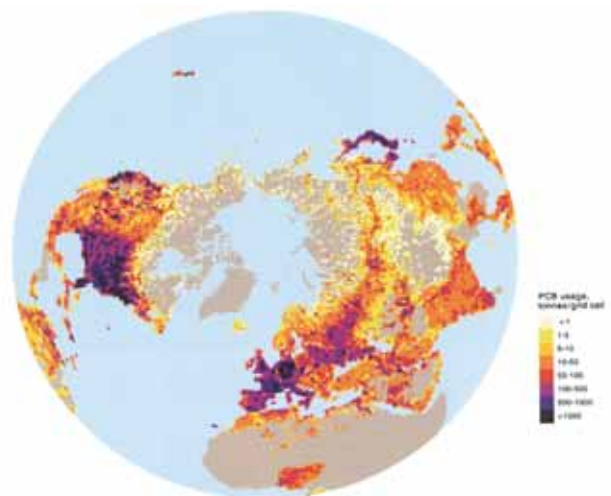


Figure 14 Estimated cumulative global usage of PCBs (1930-2000). Most of the use was in the northern temperate region.

(Source: AMAP, 2002)

probably more important for contaminant levels in the Arctic than was previously thought. Water soluble chemicals that are efficiently removed from the air by precipitation or air-to-sea gas exchange may reach the Arctic primarily via ocean currents.

The POPs are transported to the Arctic by regional and global physical processes, and are then subjected to biological mechanisms that lead to the high levels found in certain species. Given the length and complexity of the POP pathways into top predators of aquatic systems in the Arctic, exposure to these chemicals is particularly sensitive to global change (Macdonald et al., 2003).

Habitat modification in GIWA region 1, Northern Greenland

Climate change

The oceanographic and sea ice conditions around Greenland are linked to climate variability and the changes in the distributions of atmospheric pressures on the northern hemisphere. The last decades warming of the northern hemisphere has given reduced summer ice cover and increased open-water periods in East Greenland, however, at the same time regional lower temperatures, increased ice cover, and reduced open-water periods has been observed in West Greenland (e.g. Stern and Heide-Jørgensen, 2003). These changes have major impact on the marine ecosystems and the habitats for the Arctic animals.

In Northeast Greenland, Rysgaard et al. (1999) expects future increase in the annual pelagic primary production, secondary production, and hence food production for higher trophic level animals in a wide range of Arctic marine areas, as a consequence of reduction and thinning of sea ice cover due to global warming. However, the reduction in sea ice may be a benefit to some marine mammals e.g. Atlantic walrus (Born et al., 2003), but probably not for others e.g. polar bears (Wiig et al., 2003).

In West Greenland, Heide-Jørgensen and Laidre (2004) found the increased ice cover and reduction in open water refugia to be a threat to a number of sea birds and marine mammals.

The above described changes in ice cover and open water occur and impact the habitats of mainly the northern high Arctic areas of East and West Greenland. In these areas the impact of climate change are predicted to be most severe whereas in South Greenland changes in climate are expected to have less impact on habitats and ecosystems.

Root causes

The root causes are the more fundamental reasons behind the direct causes for environmental decline. Experience has shown that addressing the direct, immediate causes is not sufficient to achieve sustainable results. It is equally – and sometimes more – important to identify and consider actions related to the root causes.

Examples of some fundamental root causes are population growth, unsustainable economic development, social and cultural conditions. But lack of knowledge, inadequate governance, and lack of awareness may also be important root causes. Of special importance for the fragile ecosystems of Greenland are the basic root causes related to natural and man-induced climatic changes.

Overexploitation of living resources

Climate change

Overexploitation of fish and shellfish in Greenland is linked to global changes in climate and ecosystem functioning as illustrated in the above description of historic fluctuations in the cod populations and fisheries yields. A more detailed description is given in Buch et al. (2004). Changes in the thermal regime can have a considerable impact on the abundance of fishes and shellfish. For example Northern shrimp, snow crab and Icelandic scallop prefer relatively cold temperatures in the range of 1-5°C and especially their larvae are less vulnerable to low temperatures compared to e.g. cod. The better ability of shellfish larvae to cope with low temperature environment partly explain the positive reaction of the shrimp and snow crab stocks to the changed climatic conditions observed in West Greenland in last decades. However, the shift in the underlying marine ecosystems at Greenland may have been amplified by the declining cod stock due to a release in predation pressure on e.g. sandeel and shrimp as observed in Eastern Canada (Koeller, 2000; Lilly et al, 2000).

