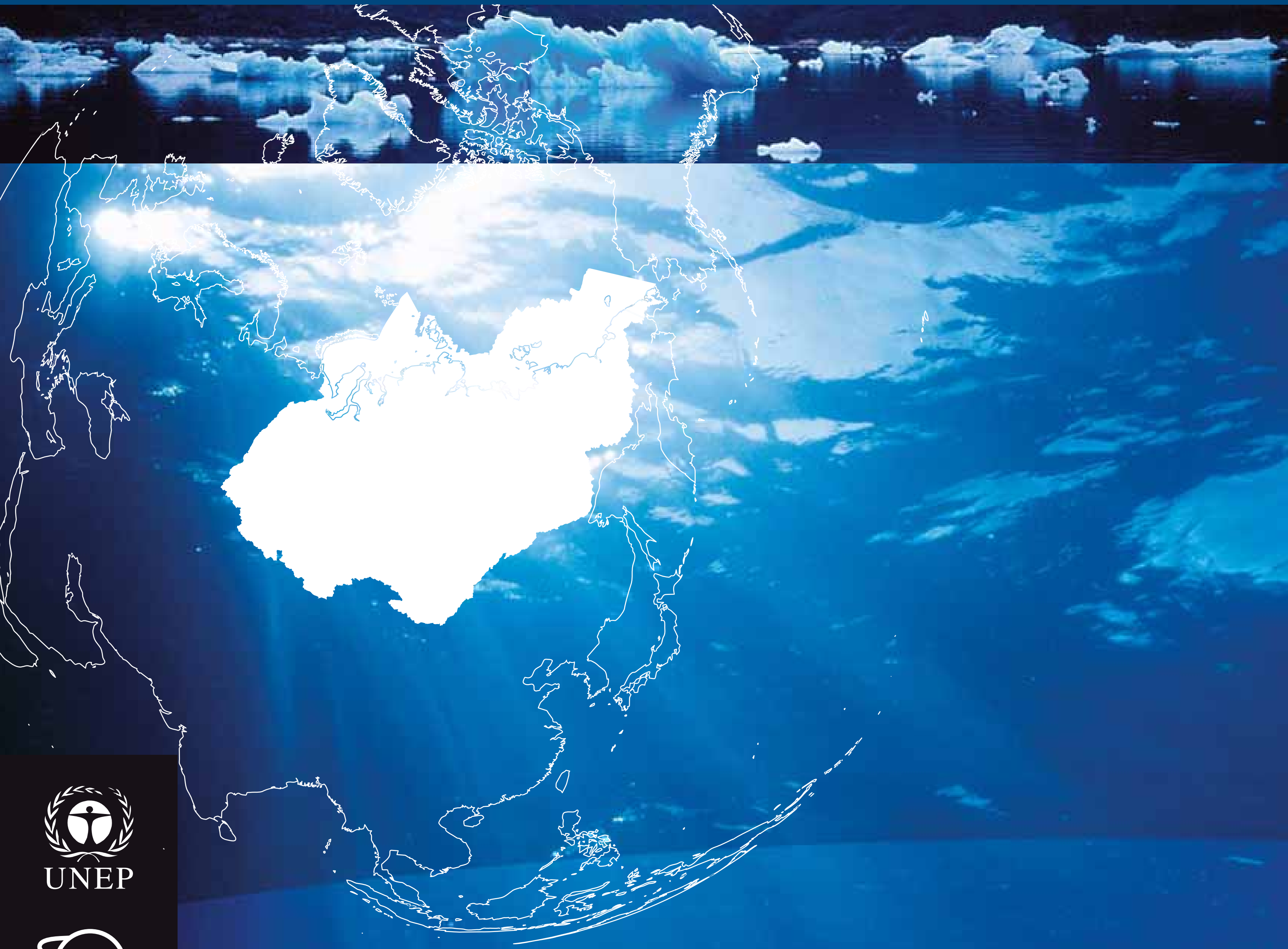
Global International Waters Assessment



Russian Arctic

GIWA Regional assessment 1a

Tsyban, A.V., Titova, G.D., Shchuka, S.A., Ranenko, V.V. and Y.A. Izrael

Global International Waters Assessment

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Global International Waters Assessment

Regional assessment 1a Russian Arctic

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Preface

This report presents the results of the Global International Waters Assessment for the Russian Arctic (GIWA region 1a), as determined during three workshops. The first Scoping and Scaling Workshop was held in Zvenigorod (Moscow) from 15-18 April 2002. To achieve the workshop's objectives, 17 scientists whose expertise included issues related to environmental and socio-economic impact assessment in the Arctic region were invited to participate. Among participants of the workshop were: GIWA/UNEP Scientific Director Mr. Dag Daler, GIWA/UNEP Coordinator Northern Hemisphere Mrs. Elina Rautalahti-Miettinen, Dr. Thor S. Larsen (UNEP/GRID-Arendal, Norway), Deputy Executive Secretary of AMAP Vitaly A. Kimstach (Norway), and Prof. Sergei M. Chernyak (USGS/Great Lakes Science Center, USA). The second and third workshops (Detailed impacts assessment, Causal chain analysis and Policy option analysis) were held in Moscow, Russia, on June 16-18, 2003, and September 15-19, 2003. Seven experts participated in these workshops.

The basic goal of this report is to analyse and present in a single document all available information on the environmental impacts and the transboundary consequences in the seas of the Russian Arctic. The report includes the results of investigations performed by the authors as well as data from the environmental pollution monitoring network and the scientific literature. The specific environmental characterstics of the region were considered in order to conduct a comprehensive assessment of the ecosystem stability and for the prediction of the effects of anthropogenic processes.

This report especially emphasize the life situation of the Arctic indigenous population. Taking into consideration the social and economic situations, the socio-economic part of the assessment focused mainly in the indigenous population. A review of the Health and social welfare of the Arctic indigenous population in Russia is presented in Annex V.

Executive summary

Occupying just 5% of the area covered by the world's oceans, and just 1.5% of their volume, the Arctic Ocean and its adjacent seas have a pronounced effect on the state of the Earth's climate and play a decisive role in many global processes. Arctic seas regulate the global carbon cycle, because they are an important CO_2 source in the winter and a sink for the flux of CO_2 in the summer. Recent assessments have shown that the Arctic is critically important in atmospheric CO_2 removal, both now and in the future.

Arctic seas have a profound impact on many large-scale oceanographic processes; they are a zone of deep ocean water formation, and determine to a great extent the global hydrological cycle on our planet as well as atmospheric heat absorption.

The Russian sector of the Arctic occupies a large part of the Russian Federation, extending as far as about 11 000 km from the Norwegian border on its western boundary to the Mys Dezhneva (East Cape) on the eastern one. It includes Murmansk Oblast, Nenets AD, Yamalo-Nenets and Taimyr (Dolgano-Nenets) AD, coastal Arctic uluses (small administrative units at the Arctic coast including several villages) of the Sakha Republic (Yakutia), Chukotka (Dolgano-Nenets) AD. The Russian sector of the Arctic covers about 9.46 million km^2, of which the Arctic seas cover 6.8 million km^2, or 45% of the Arctic Ocean overall. As much as 70% of the area is permantly covered by ice.

This report is about the GIWA region 1a, further referred to as the Russian Arctic, and considers only the central and eastern parts of the Russian section of the Arctic. The western/European part (the Barents Sea and White Sea) is evaluated in the GIWA Regional Assessment 11. However, because water and atmospheric transports from the western/European of the ocean exert a significant influence on the condition of the transboundary waters in region 1a, information from the Barents Sea region is provided as needed.

The Russian Arctic region includes the following seas:

- Kara Sea;
- Laptev Sea:
- East Siberian Sea;
- Chukchi Sea (the Russian section).

The total coastal area in the region is 3 460 km^2, or one-fifth of the total Russian territory. The region's population of 770 200 is just 0.54% of the country's total population. At the same time, the area's natural and resource potential are so rich and diverse that the region's stocks of some resources (for example gas and oil) can be considered a significant part not only of the Russian but also of the world's resources. Industrial production in the Arctic region today is mainly (about 90%) composed of "dirty" activity: hydrocarbon extraction, the mineral resource industry, metal manufacturing, and the building materials industry.

The depletion of mineral deposits in Russia's middle latitudes and the increase in mineral prices makes it more and more attractive to exploit polar lands and seas. Some assessments have suggested that the polar economy will develop mostly as a result of the exploitation of hydrocarbon stocks. Sea and river navigation will expand, increasing the threat of contamination of Arctic waters.

At present the transboundary waters in the Arctic region are relatively clean, and the state of the pelagic ecosystems as a whole is favourable. However, the local shelf regions of the Arctic seas and most coastal zones are considerably polluted and the state of a number of bays, gulfs and estuarine areas has been assessed as critical and even in a catastrophic state. The main contribution to pollution in the Arctic seas is from diffuse, distant sources (river run-off and long-range atmospheric transport) and local sources located in high latitudes or directly on the Arctic coast. The major hazard facing the Arctic seas is the possibility that oil and its components will enter marine ecosystems as a result of sewage discharges, accidental spills, navigation, and gas and oil production, especially directly on the shelf. Practically all petroleum hydrocarbons and HCHs in the Arctic seas (particularly the Kara Sea) are the results from run-off carried by the Ob and Yenisei Rivers.

The GIWA concerns are prioritised as follows:

1. Pollution
2. Habitat and community modification
3. Global change
4. Unsustainable exploitation of fish and other living resources
5. Freshwater shortage.

Due to substantial differences between the seas, the region is divided in two sub-systems: the Kara Sea sub-system and the Laptev Sea, East Siberian Sea and Chukchi Sea sub-system. The latter sub-system is relatively clean, and all issues have not known or slight environmental impacts. However in the Kara Sea sub-system, the following issues have moderate or severe impact: Pollution; Chemical pollution and Spills, and Habitat and Community Modification; Modification of ecosystem-Neritic, Lagoon and Estuarine systems.

The increase of negative impacts from chemical pollution, oil spills and modification of ecosystems in the Kara Sea basin can be linked to the following root causes:

Economic

- Chemical pollution: market reform failures and failures in strategic forecasting;
- Oil spills: market reform failures, growth of corruption in the oil extraction sector and the domination of corporate interests over strategic ones;
- Modification of ecosystems: inadequate funding of environmental needs, poor integration of environmental protection problems with socio-economic planning, domination of corporate interests over strategic problems.

Technological

- Chemical pollution: use of obsolete industrial technologies, absence of modern air and water decontamination systems;
- Oil spills: use of outdated equipment in oil extraction and transportation, aging transport fleet, insufficient emergency services;
- Modification of ecosystems: use of outdated equipment in minerals extraction, aging transporting fleet, outdated technologies for industrial waste neutralisation).

Governance

- All issues: insufficient control over environmental conditions, weak enforcement of ecological regulations;

Public control

- Chemical pollution: weak local control, especially indigenous peoples, over chemical pollution levels;
- Oil spills: weak local control over water pollution from oil extraction and transport companies;
- Modification of ecosystems: weak local control over chemical pollution levels, especially indigenous peoples.

Education and knowledge

- Chemical pollution: insufficient awareness of the local population about the principles of sustainable development as stated in Agenda 21; poor or inadequate access to environmental information;
- Oil spills: insufficient knowledge on the part of the local population about the principles of sustainable development as stated in Agenda 21, poor or inadequate access to environmental information, lack of experience with large-tonnage tanker navigation under Arctic conditions;
- Modification of ecosystems: insufficient knowledge on the part of oil/gas administrators and the local population about the principles of sustainable development as stated in Agenda 21, poor or inadequate access to environmental information; poor or inadequate investigation into problems caused by chemical pollution in the Arctic seas ecosystems.

Legal

- Absence of sound regulatory and legislative systems for all activity in the region with regard to sustainable development.

Political

- Chemical pollution: absence of an effective system for combating transboundary air and water pollution;
- Modification of ecosystems: absence of international cooperative programs and projects that follow sustainable development principles in the Arctic region.

The Causal chain analysis showed that the root causes of the three issues identified above are very similar. Therefore the Policy option analysis was conducted for all three issues together. The policy options detailed for the problems with chemical pollution, oil spills and modification of ecosystems in the Russian Arctic region are based on the policies adopted at the World Summits on sustainable development held in

Rio de Janeiro (1992) and Johannesburg (2002). Russian legislation concerning environmental protection and sustainable development was also employed.

The main measures identified in the Policy option analysis are designed not only to preserve and restore the water ecosystems in the region, but also to reduce polluting substances in the air and water. Another goal is to aid the local population with its struggle with poverty, as well as to increase the level of education, while lowering the growth in costs of public health services.

Abbreviations and acronyms

AD	Autonomous Districts (or: autonomous okrugs)
AMAP	Arctic Monitoring and Assessment Program
BERPAC	A Program for Long-term Ecological Research of Ecosystems of the Bering and Chukchi Seas and the Pacific Ocean
BD	Bacterial Destruction
BP	Benzo(a)pyrene
CIS	Commonwealth of Independent States
DDT	Dichlorodiphenyltrichloroethane
DDE	Dichlorodiphenylethane
DDD	Dichlorodiphenyldichloroethane
GDP	Gross Domestic Product
GESAMP	Group of Experts on the Scientific Aspects of Marine Pollution
GIWA	Global International Waters Assessment
GOIN	State Oceanographic Institute
α-HCCH	alpha-hexachlorocyclohexane
γ-HCCH	gamma-hexachlorocyclohexane
IGCE	Institute of Global Climate and Ecology
MPC	Maximum Permissible Concentration
NSR	Northern Sea Route
Ocs	Organochlorine Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PHs	Petroleum Hydrocarbons
RAS	the Russian Academy of Sciences
RAZ	Russian Arctic Zone
RF	Russian Federation
RSFSR	Russian Soviet Federative Socialist Republic
SSAS	Synthetic Surface Active Substances
TIR	Total Initial Resources
USSR	Union of Soviet Socialist Republics
VOC	Volatile Organic Compounds

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Regional definition

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA Assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the region

The GIWA region Russian Arctic occupies a large part of the Russian Federation, extending about from Novaya Zemblya on the western edge to the Mys Dezhneva (East Cape) on the eastern one (Figure 1). The coastal parts of the Russian Arctic region include the entire territories

Figure 1 Boundaries of the Russian Arctic region.

Table 1 Physical, geographical and climate characteristics of the seas of the Russian Arctic region.

Sea	Area (km^2)	Volume (km^3)	Depth Average/Max (m)	Position	Water temperature Min/Max(°C)	Salinity Min/Max (PSU)	Average wind velocity (m/s)	Average air temperature Min/Max (°C)	Annual flow (km^3/year)
Kara	883 000	98 000	111/600	68-81° N/50-105° E	-1.7/6	5/35	5-7	-28 (March)/6 (July)	1 290
Laptev	662 000	353 000	533/3 385	71-81° N/105-140° E	-1.7/5	5/35	4-8	-29 (March)/5 (August)	720
East Siberian	913 000	49 000	54/915	69-79° N/140-180° E	-1.8/8	4/32	6-15	-30 (January)/3 (July)	255
Chukchi	595 000*	42 000*	71/1 256*	67-76° N/178° E-156° W	-1.8/8	24/34	4-8	-28 (February)/4 (July)	18 (72*)

*Note: *Russian and American part. (Source: Zalogin and Kosarev 1999)*

of the following parts of the Russian Federation: Nenets AD, Yamal-Nenets AD, Taimyr (Dolgan-Nenets) AD, Chukotski AD, and the Norilsk industrial complex of Krasnoyarskiy kray. In addition, the area also includes parts of some administrative districts of the Sakha Republic (Yakutia). The areas in the Sakha Republic that are included in this report are Allaihovsky, Anabarsky, Bulunsky, Nezhnekolymsky, and Ust-Yanskiy uluses.

This report considers only the central and eastern parts of the entire Russian sector of the Arctic. The western/European part of the Russian Arctic (the Barents Sea and White Sea) has been evaluated in the GIWA Regional Assessment 11 Barents Sea. However, because water and atmospheric transports from the western/European sector exert a significant influence on the condition of transboundary waters in the Russian Arctic region, information from GIWA region Barents Sea is in some cases provided.

The GIWA region Russian Arctic includes the following seas:

- Kara Sea;
- Laptev Sea:
- East Siberian Sea;
- Chukchi Sea (the Russian section).

The GIWA Task team agreed that the borders of the region should be the following: the southern border of the region lies along the borders of the drainage basins; the northern border is open as far as the limits of available information; the western border is the GIWA region 11 Barents Sea region, and the eastern border is the GIWA region 1b Arctic Greenland region (Figure 1). Parts of region´s drainage area are located in Kazakhstan and Mongolia. However, their influence is considerd to be of minor importance and therefore, they will not be discussed in this report.

The marine waters in the Russian Arctic region that are considered international waters according to the international laws and norms will be regarded as transboundary waters. The region is divided into two sub-systems: (i) Kara Sea, with two main drainage basins, the Ob and Yenisei; and (ii) Laptev Sea, East Siberian Sea and the Russian sector of the Chukchi Sea including their drainage basins. All of these river basins are situated in Russia and are therefore not considered transboundary.

Physical characteristics

Table 1 shows the physical, geographical and climate characteristics of the Russian Arctic region.

Environmental protection problems that are specific to Arctic and subarctic marine ecosystems are becoming more and more important in connection with the intensification of economic activities in the Russian Arctic region, especially in consideration of the high sensitivity of those ecosystems to anthropogenic impacts. The Arctic seas are characterised by long light period in summer and diminished solar radiation in winter, substantial freeze-up periods and thick, long-lasting ice cover, low water temperatures, foreshortened food webs, limited species diversity, and widespread long-living organisms with a high lipid content, which allows for the bioaccumulation of many toxic substances. Owing to the low water temperature, the rate of microbial degradation in the Arctic seas is not nearly as rapid as in the mid-latitudes, which is particularly problematic with respect to the accumulation of toxic pollutants in different components of marine ecosystems.

Another important problem is the fact that people in the Arctic regions consume fat-rich foods, which tend to accumulate organochlorine compounds with toxic, mutagenic and carcinogenic properties. In sum, the unique features of the Arctic environment aggravate the impact of anthropogenic factors and require that the pollutant discharges to the Arctic seas be immediately controlled, along with constant monitoring of the situation with an eye to controlling discharges, and an assessment of the region's ecological capacity.

Climate

Occupying just 5% of the world's oceans, and just 1.5% of their volume, the Arctic Ocean and its adjacent seas have a pronounced effect on the state of the Earth's climate and play a decisive role in many global processes. The Russian Arctic seas regulate the global carbon cycle since they are an important CO_2 source in the winter and a CO_2 sink in the summer. Recent assessments have shown that the Arctic is critically important in atmospheric CO_2 removal, both now and in the future (Moritz 1990, IPCC 1996, 2001). Figure 2 depicts the elements of global

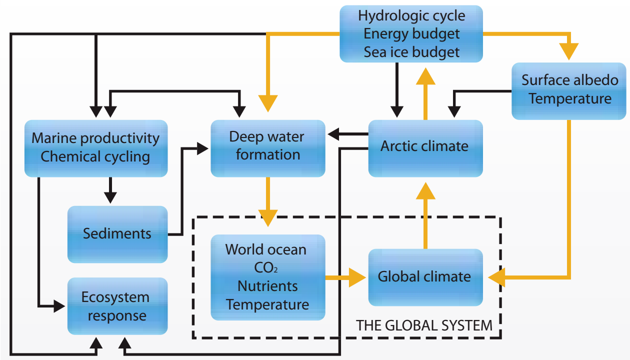

Figure 2 Global and Arctic marine climate systems.
(Note: Dashed lines: Global climate system. Solid lines: Arctic marine system. Causal linkages are indicated by black and feedback loops by yellow arrows.)
(Source: Arctic system science 1990)

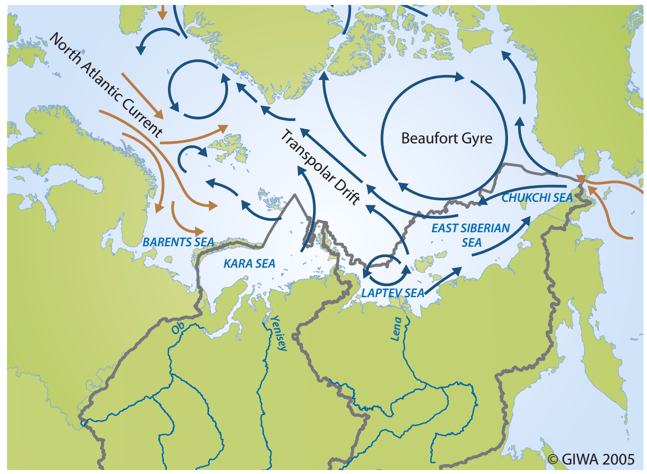

Figure 3 Surface ocean currents in the Arctic Ocean.
(Source: AMAP 1998)

climate systems and Arctic marine systems. The Russian Arctic seas also have a profound impact on many large-scale oceanographic processes, as they are a zone of deep ocean water formation and determine to a great extent the global hydrological cycle and atmospheric heat absorption (Figure 3).

The climate of the Russian Arctic region is characterised by a lack of solar radiation in the winter, which leads to very low temperatures. In contrast to winter, the summer is characterised by a significant solar radiation flux, but temperatures are not high because most of the incoming solar energy is expended in the melting of snow or ice. Atmospheric circulation is characterised by cyclonic activity in all seasons, which mediates the exchange of air masses between middle and high latitudes. The climate in the western part of the Russian Arctic is moderated by the Atlantic Ocean to a greater extent than the central and eastern parts because of the prevailing western atmospheric flows. The western Russian Arctic is the warmest part of the region and the temperature range between winter and summer is much lower than in the northeastern part of Russia, which is characterised by the most severe climatic conditions (Figure 4).

Rivers systems

Table 2 shows the main morphological characteristics of the largest rivers in the region. The greatest run-off volume is in the Kara Sea Basin (1 290 km^3). The Arctic seas in this region may be arranged in descending order of river run-off as follows: Kara Sea, Laptev Sea, East Siberian Sea, and Chukchi Sea. The largest rivers that empty into the

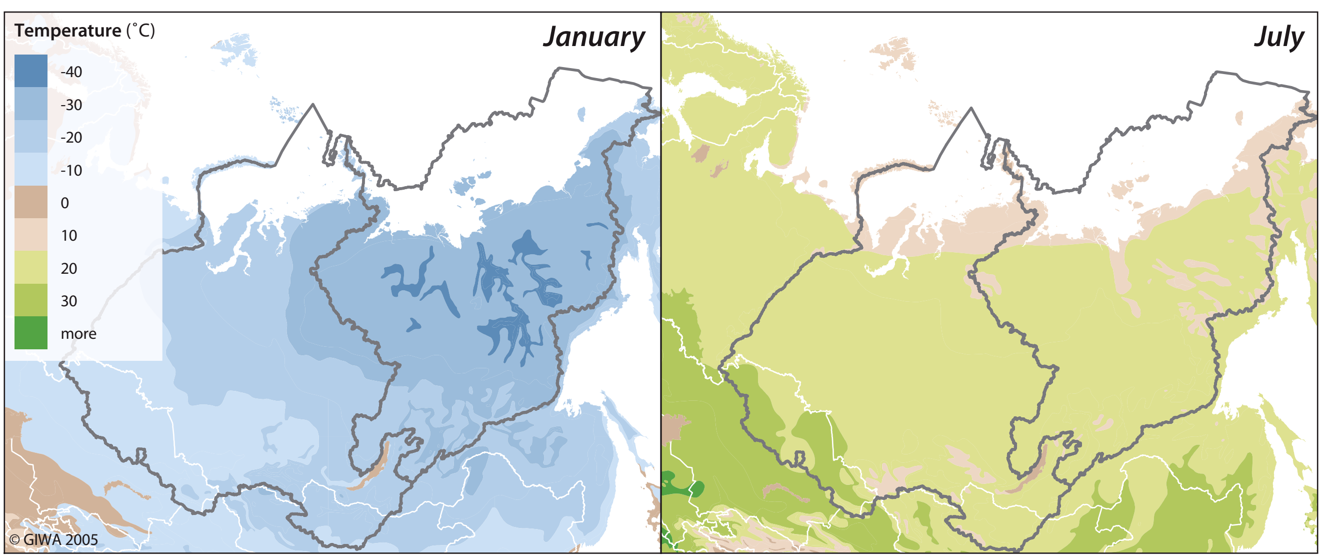

Figure 4 Summer and winter air temeratures in the Russian Arctic region.
(Source: ESRI 1996)

Table 2 Main river basins in the Russian Arctic region.

River	Basin area (km^2)	Length (km)	Annual flow (km^3)	Provision of water (m^3/year)	
				per km^2	per capita
Kara Sea					
Yenisei (with Angara)	2 580 000	3 844	585	244 200	221 500
Ob (with Irtysh)	2 470 000	3 676	403	178 600	54 400
Taz	150 000	1 401	33	ND	ND
Pur	112 000	1 024	29	ND	ND
Laptev Sea					
Lena	2 472 000	4 337	489	209 200	446 700
Anabar	100 000	939	17	ND	ND
Olenek	219 000	2 292	46	ND	ND
East Siberian Sea					
The rivers of the coastal area including:	1 098 000	-	255	232 300	952 500
Kolyma	644 000	2 150	83	ND	ND
Indigirka	360 000	1 790	38	ND	ND

Note: ND = No Data.

(Source: Roshydromet 1996a, b, 1997, 1998, 1999, 2000, 2001, 2002)

Laptev Sea are the Anabar, Olenek and Lena. Lena River is the second largest river in the region after Yenisei River, which drains into Kara Sea. Other large river basins in the Kara Sea drainage area are Ob, Taz and Pur rivers. The main rivers of the East Siberian Sea Basin are the Indigirka and Kolyma rivers. The water volume of the Kolyma River is more than two times that of Indigirka.

Socio-economic characteristics

In this report only the are coastal administrative units of the region are considered: Nenets AD, Yamal-Nenets AD, Taimyr (Dolgan-Nenets) AD, Chukotski AD, as well as the Norilsk industrial complex of Krasnoyarskiy Kray. In addition, the region also includes parts of some administrative districts of the Sakha Republic: the Allaihovsky, Anabarsky, Bulunsky, Nezhnekolymsky, and Ust-Yanskiy uluses. Most of Russia's indigenous population (northern minorities) lives in this zone. (Statistical data for the entire Republic of Sakha were used for characterising the uluses listed. Corrections to the data are based on unofficial information.)