Inadequate management

An overall difficulty in fisheries and hunting assessment is to assess whether changes in the stocks are due to overexploitation or environmental changes (changes in climate, ocean circulation, turbulence etc.). Up until now the fisheries assessment and the subsequent management methods used have generally been inadequate (e.g. Maguire, 2001).

During the task team meeting in Nuuk a number of root causes for overexploitation of fishes, shellfish, sea birds and marine mammals were mentioned and discussed. They are listed according to the four dimensions of a fishery system as used by the ICES Working Group

on Fishery Systems (WGFS, 2003), i.e., scientific, political, related to monitoring, control and surveillances (MCS), and user group related.

(a) Scientific documentation

- Inadequate data: For example for inshore cod.
- No quantitative and analytical biological assessment and advice: For example offshore snow crab.
- Inadequate stock assessment: For example cod. The biological advice for and management of the cod fishery off Greenland is based on a combined assessment of cod in its distribution area East and West Greenland. However, the cod populations in these areas are partly separate and additionally connected to the Icelandic cod stock in a complicated way, resulting in a complex stock structure (e.g., Wieland and Hovgaard, 2002; Stein et al., 2002; Anon., 2003c). The complexity of the stock structure is not considered in the assessment as it is done today by ICES. There is a need for improved assessments by a better use of the available biological and hydrographic knowledge in the assessments not only for cod but also for several other exploited resources of fish, shellfish, sea birds and marine mammals.
- There is a need for improved regional stock assessments by development of coupled models of the dynamic relationship between climate, ocean circulation, and variability in key species abundance not only for cod but also for several other exploited resources of fish, shellfish, sea birds and marine mammals (e.g. Pedersen et al., 2002; Pedersen and Bergström, 2003; Ribergaard et al., 2004; Heide-Jørgensen and Laidre, 2004).

(b) Political constraints

- No regulations or inadequate regulations: This mostly applies to widely distributed fish stocks such as Greenland halibut. Often, inefficient and uncoordinated management measures lead to an uncontrolled and most probably high exploitation of the resource as is the case for Greenland halibut in East Greenland and Iceland. No formal agreement on the management of the shared Greenland halibut stocks exists among the three coastal states, Greenland, Iceland and the Faroe Islands. The regulation schemes of those states have previously resulted in catches well in excess of TAC's advised by ICES.
- The Government subsidises fishing and hunting gear, boats and engines.
- Foreign nations that are non-members of commissions are not restricted by regulations and measures set up by the respective coastal nations or commissions that have taken the responsibility to regulate international fisheries. Examples of this is seen in the pelagic redfish fishery in the Irminger Sea and adjacent areas,

where vessels belonging to a member state of the Northeast Atlantic Fisheries Commission, re-flag under a non-member country, thereby avoiding restrictions in the fishery.

- Variable market prize differentiate fishing and hunting pressure on resources.
- Lack of transparency and accountability in the process of balancing between natural resource conservation, social and economic issues. Lack of management plans.
- Partly lack of political will to listen to biological advice.

(c) Administrative constraints

- Lack of control or inadequate control: In the wide areas of the North Atlantic schemes of control and enforcement are most often hard to accomplish, although introduction of satellite devices and a vessel monitoring system have improved control and enforcement substantially.
- Inadequate logbook reporting: For example inshore cod.
- No gear registration and no lost gear registration (in contrast to practice in, e.g., the Faroe Islands), resulting, e.g., in the possibility of ghost fishing by gill nets.
- Inadequate fishery administration: Fishery and hunting controls too costly or not prioritised.

(d) User-group related

- Many local communities and settlements are dependent on the harvest of marine resources because there are no other income possibilities.
- Improved fishing and hunting technology over the years.
- No flexibility in the medium- and large-scale fishery e.g. seasonal shifts in target species.
- Overcapitalisation (e.g., snow crab fishery).
- The need of monetary income (after change of the society to a money-based economy) increases pressure on vulnerable resources.
- Disagreement about the current resource situation between on the one hand biologists and on the other hand fishers and hunters.

Socio-economic problems

A discussion among task team members on root causes revealed the necessity to discriminate between recreational and professional fishing and hunting. For recreational fishermen and hunters a root cause may be inadequate knowledge about the resources and inadequate understanding of the importance of observing rules and restrictions. For local professional fishermen and hunters the main root cause is probably the lack of alternatives to fishing and hunting. In families with annual income of about 50 000 Dkr per family (i.e., well below

the poverty line), it is naturally difficult to reduce exploitation and thereby family budgets. Therefore, to rebuild overexploited resources, alternative income possibilities must be offered to the professional fishermen and hunters.