The total land area included in the region equals 11.7 million km^2. The coastal administrative units have an area of 5.23 million km^2, which is nearly one-third of Russia's total area. If just the coastal uluses of the Sakha Republic (Yakutia) are taken into account, the area will be smaller and will amount to about 3.46 million km^2, or one-fifth of the total territory of the country (Table 3).

Natural resources

The borders of the Russian Federation Arctic Zone (RAZ) inlcude the GIWA regions Barents Sea and Russian Arctic. The borders were defined by the State Commission of the Council of Ministers of the USSR in 1989 and include the Exclusive Economic Zone and Continental Shelf of the Russian Arctic. The State Commission have recently prepared an evaluation of the law regarding RAZ which determined that the RAZ should also include the coastline, inland waters and territorial seas of the Russian Arctic coast.

The rich natural resources in the Russian Arctic region make the area an important part of not only of Russia's resource base but also the

Table 3 Characteristics of the coastal regions as compared to Russia.

Administrative unit	Territory		Population		GDP in 2000		Industrial production		Agricultural production	
	Area (km^2)	Part of Russia (%)	Total	Part of Russia (%)	(million RUB)	Total Russia (%)	(million rubles)	Total Russia (%)	(million RUB)	Total Russia (%)
Nenets AD	176 700	1.03	44 900		9 088.9		5 711		206	
Yamalo-Nenets AD	750 300	4.39	508 900		127 907.6		10 4915		316	
Taimyr (Dolgano-Nenets) AD	826 100	5.05	44 300		2 152		200		44	
Norilsk industrial complex[1]			200 000		133 000		99 800			
Republic of Sakha (Yakutia)	3 103 200	19.3	982 900		81 918.9		80 594		7 044	
Republic of Sakha (coastal Arctic uluses)	930 900	5.79	98 300		8 191.9		5 600		350	
Chukotski AD	373 700	4.32	73 800		4 128.6		2 929		108	
Total	5 230 000	33.0	1 854 800	1.3	358 196	5.71	294 149	5.0	7 718	0.8

Notes: [1]Norilsk industrial complex is located on territory Taimyr (Dolgano-Nenets) AD but is in administrative sub-ordination of Krasnoyarskiy kray.
(Source: Regions of Russia 2002)

world's. The Russian Arctic Zone (RAZ) includes substantial parts of well-known oil and gas provinces, for example Timano-Pecherskaya, Western Siberian, Lena-Tungusskaya, Hatango-Viluiskaya, Kolymo-Indigirskaya, Enisey-Lenskaya, Chukotsko-Alaskinskaya and Novosibirsko-Chukotskaya. The Nenets AD has 53.4% of the total initial resources (TIR) of oil, 38.9% of the TIR of gas, 12.3% of the TIR of gas condensate for all of the Timano-Pechora resources (Table 4). Giant gas fields in the Western Siberian province are an exceptional resource in the Arctic as a whole. These fields are situated mostly in the Yamal-Nenets AD. Most of these stocks are shallow, which makes it highly efficient to extract them (Granberg et al. 2000). The predicted resources of the northern regions of Krasnoyarsk territory (Taymyr AD) and the continental areas of Anadyrskiy and Hatyrskiy to as far south as the Chukot Peninsula are also shown in Table 4.

Table 4 Oil and gas resources in some areas in the Russian Arctic region.

Administrative unit	Total initial resources		
	Oil	Gas	Gas condensate
Nenets AD	13.76×10^{12} tonnes	2.4×10^{18} m^3	352.9×10^{18} tonnes
Western Siberian province (Yamal-Nenets AD)	2.5×10^{12} tonnes	30×10^{18} m^3	0.9×10^{9} tonnes
Northern areas of Krasnoyarsk territory (Taymyr AD)	3.2×10^{12} tonnes	14.6×10^{12} m^3	
Continental areas of Anadyrskiy and Hatyrskiy	0.5×10^{9} tonnes	250×10^{12} m^3	

(Source: Granberg et al. 2000, Oil and Capital 2001)

The region contains unique stocks and probable reserves of copper-nickel ores, tin, platinum less-common metals, and rare earth elements, as well as large stocks and probable reserves of gold, diamonds, tungsten, mercury, ferrous metals, optical raw materials and ornamental stones. The main mineral resources of the central and eastern parts of the RAZ are located in the following provinces:

- Taimyr-Norilskaya (copper-nickel ores, platinoids);
- Maymecha-Kotuyskaya and Udzhinskaya (phosphorus, iron, niobium, platinoids, diamonds);
- Taimyr-Severozemelskaya (gold, mica, molybdenum, tungsten, chrome, vanadium, polymetals);
- Anabarskaya and Yakutskata (diamonds, iron, rare metals);
- Verkhoyanskaya and Yano-Chukotskaya (tin, gold, mercury, tungsten, copper, molybdenum, silver, platinoids, polymetals).

The continental shelf and archipelagos in the RAZ contain stocks and probable reserves of almost all the categories of stream tin, gold and diamonds, silver, manganese, polymetals, fluorite and ornamental stones, titanium and zirconium (Barsegov et al. 2000).

Coal fields are also found in the region, for example in Taimyrskiy, Norilskiy coal areas of the Dolgano-Nenets AD, Lenskiy, Anabarskiy, Olenekskiy coal basins in the northern part of the Republic of Sakha, and the Anadirskoye and other coal fields of the Chukotski AD. Coal fields in the eastern part of the Russian Arctic are less explored and the demand for them is smaller than for the western ones. As a whole, the probable coal reserves of the RAZ are estimated at 780×10^{12} tonnes, including 81×10^{12} tonnes of coking coals.

The number of species and the total stocks of biological resources in the Kara Sea, the East Siberian Sea, the Chukchi Sea and the Laptev Sea are limited. Most of the marine catches in the RAZ is from the Barents and White seas, i.e. outside the GIWA Russian Arctic region. In these seas fish populations are to small to allow the establishment of a large industrial fishery. At the same time, these coastal areas, along with fish stocks in the region's rivers, are of great importance in supporting the small settlements of the Arctic coastal zone.

Big rivers tend to flow north-south through the territories of the central and eastern parts of the RAZ. On the one hand the rivers are a benefit: they provide transportation for the region as it lacks railway connections with the central regions of the country and with large sea ports. On the other hand, the rivers bring problems to the Arctic seas as they carry pollutants from the Ural regions, eastern and western Siberia, the Republic of Sakha and the Magadan region.

The national or Northern Sea Route (NSR) bears special importance for the region. This route passes through the Russian Arctic seas and connects Arctic areas of the Russian Federation with the coast. This route may someday become the shortest way to inter-connect centres of global economy such as the Asian-Pacific region, North America, and western Europe.

Population

The coastal administrative units of the region have a population of approximately 1.8 million people (0.9 million if only coastal Yakutia's uluses are included), which amounts to only 1.3% (0.68%) of Russia's total population (Table 3). The average population density in the region is very low (0.32 persons per km^2), with the highest value in the Yamalo-Nenets AD (0.68 persons per km^2). Because of the low ecological capacity of the tundra territories, settlement densities have only reached to the maximum density of 2 persons per 100 km^2 as compared to 17-18 persons per 100 km^2 in the forest-steppe zone (Myagkov 1995).

The current population of the Russian Arctic region includes an indigenous population (northern minorities), old settlers (the Russian

Figure 5 Indigenous people of the Arctic.
(Source: AMAP 2002)

population that has lived in the territory for several centuries in the Mezen region, the Ust-Russkoe region, and the Yakut population in the northern part of eastern Siberia) and newcomers, who settled the region mainly during the 20th century. The majority of newcomers are Russian, Ukrainian, and Belorussian. The indigenous population of the Russian north is composed of 30 northern minorities (about 200 million people). These minorities live in 27 territories of the Russian Federation. Eleven minorities live in the Arctic region: Saami, Enets, Nenets, Khants, Nganasans, Dolgans, Evens, Evenks, Chukchi, Eskimos, and Yukagirs. The Selkups, Chuvans, Mansi, Kets, and Koryaks live in the adjacent GIWA regions (Figure 5). For more information in the Arctic indigenous people in Russia see Annex V.

The regions of the northern Russian have always been characterised by intense migrational movement. Between 1970 and 1989 the direction of the flow was towards far northern Russia. The direction of these flows was mostly defined by the state policy of exploration of regions with extreme living conditions. The state encouraged the influx of people from different areas of Russia to the region for permanent or temporary residency.

Under the conditions of the USSR's planned economy there were regional and sectoral factors that resulted in an increase in wages as an incentive. The state also provided stable prices for consumer goods and services, periodic free round-trip travel for workers and members of their family to other areas of the USSR, and gave the children of these settlers privileges in terms of admission to institutes, as well as other incentives. These incentives encouraged long-term settlement, which is why those who came for temporary or short-term employment eventually became old residents and formed a constant staff base for the development of the regional economy and social infrastructure. While the total population of the Russian Federation between the 1970 and 1989 census increased by 13.4%, the population in the north increased more than 30% and in several of the mostly northerly regions (above the 61st parallel, in particular in the Yamalo-Nenets and Khanty-Mansiyskiy AD) it increased by four to six-fold. This growth was also connected with the exploration of the oil fields and the associated inflow of people (Barsegov et al. 2002). However, after the USSR's collapse, the region's population started to decrease. The population density is shown in Figure 6.

The dissolution of the Soviet Union was also marked by economic reforms that resulted in pay losses, uncontrolled privatisation, liquidation of people's savings, reduction in wages and back pay that took months to pay out, mass unemployment, and both reductions and instability in food and fuel delivery to the northern regions. This upheaval caused an intensive out migration of people both from the regions of the Russian Arctic region and from all the other areas and territories of the northern Russia. The region's extreme climate and remote nature meant that northern residents felt the economic and social impacts of market reform failures more acutely than in other parts of Russia. During the reforms, state support for northern regions was reduced. More than a million people left the sparsely populated northern Russia during the years of reforms. The average decrease in the population of the region was about 15-20% from 1991-2001. As a result, during the period from 1990-1991 until 2002 the population of Chukotski AD was reduced by 2.2-fold, while that of the Taimyrski (Dolgano-Nenets) decreased by 1.3-fold. During the same period the population of the Yamal-Nenets autonomous region increased by 1.6% (Table 5).

This seemingly anomalous increase can be explained by the immigration of people to regions with intensive oil and gas extraction. But a natural increase had also occurred as a result of relatively higher standards of living. Statistical information that summarises the region provides a clear view of the changes in the socio-economic conditions in the Russian Arctic region. However, frequent "spot" observations run the risk of emphasising the direction and acuteness of general

Table 5 Changes in population in the Russian Arctic region.

Administrative unit	1991	1996	2000	2002	Change (%)
Nenets AD	54 000	47 000	45 000	45 000	83.3
Yamal-Nenets AD	501 000	497 000	504 000	509 000	101.6
Taimyr (Dolgano-Nenets) AD	54 000	47 000	44 000	44 000	81.5
Republic of Sakha (Yakutia)	1 122 000	1 036 000	989 000	983 000	87.6
Chukotski AD	160 000	97 000	83 000	74 000	46.3

(Source: Regions of Russia 2002)

Figure 6 Population density in the Russian Arctic region.
(Source: ORNL 2003)

tendencies. For example the northern settlements of the republic of Sakha and the settelements of Chukotski are still experiencing a net outflow of people.

The decrease in birth rate, increase in mortality and in emigration are causes of the decrease in the population in the eastern part of the region during the last 10-13 years. The birth rate in these regions (number of births per 1000 population), which significantly exceeded the average level for the Russian Federation as a part of the USSR in the 1980s to the 1990s, is decreasing annually by 3-5% (Table 6).

Additionally, the mortality rate has increased in the region. For example, the number of people who died increased during the period of 1990-2001: in the Nenets AD the mortality rate increased 1.7-fold, in Chukotski AD, the increase was 1.8-fold , while in Russia overall, the average growth in the mortality rate has increased by 1.4-fold. The growth of mortality in children, including infants, is notable. During the last five years this mortality level has significantly exceeded the average level for Russia:

Table 6 Fertility and mortality rates in the Russian Arctic region.

Administrative unit	Fertility (births/1 000)			Mortality (deaths/1 000)			Infant mortality (deaths/1 000)	
	1990	1995	2001	1990	1995	2001	1998	2001
Nenets AD	16.7	12.4	13.0	7.0	11.7	12.2	19.5	20.1
Yamal-Nenets AD	16.3	13.1	12.8	3.3	6.4	6.1	14.6	15.6
Taimyr (Dolgano-Nenets) AD	15.6	11.4	13.0	6.7	10.7	10.1	16.2	24.3
Republic of Sakha (Yakutia)	19.6	15.3	13.6	6.8	9.8	10.0	19.7	17.5
Chukotski AD	14.3	9.8	10.6	3.9	8.6	7.1	33.1	42.1
Average for Russia	13.4	9.3	9.1	1.2	15.0	15.6	16.5	14.6

(Source: Regions of Russia 2002)

20.1 infants of every 1 000 born in 2001 in the Nenets AD died, while that number was 24.3 in the Taimyr (Dolgano-Nenets) AD (a number that has increased by 150% from 1998), and 42.1 deaths per 1 000 in the Chukotski AD (Regions of Russia 2002).

The migratory outflow over the last years has changed the ratio of the urban and rural populations in the region. Residents of cities and urban areas have left their homes, mostly because of unemployment. Indigenous peoples and old residents who raise deer, fish, trap, hunt and cultivate land stay in rural areas. The population loss is at the expense of urban residents. The share of the urban population out of the total population of the Nenets AD during 1991-2002 decreased from 63.1% to 60.8%; in the Taimyr AD from 66.5% to 63.9%; in the Republic of Sakha from 66.8% to 64.5%; and in the Chukotski AD from 72.5% to 68.4%. At the same time, the share of the urban population in the Yamal-Nenets AD increased by 0.1% because of the growth in the oil and gas industry. This autonomous district contains several large cities such as Salekhard (343 000), Noyabrsk (99 300), Novyi Urengoy (92 100), and Nadym (45 300). As is typical in the north, cities and villages are often located very far from each other, separated by great empty areas.

The negative impacts of the Russian reforms of the last decade have resulted in the growth of the social burdens borne by the political units of the region. The increase in mortality and migrational outflow in the last decade has led to a decrease in those who are employed and a decrease in real employment in the region. Young skilled workers tend to leave the region, while pensioners and women have stayed. Traditionally, there are fewer jobs for women than for men. For example, in the northern Tyumen region the ratio of jobs available for women versus men is one to 50 (Barsegov et al. 2002). However, the share of individuals employed in private enterprises and organisations has increased (Regions of Russia 2002).

Table 7 reflects the growth in the share of female and aged population in recent years. The table shows the growth in the population of the region that are older than employable age and who need municipal and regional subsidies that unfortunately cannot be paid for by government budgets.

The level of education of workers in the region is shown in Table 8. The population of the Nenets AD and Yamalo-Nenets AD is the most well-educated. The Chukotski AD has the lowest level of education, which corresponds to the dynamics of the demographic situation described earlier (Regions of Russia 2002).

Table 7 Gender and age structure of the population.

Administrative unit	Women per 1 000 men		Share of people older than employable age (%)	
	1991	2002	1991	2002
Nenets AD	932	1 052	8.5	13.2
Yamalo-Nenets AD	922	951	2.7	6.6
Taimyr AD	947	961	5.4	9.6
Republic of Sakha	986	1 018	7.1	10.7
Chukotski AD	917	920	2.8	10.1

(Source: Regions of Russia 2002)

Table 8 Level of education of employed population 2001.

Administrative unit	High and unfinished high (% of total)	Secondary professional (% of total)	Elementary professional (% of total)	Secondary general (% of total)	Elementary general (% of total)
Nenets AD	20.1	43.0	14.4	11.1	1.0
Yamalo-Nenets AD	20.3	35.3	30.5	14.0	0.1
Taimyr (Dolgano-Nenets) AD	20.0	25.9	8.4	34.6	1.8
Republic of Sakha (Yakutia)	23.5	33.8	11.1	20.8	0.6
Chukotski AD	17.5	39.0	16.6	21.2	1.7
Total for Russia	25.1	31.3	11.6	23.4	1.1

(Source: Regions of Russia 2002)

Economy

After a long decline during the first part of the 1990s, some growth has now been observed in the region's economy (Regions of Russia 2002). Incomes in the Russian Arctic region have been growing in recent years. In several districts, e.g. the Nenets AD and Taimyr AD, this growth is faster than the average for Russia during 1997-2001 (Figure 7). At the same time, the eastern areas have seen a slower growth in wages and a rate of growth that lags behind the average growth of wages in Russia,

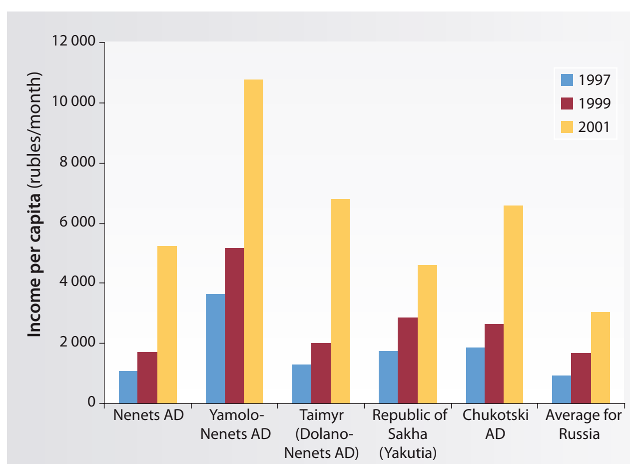

Figure 7 Income per capita in the Russian Arctic region as compared to the whole of Russia.
(Source: Regions of Russia)

even without adjustments for inflation and the increased prices for consumer goods. However, the region does benefit from high share of hidden wages (in the form of cash, insurance, natural and other kinds) in the average incomes per capita. This estimated share is about 21-29%.

Currently the GDP of the region is not high, only 3.59% of Russia's total GDP (if the GDP of the whole Republic of Sakha is included). If the GDP of just the Arctic uluses of the Republic of Sakha is used in the calculation, the GDP of the region totals to just 2.4% of the GDP of Russia. The region's share of industrial production is about 3.2% (2%), while its share of agricultural production is only 0.8%.

Great differences in income are typical in the region. The income level is much lower than in countries with a more developed market economy. This difference in incomes is higher between those who come to the region to work and have a stable income and indigenous peoples who live in less developed areas. According to the Russian Ministry of National Policy, the nominal incomes of northern indigenous peoples are two to three times lower than average for Russia. Because many native peoples lack the means to make a living, these peoples (Chukchi, Nenets, Komi and Khanty) are close to extinction. As a result, the aboriginal populations perceive markets as a negative force; which in turn results in a negative attitude towards newly arrived individuals, in particular entrepreneurs (Barsegov et al. 2000).

Table 9 Number and form of property of enterprises and organisations in the region.

Administrative unit	Number		Form (%)		
	1996	2001	State	Municipal	Private
Nenets AD	461	703	17.9	11.5	46.7
Yamalo-Nenets AD	9 086	9 694	5.5	10.0	72.8
Taimyr (Dolgano-Nenets) AD	515	688	23.1	15.7	38.3
Republic of Sakha (Yakutia)	17 455	20 260	20.1	0.1	64.6
Chukotski AD	1 216	1 607	18.8	20.1	47.2
Average for Russia			4.3	6.4	76.1

(Source: Regions of Russia 2002)

The growth in incomes results in an increase in demand for personal services, which in turn results in a net improvement in the quality of life. For example, the creation of paid service jobs in the Yamalo-Nenets AD (8 163 RUB per capita in 2001) and the Republic of Sakha (7 317 RUB per capita in 2001) significantly exceeds the average level for Russia (5 694 RUB per capita in 2001) (Regions of Russia 2002).

The current structure of the economy in the region is based on industry (10-12% of the total number of enterprises), construction (11-13%, with 27% for the Yamalo-Nenets AD), trade and food industry (12-15%, 24% for the Yamalo-Nenets AD), transportation (3.5-6%), as well as other sectors (Regions of Russia 2002). Table 9 shows the classification of enterprises and organisations by type. Private enterprises clearly dominate after the first phase of privatisation.

The share of unprofitable enterprises and organisations has decreased from 68% to 52% on average in the Arctic regions of the Russian Federation (Regions of Russia 2002). Investments in fixed capital have increased by 6-fold on an absolute and by 9-fold on a per capita level. The unemployment level is lower than is average for Russia, and shows an increase in demand for workers.

Industry

The industrial production sector is relatively well-developed in the Nenets and Yamalo-Nenets AD and falls mostly (95%) in the fuel sector (hydrocarbons extraction). In other districts construction materials production (Chukotski AD) and the food industry (Dolgano-Nenets AD) are dominant (Table 10). The highest level of oil extraction including condensate in the Timano-Pechorskaya oil and gas province (19.2 million tonnes, Nenets AD included) was reached in 1997. Current extraction rates have dropped to 11 million tonnes, or by a factor of 1.7. At present the Norilsk industrial metallurgical complex located in the territory of Taimyr (Dolgano-Nenets) AD provides up to 20% of nickel and cobalt, 65-70% of copper and about 100% of platinum metals extracted in the world (Anon. 1998).

Table 10 Industrial production in 2001.

Administrative unit	Industrial production (%)						
	Fuel	(Petro) chemical industry	Heavy machine construction, metal-work	Forestry, wood processing and pulp & paper	Construction material	Food industry	Non-ferrous metallurgy
Nenets AD	95	0	0.1	0.4	0	2.4	0
Yamalo-Nenets AD	96.5	0	0.7	0.1	0.5	0.6	0
Taimyr (Dolgano-Nenets) AD	0.04	0	0	0	0	0	99.8
Republic of Sakha (Yakutia)	11.8	0.7	14.7	4.7	0.8	2	0
Chukotski AD	6.2	0	21.5	8.7	31.7	11.5	0

(Source: Regions of Russia 2002)

Table 11 Navigation in the Russian Arctic 1985-2000.

	1985	1987	1989	1991	1993	1995	1997	1999	2000
Transport in the region (tonnes/year)									
Coastal transport	3 172 400	3302 400	2 953 300	2 431 600	1 519 300	839 600	739 300	706 700	780 000
Transit	38, 100	1 000	55 200	176 200	208 600	100 200	0	0	0
Export	2 569 300	2 765 600	2 800 400	2 194 300	1 284 800	1 372 000	1 180 400	860 500	804 600
Import	401 500	509 800	14 100	1 900	3 000	49 500	35 600	10 400	2 400
Total	6 181 300	6 578 800	5 823 000	4 804 000	3 015 700	2 361 300	1 945 300	1 580 200	1 587 000
Transport in the region (number/year)									
Freight vessels (number/year)	296	331	273	243	177	134	70	49	52
Transport runs (number/year)	1 115	1 306	928	811	463	309	220	155	169

(Source: Regions of Russia 2002)

Agriculture

Agricultural production in the region is very weakly developed, which is to be expected given the extreme climate conditions of the region. About 60-70% of the meat, potatoes and vegetables are produced on personal plots. The region's food requirements are met mostly by the costly "northern delivery" (the delivery of essential goods and fuel to the regions of the northern Russia) of food from central regions of the country. After the transition to a market economy (after 1991), the system for northern delivery that was supported by the planned economy was destroyed. Commercial organisations that were attracted by local authorities always fell behind in deliveries and exceeded contract amounts. This led to some emergencies.

In 1995 the Russian government issued a resolution concerning the organisation of delivery and transportation of products to support the economies and populations of the northern regions (No 450 from May 1995). It defined the obligations of executive bodies and organisations to deliver goods to sea and river ports on time, with an acknowledgement of the time required to ship goods, and the sometimes difficult nature of navigating and transporting goods in northern conditions. Nonetheless, deliveries continued to fail in 2001; but by 2002, the different companies providing river and sea transport had nearly met their goal. In 2003 deliveries to the Taimyr and Nenets AD was completed by the end of September.

Forestry, fisheries, and aquaculture

Because most of the territory in the region is located to the north of the Arctic Circle, there is no forestry. An industrial fishery in the seas of the central and eastern Arctic is essentially nonexistent. The seas are not sufficiently productive to support a commercial fishery, with the exception of the narrow coastal and embouchement areas. Nor has aquaculture been developed.

At the same time, the Siberian rivers (particularly those of the Kara Sea Basin) are of great historical importance in providing fish for the population. The rivers of western Siberia supply valuable roundfish (whitefishes, sturgeons and nelma), which amount to 40% of the total catch. Data shows that catches decreased in the 1990s in western Siberian rivers by more than three-fold as compared to the previous 40 year period (Luzanskaya 1970, Anon. 2000).

The western Siberian rivers that flow to the Arctic seas saw their annual average catch decrease from 10 000 tonnes in 1959-1966 (Luzanskaya 1970) to 2 000 tonnes in the 1990s (Anon. 2000). Scientists do not believe this decrease is due solely to the overexploitation of fish stocks. Part of the decrease is due to a decrease in fishing effort, mainly due to a declining regional economy. Fishing in rivers has never been highly profitable and it was sometimes supported with subsidies; the market reforms associated with the dissolution of the Soviet Union caused many of these small fisheries to go bankrupt.

Transport

As much as 1.5 million tonnes of cargo was shipped in 2000 along the Russia's Northern Sea Route (NSR). However this is four times less than was shipped 15 years ago, and the trend seems to be for the shipping rates to continue to decline (Table 11). The eastern part of the region is served by a smaller fleet than the western part. During the years of reforms, in the 1990s the number of vessels in the Arctic was reduced by a factor of 6, while the number of transport runs decreased by 10. Recently there has been a notable constant increase in transportation along the NSR, which reflects improvements in the country's overall economy (Andreev 2001).

The main supplier of cargo in the eastern part of the NSR is the Norilsk metallurgical plant, which sends and receives 0.9-1.2 million tonnes of cargo by river and sea via the port of Dudinka. At the end of the 1980s about 1.2 million tonnes of forestry-related cargo was transported along the NSR from Igarka, Lesosibirsk and Krasnoyarsk. But during the years of reforms, this traffic sharply decreased.

Tourism

Due to the extreme conditions and the distance from populated areas, tourism has not been developed in the region.