Chemical pollution in East Greenland

Lack of knowledge

In spite of recent progress, in particular due to the findings of the AMAP programme, there are still considerable uncertainties about the sources, the transport mechanisms and the impacts of the arctic food chains of chemical pollutants. In particular, documentation to pinpoint key international causes is needed to form a better scientific basis for reduction of the impacts

Lack of international governance

The major sources for the chemical contamination of the waters and the ecosystems around Greenland can be found in the pollutant releases in Europe, Asia and North America. The only possibility of reducing these sources is a continued focused and significant international effort to control these emissions, and to enforce existing agreements.

Socio-economic conditions

The combination of environmental conditions and biomagnification in the marine food webs result in accumulation of certain persistent contaminants in traditional food of the Greenland people. For many reasons, traditional food still plays an important role in the diet of the population, in particular in the settlements

The consumption of marine mammals, fish and sea birds is high but the young and the population in towns eat considerably less than the elderly and the population in the villages. Seal is the most often consumed traditional food item followed by fish. On average, 20% of the Greenlanders eat seal 4 times a week or more often while 17% eat fish similarly often. Traditional food is valued higher than imported food; the highest preference is given to mattak (whale skin), dried cod, guillemot, and blackberries. Almost all value traditional food as important for health and less than one percent (in 1993-94) restricted their consumption of marine mammals or fish because of fear of contaminants (Bjerregaard, 2003).

Habitat modification

Climate change

The main root cause for habitat modifications in the Northern waters is variability in climate, and hence, global climate change. In addition to the natural variations, anthropogenic climate change is one of the major emerging environmental problems. Although the climate

system is complex and large uncertainties exist in the understanding and prediction of climate change, the question is no longer if we will experience climate change, but how large anthropogenic and natural changes will be, how fast they will appear and their regional variations (Jørgensen et al., 2001).

Analyses with global climate models show the following general trend for the climate in Greenland in 2100 in relation to 1990 (Anon., 2003a):

- In South Greenland a rise in mean annual temperature of just over 2°C, slightly more in winter and slightly closer to 2°C in summer, and in North Greenland, a rise in temperature of 6-10°C in winter but only small rises in summer;
- A general increase of 10-50% in precipitation, but little or no increase in Southeast Greenland. In winter, however, a considerably bigger increase in North Greenland, locally up to more than 100%.

Such changes will cause significant impacts on the oceanographic conditions and on the stability of the ice cover. It is questionable if the present arctic ecosystems will be able to accommodate these changes.

Lack of knowledge

There is a considerable lack of both data and understanding of how the arctic ecosystems will react to possible drastic changes in the climate and ice-cover.

Conclusion

Overexploitation of the marine resources, in particular in West Greenland, GIWA region 16, partly due to climate change, inadequate knowledge of the living resource dynamics, and management, and partly due to the ability or inability of the municipality to react and adapt to changes, is a severe problem and one of the large challenges for Greenland now and in the future (Figure 15).

Chemical pollution from outside Greenland is a threat to the biota at higher trophic levels, human health and the culture of the Arctic people, in particular in East Greenland, GIWA region 15 (Figure 16).

And finally, habitat and community modifications due to climate change, but also overexploitation are threats to many unique Arctic animals, (e.g., polar bears, walrus) in particular in the North, GIWA region 1