Economic development outlook

The outlook for economic development in the region is determined by its natural resource potential and the growing demand for raw materials in both domestic and world markets. The depletion of mineral fields in the mid-latitudes of the country and the associated price increase makes it more and more economic to exploit resources in polar lands and seas. This explains the growing interest on the part of Russian and foreign corporations in the fields found in the central and eastern territories of the region.

Some estimates for the Nenets AD predict that economic growth will mainly rely on the development of hydrocarbon stocks. Total resources in 75 fields that have already been discovered fields about 2 400 billion tonnes of oil and 1.2 billion km^3 of gas. Twenty-six fields are ready for industrial extraction with their proven stocks totalling about 525 million tonnes of oil and 511 000 km^3 of gas. The report "Energy strategy for Russia until 2020" from the Russian Federal Council (2002) assumes a growth in oil extraction in the Timano-Pechorsk oil -and gas province (which includes the Nenets AD) from a recent 11 million tonnes to 37 million tonnes by 2010. An estimated 10 milion tonnes is planned for extraction from the continental shelf. The Nenets AD contains 53.8% of the oil, 38.9% of the gas and 12.3% of the condensate in the province.

The Yamalo-Nenets AD has the largest gas fields in the developing world (every fourth cubic metre of all the world's gas is extracted from this area). There are 205 hydrocarbon fields located in the autonomous district, including world's largest, Urengoyskoye, Yamburgskoye, and Zapoliarnoye. Pipeline transportation is well developed and is continuing to be developed, with pipelines such as the "Northern Light" and the "Urengoy-Pomary-Uzhgorod-Western Europe". With the completion of the "Yamal-Europe" pipeline in 2020, the estimated annual supply of Yamal gas to Western Europe could reach $150x10^{12}$ m^3.

Along the Yamal Peninsula seaside some offshore moorings for loading tankers have already been built. The main one is in Harasavey township. This township is home to a tank port project, with the estimated turnover of condensed gas at about 20.9 million tonnes per year. The river ports of the region, such as Labytnangi, Salekhard and others are available to allow for the sea export of oil and gas. The development in the Yamal-Nenets AD of chromite ores, which are scarce in Russia, is also promising, with the estimated resources at about 700 million tonnes. The same is true for titanium-magnetite ores (32.8 million tonnes), and precious and semi-precious stones.

The outlook for economic development in Taimyr (the Dolgano-Nenets AD) is related to the development of the Norilsk industrial complex, which provides up to 20% of the world's nickel and cobalt, 65-70% of the world's copper and essentially 100% of the world's platinum metals. The northern Krasnoyarsk region, which includes Taimyr, in the Dolgano-Nenets AD, contains oil and gas regions (Yenisei-Khatanga, Anabaro-Khantanga and others) with estimated oil resources of about 3.2 000 billion tonnes and about 14.6 billion km^3 of gas and condensate. Gas extracted in this region now mainly supplies the Norilsk metallurgic plant (Gramberg et al. 2000).

The oil and gas potential of the arctic regions of the Republic of Sakha and Chukotka is not well known. The estimated supply in the Bering Sea basin (which adjoins Chukotka) is more than 16 000 billion tonnes of oil equivalent. Among the most promising issues for the development of the Chukotski AD is the extraction of non-ferrous metals: gold (up to 30 tonnes per year), silver, tin, tungsten, and coal (up to 800 000 tonnes per year). In the long-term, development of the oil and gas fields on the continental shelf will also be an option.

With the development of extracting industry in nearly the entire Russian Arctic region it is expected a growth of production volume in transporting, services sectors in traditional spheres of living of aborigines.

A significant growth in both sea and river navigation in this region is expected, given the following factors:

- The coastal eastern arctic zone of Russia includes existing and projected oil and gas, mining and metallurgic enterprises and attracts cargo traffic from other export-oriented companies from the Krasnoyarsk region, Yakutia, the Novosibirsk region and other regions in the Russian Federation that are located in the basins of the main north-south rivers.
- More than 30% of Russian timber, carving wood, cellulose and paper are made in the territories that can be served by the NSR. Sea and river transportation of forest cargo from Igarka, Lesosibirsk and Krasnoyarsk are planned to be restored to former levels (1.2 million tonnes).

- The growth of traffic via the port of Dudinka is expected: magnesite (200 000-350 000 tonnes), aluminium (up to 900 000 tonnes) from Angaro-Yenisei region, and coal from Yakutia and Kemerovo areas (up to 1 million tonnes).

The NSR is in many ways a possible international sea route. It connects the centres of the world's economy (the USA, western European and Asian countries). If the problems of year-round and seasonal ice pilotage, rescue, navigation and other problems are solved, the NSR will be able to serve as an international transport corridor. This will, on the other hand, increase the number of operating vessels that contribute to pollution. The potential transit through the NSR is estimated to be from 12 million tonnes in 2010 up to 50 million tonnes in 2020.

However, the use of the NSR for international trade at a broad scale is linked not only to solutions for the region's technical and economic problems but also with the solution of a complex of political, legal and environmental problems. A comprehensive international study is currently being carried out by the Norwegian Fridtjof Nansen Institute, which offers the hope that in the long run the NSR could become the most important route for of oil and condensed gas transportation from sea fields to markets in western Europe, North America (particularly Alaska), and Asian and Pacific countries. This magnitude of development will require supertankers and ice-class gas carriers. But the high costs of transportation along the NSR may also be a deterrent in the development of navigation in the Arctic regions of Russia (Andreev 2001).

International cooperation

In September 1996 eight Arctic countries signed the Ottawa declaration, which created the Arctic Council Board, an international forum for Arctic countries. This board is the most appropriate instrument for addressing Arctic pollution problems, in particular, the problems of sustainable development and Arctic environmental protection (Andreev 2001). The Arctic Council Board has been crafted to address the issue of sustainable development in the Arctic. This concept includes economic development, preservation and sustainable use of natural resources, social development and protection of Arctic ecosystems and biodiversity in this region. The Arctic Council Board does not have the status of an international organisation. The Arctic Board is a forum for Arctic countries. Joint activity is realised in accordance with the mandates of the eight countries.

The Arctic Council Board has tried to create a programme for sustainable arctic development. However the Arctic countries did not agree on the programme priorities. Subsequently, the Ikalyuitskaya declaration from September 1998 defined the programme of sustainable development in terms of seven independent projects. Integration of these projects will be realised by the Arctic Council Board. A working group was organised for the implementation of the separate projects.

The projects generally concern the control of various activities:

- A strategic approach to the control of sustainable development;
- The Arctic and the problems of sustainable development;
- The control of Arctic resources.

The strategy of the board has been to take a gradual approach in implementing this programme. An important role in this process will belong to the Working Group of the Arctic Council Board, as well as to regional scientific cooperators, non-governmental organisations of the Arctic indigenous population, and the international documents and agreements concerning the protection of indigenous civil laws and interests.

Aside from the Arctic Council Board, there are other international organisations, committees and programmes in the Arctic, such as International Arctic Science Committee (IASC), Arctic Environmental Impact Assessment (ARIA), Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Protection of the Arctic Marine Environment (PAME) and others. Their tasks are described in Annex III.

The protection of the environment in the Arctic is also regulated in association with many international agreements and laws (see Annex IV).

- The main trends in international cooperation for the protection of the Arctic environment are:
- Fulfilment of obligations connected with Russia's membership in different international organisations and conventions concerning the protection of the Arctic environment;
- Protecting the interests of the Russian Arctic region with respect to the activities of international organisations;
- Unification of efforts to solve global and regional ecological problems;
- The application of international experience in solving regional ecological problems;
- The attraction of foreign and international investments for the implementation of ecological investment projects, as well as projects that allow for the protection of nature (Andreev 2001).

Assessment

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.

Table 12 Scoring tables for the Russian Arctic region.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter).

IMPACT 0 No known impact; IMPACT 1 Slight impact; IMPACT 2 Moderate impact; IMPACT 3 Severe impact

The arrow indicates the likely direction of future changes. ↗ Increased impact; → No changes; ↘ Decreased impact

Kara Sea	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	0* →	1 →	1 →	0 →	0.5	5
Modification of stream flow	0					
Pollution of existing supplies	1					
Changes in the water table	0					
Pollution	2* ↗	1 →	2 →	2 →	1.8	2
Microbiological pollution	0					
Eutrophication	0					
Chemical	2					
Suspended solids	0					
Solid waste	1					
Thermal	0					
Radionuclides	1					
Spills	2					
Habitat and community modification	1* ↗	2 →	3 →	3 →	2.3	1
Loss of ecosystems	1					
Modification of ecosystems	1					
Unsustainable exploitation of fish	1* →	2 →	1 →	1 →	1.3	3
Overexploitation	2					
Excessive by-catch and discards	0					
Destructive fishing practices	0					
Decreased viability of stock	1					
Impact on biological and genetic diversity	0					
Global change	1* →	1 →	0 →	1 →	0.8	5
Changes in hydrological cycle	1					
Sea level change	0					
Increased UV-B radiation	1					
Changes in ocean CO_2 source/sink function	1					

Laptev, East Siberian and Chukchi seas	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	0* →	1 →	0 →	0 →	0.3	5
Modification of stream flow	0					
Pollution of existing supplies	0					
Changes in the water table	0					
Pollution	1* →	0 →	1 →	2 →	1.0	2
Microbiological pollution	0					
Eutrophication	0					
Chemical	1					
Suspended solids	0					
Solid waste	0					
Thermal	0					
Radionuclides	0					
Spills	1					
Habitat and community modification	1* →	1 →	3 →	3 →	2.0	1
Loss of ecosystems	1					
Modification of ecosystems	1					
Unsustainable exploitation of fish	0* →	1 →	1 →	1 →	0.8	4
Overexploitation	1					
Excessive by-catch and discards	0					
Destructive fishing practices	0					
Decreased viability of stock	1					
Impact on biological and genetic diversity	0					
Global change	1* →	1 →	0 →	1 →	0.8	3
Changes in hydrological cycle	1					
Sea level change	0					
Increased UV-B radiation	1					
Changes in ocean CO_2 source/sink function	1					

* This value represents an average weighted score of the environmental issues associated to the concern.

** This value represents the overall score including environmental, socio-economic and likely future impacts.

*** Priority refers to the ranking of GIWA concerns.

Freshwater shortage

Kara Sea **Laptev, East Siberian and Chukchi seas**

The three largest river basins in the region are Yenisei, Ob and Lena, the first two draining into Kara Sea and the latter into Laptev Sea. Other large river basins in the Kara Sea drainage area are Taz and Pur rivers. The main rivers of the East Siberian Sea Basin are the Indigirka and Kolyma rivers. The quiality of these water bodies is affected by industrial and domestic pollution such as wastewater and atmospheric emissions. The two issues modification of stream flow and changes in water table were both assessed as having no known impacts in the region and are therefore not further discussed.

Environmental impacts

Pollution of existing supplies

Kara Sea

Pollution of existing supplies was assessed to have a slight impact in the Kara Sea sub-system. The main rivers of the Kara Sea Basin are the Ob, the Pur, the Taz and the Yenisei. The Ob and the Yenisei are among the largest rivers in the Arctic. The quality of the water bodies in the Ob Basin is greatly affected by industrial atmospheric emissions, and the effects of forest tracts (often swamped), which enrich the water with a great amount of organic substances that do not dissolve easily, including phenols, and low- and high-molecular petroleum hydrocarbons. The downstream portion of the Ob is polluted by phenols, petroleum, and iron compounds (Table 13). The maximum concentrations found were 0.009 mg/l for copper, 0.15 mg/l for zinc, 1.75 mg/l for petroleum, and 0.085 mg/l for phenols (Roshydromet 1997-2002). It should be noted that the petroleum pollution levels in the vicinity of large industrial enterprises are lower than in the vicinity of intensive oil production. The main contributor to water pollution in the lower Yenisei River is the wastewater of the Podtesosk ship-repair yard, the Yenisei timber-rafting agency, the Lesosibirsk and Novoyeniseisk sawmills and wood-working integrated works, the Igarka timber transhipment integrated works, and the Igarka river port. The water is most polluted by petroleum, copper, zinc and iron (Table 13) (Roshydromet 1997-2002).

Laptev, East Siberian and Chukchi seas

Generally, no known impact of pollution of existing supplies was assigned to the Laptev, East Siberian and Chukchi seas sub-system. However, local impacts occur. The large rivers that empty into the Laptev Sea are the Anabar, Olenek, Lena and the Yana. The Lena is the second largest river in the Arctic after the Yenisei River (Figure 8). Wastewater from the Lenarechenergo, Lenzoloto, and Siberian Gold companies, and river crafts, ports, petroleum bases, and shipyards have a pronounced effect on water quality of the Lena River. The downstream waters are polluted by phenols, copper compounds, and zinc (Table 13) (Roshydromet 1996a, 1996b, 1997-2002). Waters in the Anabar River contain concentrations of copper compounds as high as 0.013 mg/l, as well as high concentrations of petroleum. The waters of the Yana are heavily polluted by phenols, and by copper, zinc, and iron (Table 13) (Roshydromet 1996a, 1996b, 1997-2002).

Table 13 Water pollution in some of the rivers in the Russian Arctic region.

River	Phenols (mg/l)	Petroleum (mg/l)	Iron (mg/l)	Copper (mg/l)	Zinc (mg/l)	Mercury (mg/l)
Ob	0.026	0.7	1.3	ND	ND	ND
Yenisei	ND	0.25-0.6	0.1-0.5	0.005-0.015	0.01-0.05	ND
Lena	0.002-0.007	ND	ND	0.001-0.012	0.01-0.03	ND
Yana	0.001-0.005	ND	0.1-1.1	0.002-0.009	0.01-0.04	ND
Kolyma	0.001-0.004	0.1-0.4	0.1-0.3	0.002-0.006	ND	ND
Indigirka	0.006-0.008	ND	0.1-1.8	0.002-0.007	ND	0.015

Note: ND = No Data.

(Source: Roshydromet 1996a,b, 1997, 1998, 1999, 2000, 2001, 2002)

The main rivers of the East Siberian Sea Basin are the Indigirka and the Kolyma. The water volume of the Kolyma is more than two times that of the Indigirka. The main pollution sources in the Kolyma River Basin are the wastewater from the gold mining industry, housing and communal services. The water is polluted by petroleum, phenols, copper compounds and iron (Table 13). Maximum concentrations of petroleum, phenols, and copper compounds amounted to 0.45, 0.016 and 0.011 mg/l, respectively (Roshydromet 1996a, 1996b, 1997-2002). The Indigirka River is polluted by phenols, copper compounds and iron (Table 13). Mercury was also found in the water with concentraions up to 0.015 mg/l. The maximum phenol concentration was 0.037 mg/l (Roshydromet 1996a, 1996b, 1997-2002).

Socio-economic impacts

The socio-economic impacts of freshwater shortage are not significant in the region. However, the GIWA Task team assessed economic and health impacts to be slight. There is no precise statistical evidence of diseases caused by pollution of freshwaters, but there are single records of diseases resulting from poor water quality (dysentery, hepatitis) in the Kara Sea sub-system There are no records of other social and community impacts in the region.

Conclusions and future outlook

Freshwater shortage is not a problem for the region under present conditions, and it is unlikely that it will become a problem in the near future.

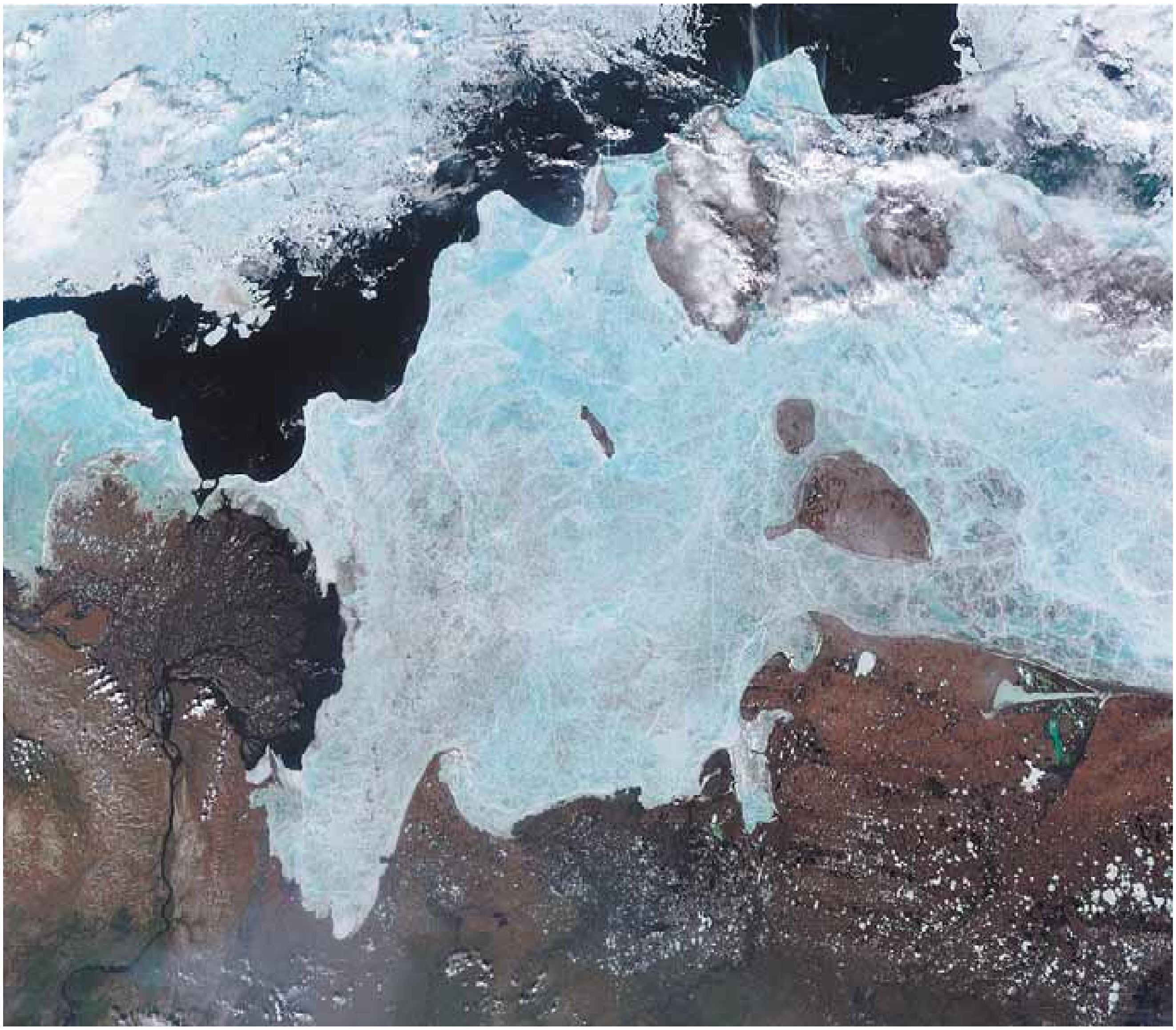

Figure 8 Lena River Delta and East Siberian Sea.
(Photo: NASA)

Pollution

IMPACT **Kara Sea** IMPACT **Laptev, East Siberian and Chukchi seas**

The current anthropogenic impact on the Arctic marine environment consists mainly of the increasing rate of pollutant transport from both local and regional sources. Anthropogenic activities in the Russian Arctic region causing pollution include:

- Direct dumping of waste from industrial, municipal, and agricultural enterprises situated on the coast;
- Burial of toxic material;
- Maritime accidents;
- Run-off via rivers from various land uses;
- Operation of transport facilities such as marine and river craft, aviation, timber rafting, road and pipeline transport;
- Mineral extraction;
- Atmospheric pollution from e.g. industries.

The large river run-off has substantial effects on the Arctic seas. This flow is the equivalent of about 10% of the total global run-off. Significant quantities of chemically reactive and biogenic material may be transported by the rivers. Human activities have significant direct and indirect consequences for the amount and timing of the run-off into the Arctic Ocean.

At present, large mining and smelting integrated plants (Pechenga-Nickel, Monchegorsk, Norilsk), many open pits and polygons, and an extensive network of pipelines are operated in the Russian Arctic region. In addition, 25 coal mines, five strip mines, more than 20 large mines and associated concentrating mills, 200 gold excavation and precious metal mining and hundreds of oil and gas wells are operated in the region. Carbon dioxide emissions in the Russian Arctic account for 33% of the total emissions from Russia's entire territory; emissions of copper, nickel, sulphuric acid, soot and chlorine account for 61, 88, 82, 23 and 40% of the country's total emissions, respectively. Oil pollution is becoming highly problematic in some bays and offshore regions of the Arctic seas (SB RF 1995).

Pollution sources

Mining and process industries make a significant contribution to environmental pollution in the Russian Arctic. They are sources of emissions containing sulphur dioxide, carbon and nitrogen oxides, ammonia, hydrogen sulphide, formaldehyde, phenol, benzo(a)pyrene, trace metals, dioxins, and polychlorinated biphenyls. The coal mining industry is a source of polycyclic aromatic hydrocarbons and a great amount of sulphur, nitrogen and carbon oxides, and trace metals. Wood processing industry complexes, especially integrated pulp-and-paper mills, discharge phenols, benzo(a)pyrene and formaldehyde.

Accidental oil spills associated with navigation, oil and gas production and exploitation on both the land and the Arctic shelf are a major issue for Arctic seas. As a result, there are practically no rivers in western Siberia that are free of oil pollution (MEPNR 1994, Roshydromet 1996a, 1996b, 1997-2002). Discharges of raw or inadequately purified wastewater also contaminate estuarine areas.

Table 14 shows areas most impacted by pollution in the Russian Arctic region as well as the adjacent GIWA region Barents Sea. Industries in the Murmansk and Arkhangelsk oblasts are a source of atmospheric and water contamination that is subsequently transported to the central and eastern Arctic regions. Due to the atmospheric and riverine transport of pollutants, the influence of the industrial centres can be seen over a substantial distance. This long-range transport has a pronounced effect on the state of marine ecosystems.

Atmospheric transport

The importance of atmospheric transport in polluting the world's oceans has only been recognised in the last few decades. For example, hundreds of thousand tonnes of lead compounds, and tens of thousand tonnes of chlorinated hydrocarbons, including PCBs, HCHs, dibenzodioxines and other toxic compounds precipitate from the atmosphere onto the ocean surface every year (Izrael & Tsyban 1989). Essentially all known contaminants have been found in the atmosphere above the Arctic. At the same time, there is relatively little specific data about these contaminants and their concentrations in the Arctic. Air samples have been collected by the Roshydromet background monitoring network (Rovinsky & Gromov 1996, Roshydromet 1997-2002) and in during different expeditions (Izrael & Tsyban 1992, Izrael & Tsyban 2000, Tsyban 1999, Bidleman et al. 1996, Chernyak et al. 1996).

The sources of air pollution above the Russian Arctic seas are primarily industrial centres, towns and settlements in the immediate vicinity of the seas. These sources, as a rule, are located in the western Arctic (Table 14). For example, every year, the following substances are discharged to the air (SB RF 1995, Igamberdiev & Tereshnikov 1994, Roshydromet 1997-2002):

- Murmansk region: 61 180 tonnes of solid substances, 12 070 tonnes of hydrocarbons, 1 140 tonnes of hydrocarbons and 10 tonnes of phenol.
- Arkhangelsk region: 55.3 tonnes of solid substances.
- Komi Republic: 138 800 tonnes of solid substances and dust.
- Taimyr Autonomous Area 29 700 tonnes of solid substances, 1 300 tonnes of nickel, 3 000 tonnes of copper and 44 tonnes of lead.
- Chukot Autonomous Area 13 700 tonnes of lead.

Atmospheric transport of dust and solid substances results in the deposition of materials of continental origin in the open areas of the

Table 14 Pollution impact areas in the Russian Arctic region.

Area (Industrial centres)	Pollution sources	Polluting substances
The Kola Peninsula (Murmansk, Nickel, Zapolarny, Monchegorsk, Olenegorsk) *	Metallurgy, mining industry, municipal sewage, nuclear power plants, transport and other	Trace metals, petroleum, PAHs, radionuclides, dust
Northern Dvina (Arkhangelsk, Novodvinsk) *	Pulp-and-paper industry, municipal sewage, thermal power plant and others	Phenols, petroleum, PAHs, chlorinated hydrocarbons, dust, trace metals, radionuclides
Timano-Pechersk	Oil and gas production, wood-working industry and others	Petroleum, phenols, trace metals, chlorinated hydrocarbons
Ob	Oil and gas production and others	Petroleum, phenols, chlorinated hydrocarbons, trace metals
Yenisei	Wood-working industry, river ports and others	Petroleum, phenols, chlorinated hydrocarbons, trace metals
Norilsk	Metallurgy, mining industry	Trace metals, PAHs, dust
Yana-Indigirka	Mining industry	Trace metals, radionuclides, petroleum, dust
Valkumeisk	Mining industry, thermal power plants	Trace metals, PAHs, radionuclides, dust

*Note: * Part of GIWA region 11 Barents Sea.*

(Source: SB RF 1995, MEPNR 1994, Roshydromet 1996a,b, 1997, 1998, 1999, 2000, 2001, 2002)

seas. They can also inhibit photosynthetic processes, resulting in the decreased transparency of the ocean's surface layers.

It is noteworthy that rather high concentrations of some pollutants have been found in the air above industrial centres in the Arctic. For example, above the Murmansk region industrial centres in the GIWA region Barents Sea, the benzo(a)pyrene (BP) concentration varied between 1.1 and 9.5 μg/m^3 while the concentration ranged from 1.2-2.0 μg/m^3 in the Chukchi Autonomous Area. It should be noted that BP possesses toxic, mutagenic and carcinogenic properties. BP also circulates actively in arctic ecosystems and accumulates in marine biota, including commercially valuable fish. Annually, about 1.4 tonnes of BP is transported to the Russian Arctic region, which represents 0.9% of the total emissions from CIS and Baltic countries (Izrael et al. 1992).

As a result of the long-range atmospheric transport of pollutants from industrial regions, the Arctic seas are contaminated when aerosolised pollutants are washed out of the atmosphere (Burova 1992). This is demonstrated in part by the contrast between HCH concentrations in the open regions of the Kara Sea, which were higher than those in offshore areas; a finding that can only be explained by atmospheric transport (GOIN 1996d).