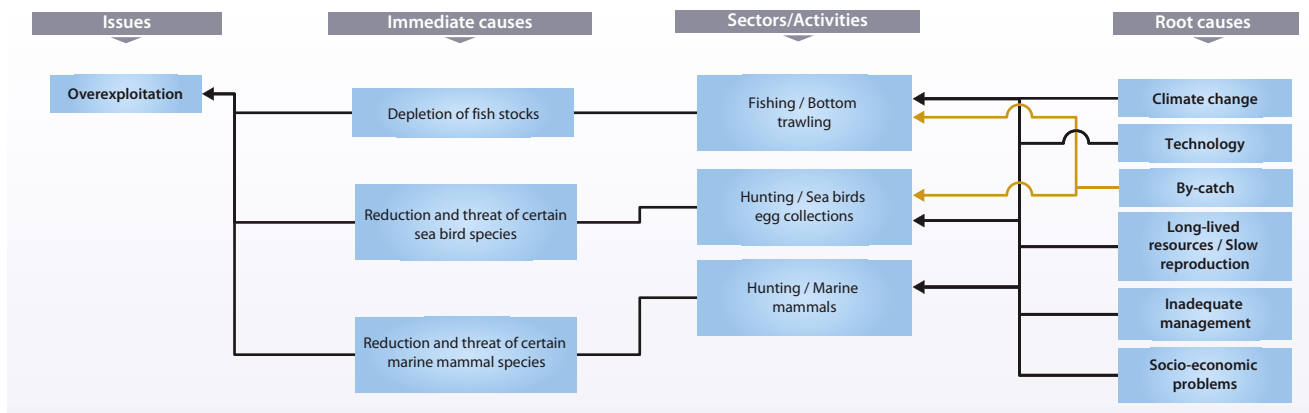


Figure 15 Causal chain analyses regarding overexploitation.

Complex models of interactions are not easily tractable and it will be necessary to extract from complex interactions, those processes which are the most important in the causal-chain analyses. The essential task is to discover how to combine social and natural science scale analyses to understand the impact of natural systems on people and the impact of people on natural systems (Perry and Ommer, 2003). The causal-chain analysis represents a general picture. Overexploitation in Greenland is a complex function of many factors, which interact in complex ways. Key factors are: 1) a climate with large short-term variability and long-term changes which affects the productivity and distributions of natural resources, 2) a technology which constantly is developed and becoming more effective, 3) by-catch of non-target species, 4) long-lived resources with slow growth in a cold environment, slow reproduction and therefore vulnerable to fishing and hunting, 5) inadequate management due to e.g. lack of knowledge, economy and political will, 6) socio-economic problems due to increased human needs of modern equipment and technology (e.g. TVs, motor boats, etc.) and lack of natural resources to support economical development due to overexploitation, 7) gradual societal shift from commercial to recreational exploitation.

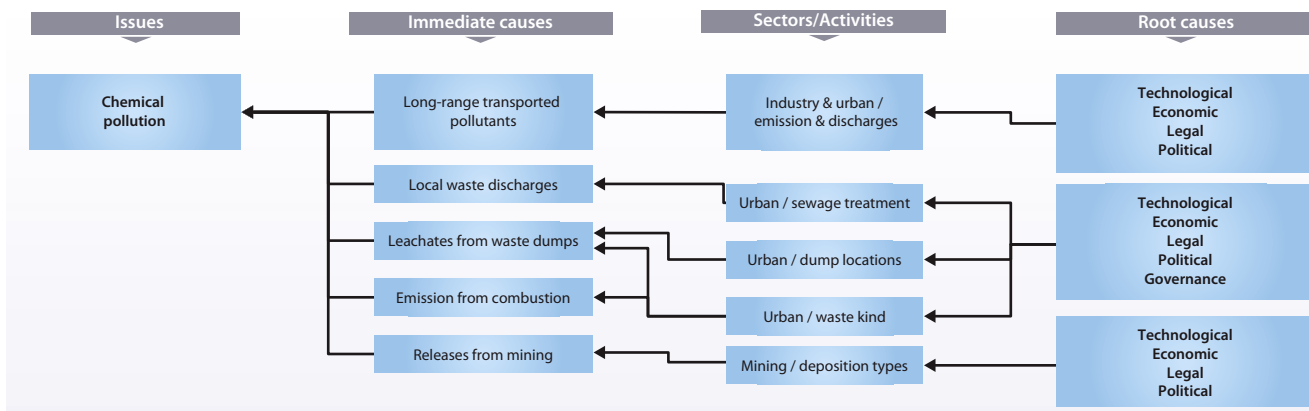


Figure 16 Causal chain analyses regarding chemical pollution.

The major sources for the chemical contamination of the waters and the ecosystems around Greenland can be found in the pollutant releases in Europe, Asia and North America (Macdonald et al., 2003). The only possibility of reducing these sources is a continued focused and significant international effort to control these emissions, and to enforce existing agreements. Local pollution is generally a minor problem in Greenland. For example there is a need to reduce the leaching from several locations all over Greenland.

Some of the root causes for the key environmental concerns of Greenland's marine resources are to be found and solved within Greenland. However, climate change greatly influences the natural resources and is a very important factor for Greenland's ability to manage natural resources and socio-economics relationships in the society.

Hence, the main international problems for the waters around Greenland, the biota and the society are chemical pollution and climate change. Both these problems are caused by the industrialised world and they are global international problems to be solved in international cooperation.