The transport of air masses to the Arctic is complicated and highly variable. It is presumed that winter air masses come to the Arctic mainly from Eurasia, while in summer this flux moves in the opposite direction. Air masses also typically come from the northern regions of the Pacific (above Alaska) and Atlantic (from Greenland) Oceans. Thus, an important source of Arctic pollution is the long-range atmospheric transport of pollutants from the industrial zones of the northern hemisphere.

River run-off

River run-off plays one of the leading roles in the pollution of the Arctic seas. The huge catchment area and large water volume (70% of the total river run-off in the Russian Federation) means that river run-off transports a huge percentage of the Russian territory's total pollutant burden to the Arctic. This includes 65-75% of the organic matter, nitrogen, phosphorus, iron, and silicon compounds, 91% of petroleum, 95% of HCH isomers, 51% of DDT and 18% of DDE (Roshydromet 1996a).

The rivers of the region can be arranged in descending order based on their petroleum input to the Arctic seas (Roshydromet 1996-2002):
Ob River (Kara Sea); Yenisei River (Kara Sea); Anabar River (Laptev Sea); Lena River (Laptev Sea); Taz River (Kara Sea); Pur River (Kara Sea); Olenek River (Laptev Sea); Kolyma River (East Siberian Sea); and Indigirka River (the East Siberian Sea).

They can also be arranged with respect to organochlorine hydrocarbon (HCH, DDT, DDE) transport (Roshydromet 1996-2002):
Yenisei River (the Kara Sea); Ob River (the Kara Sea); Taz River (the Kara Sea); Anabar River (the Laptev Sea); Olenek River (the Laptev Sea); Lena River (the Laptev Sea); and Kolyma River (the East Siberian Sea).

Environmental impacts

Generally, the environmental impacts of pollution was assessed to be moderate in the Kara Sea sub-system and slight in the Laptev Sea, East Siberian Sea, Chukchi Sea sub-system. Specific impacts of the different pollution issues is discussed below. There are no records of microbiological, eutrophication or thermal pollution in the Russian Arctic region. There are either no obvious problems from water turbidity, suspended solids and associated limitation of water transparency. Solid waste was considered to have no known impact in the Laptev, East Siberian and Chukchi sub-system. These issues are therefore not further discussed. However, domestic solid waste and metal barrels pollute the shores of the Kara Sea Basin and these wastes can harm biological processes and ecosystems (GESAMP 2001). The issue was therefore considered to have slight impacts in this sub-system.

Chemical pollution

Water bodies in the region show minimal or insignificant chemical contamination. However, some chemical contaminants in the Kara Sea region are above Russian threshold limits. However, the existing level of pollution in the Laptev Sea, East Siberian Sea, Chukchi Sea sub-system is lower than the Permitted Marginal Concentration (state standards). Contaminant concentrations are described below.

Kara Sea

The Kara and Laptev seas play the leading role in the transport of ice and water masses in the Arctic. The largest Asian rivers, with catchment areas equal to almost half of the Russian territory, flow into the Kara Sea. The Ob and Yenisei river mouths create large estuaries where freshwaters mix with seawater. This freshwater influence can be traced hundreds of kilometres from the river mouths. The pollution sources for the Kara Shelf are the same as pollution sources for other Arctic seas. The largest Siberian rivers, the Ob and the Yenisei, carry a substantial amount of pollution to the Kara Sea. Almost 40% of the sea area is affected by continental freshwaters. Chemical monitoring data from the Roshydromet network (GOIN 1996d, Roshydromet 1997-2002) and the Arctic Monitoring Centre, show that trace metals and petroleum hydrocarbons are the most widespread pollutants in the Kara Sea.

According to GOIN (1996d) and Roshydromet (1997-2002) the mean DDT concentration was 0.27 ng/l in the range between 0.04 and 1.40 ng/l; the mean ΣHCH was 0.16 ng/l, with a maximum concentration of 0.37 ng/l found in the Baidarats Bay; and the mean PCB content amounted to 1.15 ng/l, with a maximum of 11 ng/l recorded in the Ob Bay. In 1995 the DDT concentrations in Kara Sea surface water varied from 0.03 to 2.5 ng/l. The maximum DDT concentrations (up to 249 ng/l) were found near Belyi Islands; maximum concentrations of HCHs (up to 2.25 ng/l) and of PCBs (up to 8.3 ng/l) were observed near the Ob Bay and near Cape Kharasavei (the southwestern sea), respectively (GOIN 1996d).

A one-time measurement of trace metal concentrations in Kara Sea surface waters in 1991 found lead, cadmium, and tin, and copper concentrations at tenths to hundredths of µg/l. Mn, Ni and Zn concentrations were found at several mg/l (GOIN 1992). Measurements in the coastal zone during the summer of 1992 found the following high concentrations (which reflect increased river discharges due to snowmelt and thawing ice): 58.8 µg/l of iron, 15.3 µg/l of zinc, 0.4 µg/l of lead, and 0.15 µg/l of cobalt (GOIN 1996a). In 1993 the highest concentrations were observed to the east of Belyi Island in the zone influenced by the Ob and Yenisei: 3.1 µg/l of manganese, 96 µg/l of iron, 0.5 µg/l of nickel, 1.9 µg/l of copper, 10 µg/l of zinc, and 0.07 µg/l tin; the Pyasina Bay showed the copper concentrations of 1.6 µg/l (GOIN 1996b). In 1994 the picture did not change: in the open sea the concentrations varied in the hundredths of mg/l for lead, cadmium, tin, and cobalt, in the tenths of µg/l for nickel, and in the tenths to whole units of µg/l for iron, manganese, copper, and zinc. Higher levels of trace metals were found in summer months in the areas of the Ob and Yenisei mouths (GOIN 1996c).

The levels of trace metal content of the seawater and bottom sediments of the Kara Sea are shown in Figure 9. It is noteworthy that higher concentrations of the pollutants in the water and bottom sediments were found in the estuaries of the Ob and Yenisei rivers as well as in the offshore area exposed to the river and terrigenous run-offs (Table 15) (GOIN 1996, Roshydromet 1997-2002).

The state of chemical water pollution in the offshore region of the Kara Sea has not changed appreciably in the last years. Toxic pollutants such as HCHs, DDTs and PCBs are found practically in all bays and estuarine zones. This fact causes serious concern in connection with the negative consequences of chronic impacts of contaminants on marine organisms.

The following concentrations of pollutants have been measured in precipitation above the central Kara Sea (expedition KAREX-94): 0.33-0.53 ng/l of α-HCH; 0.25-0.26 ng/l of γ-HCH; 0.35-0.95 ng/l of DDE; 0.07-0.33 ng/l of DDD; 0.10-0.44 ng/l of DDT; and 3.1-11.0 ng/l of PCBs (GOIN 1996c). The data presented confirm that pollution in the waters of the Arctic basin has resulted from long-range atmospheric transport, particularly in view of the fact that DDT has not been used in the Kara Sea Basin since 1977 (Roshydromet 1996a).

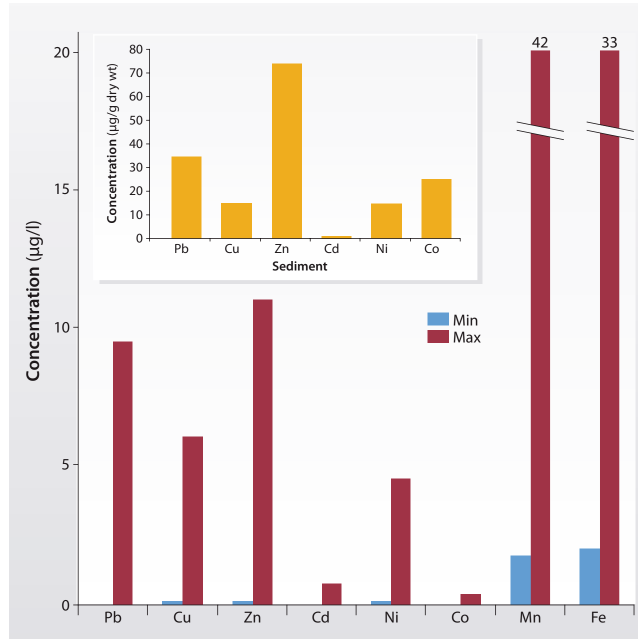

Figure 9 Metal concentrations in the Kara Sea waters and bottom sediments.
(Source: GOIN 1996, Roshydromet 1997,1998, 1999, 2000, 2001, 2002)

Table 15 Pollutants above maximum allowed concentrations in the Kara Sea sub-system.

Region	Above maximum allowable concentration								
	DDT	HCH	PCBs	PHs	Cu	Zn	Mn	Fe	PAHs
Yenisei Bay	√	√		√	√	√	√	√	√
Ushakov Island region	√								
Ob Bay		√	√	√	√	√	√	√	√
Pyasina Bay		√			√				
Taz Bay				√					
Baidarats Bay	√			√					
Yamal Coast			√						
Belyi Island region	√								
Kharasavei Cape			√	√					
Dikson				√					
Amderma				√					

(Source: GOIN 1996, Roshydromet 1997, 1998, 1999, 2000, 2001, 2002)

In air samples above the Chukchi Sea in the area of Vrangel Island, the α-HCH and γ-HCH content amounted to 73 and 20 pg/m^3, respectively (Jantunen & Bidleman 1995, Bidleman et al. 1995). In the western Arctic the PCB concentration reached 904 pg/m^3 in 1988 and 382 pg/m^3 in 1993; the DDT content was 38.00 and 34.82 ng/m^3, respectively (Hinckley et al. 1992, Izrael & Tsyban 2000). It should be noted that according to data from Bidleman et al. (1995), in the period from 1988 to 1993 the HCH content of the atmosphere above the Bering and Chukchi seas declined considerably while the HCH concentration in these seas has remained relatively unchanged since the early 1980s. The Arctic seas are currently losing their function as an HCH sink and are becoming a new HCH source for the Arctic (Bidleman et al. 1995).

Discharges of trace metals from the non-ferrous metallurgy industry make a substantial contribution to both air and ocean pollution in the region. In Norilsk (see Figure 13), for example, respectively 2 800, 1 250 and 68 tonnes per year of copper, nickel and cobalt have been emitted (Rovinskiy & Gromov 1996).

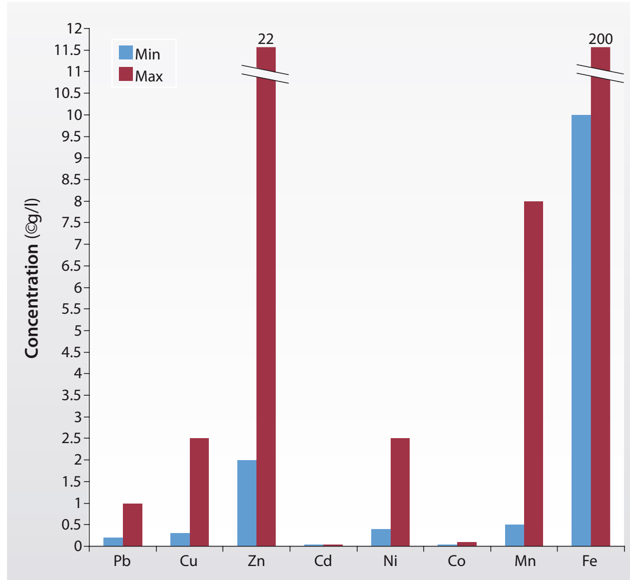

Figure 10 Metal concentrations in Laptev Sea waters.
(Source: GOIN 1996, Roshydromet 1997,1998, 1999, 2000, 2001, 2002)

Laptev, East Siberian and Chukchi seas

Because of its geographical position and hydrologic conditions, the Laptev Sea qualifies as a continental margin sea. Most of the sea is shallow; half its total area is no deeper than 50 m. The shelf regions of the sea are polluted by a number of inland activities, including oil and gas exploration and production, inland water and sea transport, ore mining and processing enterprises, accidental oil spills, floating and sunken wood, and discharges and effluent from towns and settlements situated on the coast and along rivers. River run-off and atmospheric transport play an important role in marine pollution.

Phenol concentrations in the Laptev Sea are the highest of all Arctic seas (GOIN 1996d, Roshydromet 1997-2002). The highest phenol concentrations (up to 65 mg/l) are typical for coastal areas, that are under the influence of floating and sunken wood. In 1991 the concentrations of ΣHCH amounted to 17 ng/l (GOIN 1992). In 1992 the highest concentrations of ΣDDT (up to 0.9 ng/l) were found in the region of the northern lands, while the highest concentrations of ΣHCH and ΣPCB were observed near the Novosibirsk Islands and in the Vilkitsky Strait, respectively (GOIN 1996a). In 1993 the DDT content was 2.7 ng/l in Khatanga Bay and 1.3 ng/l near the Novosibirsk Islands; the HCH concentration amounted to 1.2 ng/l near Little Taimyr Island and 2.9 ng/l in the Shokalsky Strait; and the PCB content was 5.5 ng/l near Stolbovoi Island, 4.5 ng/l in Anabar Bay and 4.5 ng/l in Olenek Bay (GOIN 1996b). The average content of the DDT group amounted to 0.2 ng/l (varying from 0.01 to 1.20 ng/l), and the HCH and PCB concentrations varied from 0.3 to 1.0 ng/l and from 2.4 to 7.0 ng/l, respectively. The highest pollution levels were found in the estuarine areas, in the Zarya Strait and near the Novosibirsk Islands (GOIN 1996, Roshydromet 1997-2002). The water concentrations of trace metals in the Laptev Sea are presented in Figure 10.

The East Siberian Sea is a marginal sea fully situated on the continental shelf. Water depths of 20 to 25 m predominate. The sources of water pollution in the East Siberian Sea, as in other Arctic seas, are marine and inland water transport, depots of combustible materials and lubricants, refuelling points, mining enterprises, towns and settlements situated on the sea coast and along rivers, transport of contaminants by air fluxes and Arctic ice, accidental spills, sunken wood, etc. According to routine statistical data collected over the last decade (GOIN 1996, Roshydromet 1997-2002), about 300 kg of oil, about 18 000 tonnes of particulate matter, 215 tonnes of sulphates, 83 tonnes of chlorides, about 980 kg of nitrates, and 167 kg of fats were discharged in the Chaun region of the East Siberian Sea. A broad spectrum of trace metals was discovered in the water and bottom sediments of the East Siberian Sea, with iron and zink being the main pollutants (Figure 11).

The Chukchi Sea is also a marginal sea, where depths of 40 to 60 m predominantly. The maximum depth is 1 256 m. The Chukchi Sea, with a high biological productivity and high species diversity, is one of the unique regions of the world's oceans. Additionally, because the area receives a substantial flux of carbon dioxide from the atmosphere, the Chukchi Sea plays an important role in shaping the Earth's climate. The

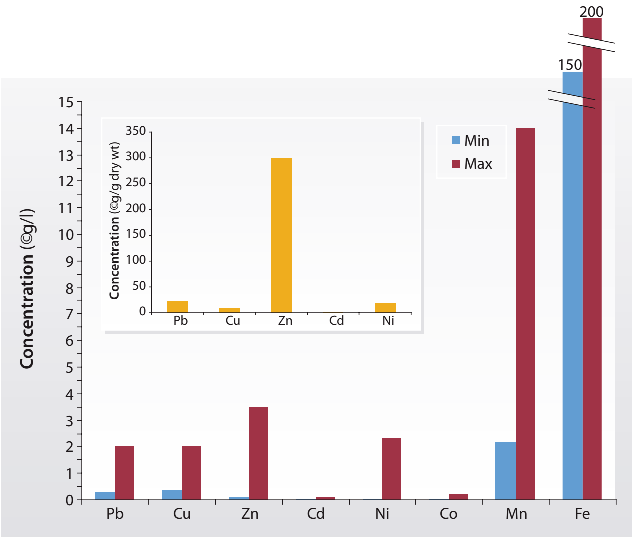

Figure 11 Metal concentrations in East Siberian Sea waters and bottom sedimets.
(Source: GOIN 1996, Roshydromet 1997,1998, 1999, 2000, 2001, 2002)

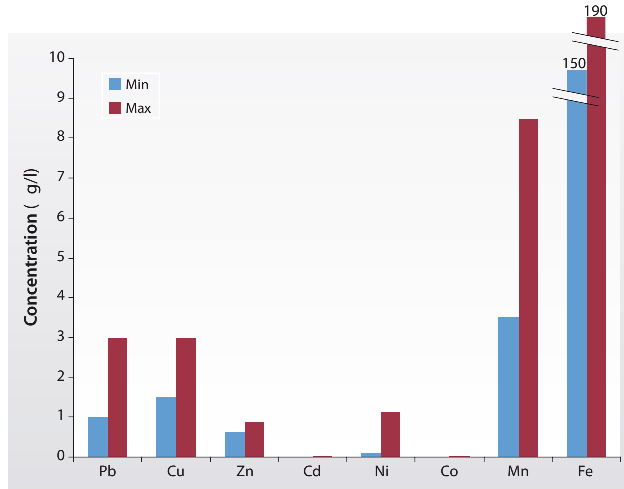

Figure 12 Metal concentrations in Chukchi Sea waters.
(Source: GOIN 1996, Roshydromet 1997,1998, 1999, 2000, 2001, 2002)

coastal waters of the Chukchi Sea are polluted by local sources, such as sewage from settlements, ships, accidental spills of combustible materials and lubricants, and decaying sunken and floating wood. According to routine statistical data collected over the last decade (GOIN 1996, Roshydromet 1997-2002), 200 kg of oil, 105 tonnes of particulate matter, 48.5 tonnes of sulphates, 65 tonnes of chlorides and 2 462 kg of nitrates have been discharged from the Russian territory (from the Schmidt Region alone) into the coastal zone of the Chukchi Sea. The open sea is mainly polluted by the transport of contaminants in the air and Arctic ice.

In spite of the considerable remoteness of the Chukchi Sea, heavy metals, aromatic and chlorinated hydrocarbons, and new contaminants (endosulfan, bromoform, dibromomethane, etc.) have been discovered over the last few years in all the main components of its ecosystems. Figure 12 shows a broad spectrum of trace metals in the surface waters of the Chukchi Sea.

A study of the chemical regime in the Chukchi Sea over the past decade (Izrael & Tsyban 1992, Tsyban 1999, Izrael & Tsyban 2000, Roshydromet 2001) has shown that the distribution of organic pollutants is becoming more and more pronounced from year to year. At the present time, it is believed that hexachlorocyclo-hexanes (HCHs) rank among the most widespread chlorinated pesticides in the Arctic seas (Bidleman et al. 1995). For example, the HCH content of water samples in Chukchi Sea waters exceeds that of other chlorinated hydrocarbons, such as polychlorinated biphenyls (PCBs) and DDTs (Table 16). While the atmospheric concentration of HCH isomers has decreased considerably, the α-HCH content of the sea water has remained unchanged for the last 5 years and that of γ-HCH has decreased 4- fold. Table 16 shows that the α-HCH accumulation in the bottom sediments is growing while that of γ-HCH has decreased pronouncedly, probably owing to biodegradation (Hinckley et al. 1992, Izrael & Tsyban 2000).

Data from a long-term investigation of the HCH distribution in the waters of the Chukchi Sea and Bering Sea show that the HCH concentration in Arctic seas has remained relatively constant since the early 1980s, while its atmospheric concentration has decreased considerably (Jantunen et al. 1995, Bidleman et al. 1995). These authors indicate that the Chukchi and Bering seas are losing their function as a HCH sink and are becoming a new HCH source to the Arctic atmosphere.

Table 16 Chlorinated hydrocarbons in the Chukchi Sea.

	Region	Water (ng/l)		Air (pg/m³)		Sediments (ng/g)	
		1988	1993	1988	1993	1988	1993
α-HCH	Western part	2.33	2.22	212	70	0.92	ND
	Eastern part	2.41	2.43	214	74	0.27	0.43
	Vrangel Island	ND	2.07	ND	73	ND	ND
γ-HCH	Western part	0.59	0.16	57	20	0.21	ND
	Eastern part	0.61	0.15	57	19	0.11	0.02
	Vrangel Island	ND	0.14	ND	20	ND	ND
DDT	Western part	0.003	0.08	38.0	34.8	3.49	ND
	Eastern part	0.004	0.095	ND	32.4	0.14	0.60
	Vrangel Island	ND	0.17	38.0	46.9	ND	ND
PCB	Western part	0.43	0.63	904	382	13	ND
	Eastern part	0.55	0.56	904	550	8.7	16.3
	Vrangel Island	ND	0.50	ND	ND	ND	ND

Note: ND = No Data.
(Source: Hinckley et al. 1992, Izrael and Tsyban 2000)

Pollution of the Chukchi Shelf by polychlorinated biphenyls (PCBs) is of major concern. Although their atmospheric content decreased in 1993 as compared to that of 1988, the water concentrations of these toxics remained unchanged. The PCB content of the bottom sediments has increased two-fold from 1988 to 1993, from 8.7 to 16.3 ng/g (Hinckley et al. 1992, Izrael & Tysban 2000). This fact demonstrates the accumulation of organochlorines in Chukchi Sea ecosystems. It is noteworthy that the long residence time of these compounds (several decades) in the marine environment determines their active circulation along food webs and accumulation in marine organisms, including commercial species. For example, the coefficients of PCB accumulation in particulate matter, plankton and neuston samples amounted from 100 to 10 000. Substantial accumulation of all chlordane components (50-100 ng/g of fat) has been found in the zooplankton samples (Hinckley et al. 1992, Izrael & Tysban 2000).The following chlorinated hydrocarbons have been found in Chukchi Sea ice: 34 ng/l of HCHs, 0.016 ng/l of DDTs, and 0.9 ng/l of PCBs (Hinckley et al. 1992, Chernyak et al. 1996).

New non-natural contaminants like endosulfan, bromoform, dibromomethane, and chloroiodomethane; as well as the pesticides chloropyriphos, chlorothalonil, phenvalerate, trifluarin have been found in the near-to-surface air layer, in fog and in Chukchi Sea waters (Chernyak et al. 1996). Their arrival is associated with long-range atmospheric transport.

In spite of the fact that many countries have limited or banned DDTs since the 1970s, these compounds are widespread and are found in many marine ecosystems owing to the combination of their long-term use and the long-range atmospheric transport of pollutants. For example, in 1988-1993 the pp'-DDT content of the Chukchi water ranged from 0.003 to 0.095 ng/l (Table 16). However, in 1993 concentrations were 20 times higher than in 1988 (Hinckley et al. 1992, Izrael & Tysban 2000). The maximum concentrations of DDT (like those of α- and γ-HCH) in the Chukchi Sea were found in the coastal waters of Alaska. Of special concern is the fact that DDT continues to accumulate in the sea bottom sediments. The coefficients of DDT accumulation in particulate matter and in zooplankton amount to 100-1 000 and 10 000-100 000, respectively. It should be noted that such hydrophobic substances as DDTs and highly chlorinated PCBs are absorbed by particulate matter and are easily transferred from the surface layers of the ocean to the depths.

A study of Chukchi Sea chemical pollution conducted by Institute of Global Climate and Ecology (IGCE) specialists used indicator organisms to evaluate the ecosystem. In the Chukchi Sea, the presence of these organisms remains low, but their distribution has expanded every year, and currently they can be found nearly everywhere (IGCE 1996).

Radionuclides

Radioactive contamination has resulted from three primary sources: atmospheric nuclear weapons testing during 1950-1980; releases from European nuclear reprocessing plants e.g. Sellafield, which peaked in the mid-1970s; and fallout from the Chernobyl accident in 1986 (AMAP 1997). There are no evident data on high concentration of radionuclides in the region (AMAP 1997, 2002). From 1992 to 1994, a joint Norwegian-Russian expert group sampled water, sediments and biota in the Barents and Kara seas (including the region of Novaya Zemlya). The results show that there is no significant contamination of the Kara Sea. In fact, the levels of radionuclides in the water are lower than in many other marine areas, such as the Irish, Baltic and North seas (AMAP 1997).

Spills

It is mainly the coastal areas of western Siberia that are exposed to oil spills. One of the main reasons for these spills is that about half of the petroleum pipelines in the region have not been maintained properly. Pipelines in western Siberia burst as often as 35 000 times per year. Only about 300 of these pipeline bursts are officially registered. Each burst pipeline discharges about 10 000 tonnes of oil. Different estimates put the total volume of the oil lost to the water at about 3-10 million tonnes from the time when oil was first exploited in the region. For example, 100 000 tonnes of oil was lost as a result of the Usinsk oil disaster, polluting about 60 km^2 (Barsegov et al. 2000). The planned growth of mining on the continental shelf of the Arctic seas will aggravate pollution problems situation in the western parts of the Kara and Chukchi seas.

Kara Sea

Navigation, oil and gas production and exploitation frequently result in oil spills in the sub-system. As a result, there are practically no rivers in western Siberia that are free of oil pollution (MEPNR 1994, Roshydromet 1996a, 1996b, 1997-2002). The Kara Sea Basin is a region that is constantly subjected to oil pollution, from both ongoing oil spills and oil that washes from the shores. Equipment is aging, obsolete technologies are in use and safety requirements for oil production are not abided by.

Trace metals and petroleum hydrocarbons are the most widespread pollutants in the Kara Sea, according to the chemical monitoring data of the Roshydromet network (GOIN 1996, Roshydromet 1997-2002) and the Arctic Monitoring centre. In 1991-1992 in the open Kara Sea, the content of petroleum hydrocarbons (PHs) ranged from 0 to 20 µg/l, while in the Baidarats, Ob and Taz bays, it did not exceed 50-70 µg/l. The Maximum Allowable Concentration (MAC) was exceeded at Cape Kharasavei (up to 92 µg/l) and near the Arctic settlements of Amderma and Dickson (above 200 µg/l) (GOIN 1996a). A lower concentration of

Figure 13 Nickel foundry at Norilsk, Russia.
(Photo: Arcticphoto)

petroleum hydrocarbons (PHs) was observed in 1993-1994, but in the Ob Bay in 1994 a concentration of 100 mg/l was observed (GOIN 1996c). Currently, the mean concentration of PHs amounts to 24 µg/l, with a maximum concentration found in Yenisei Bay (105 mg/l) (GOIN 1996, Roshydromet 1997-2002).

Laptev, East Siberian and Chukchi seas

In 1991 in the Laptev Sea, oil pollution was estimated to be at about 15-20 µg/l; the concentrations of petroleum hydrocarbons exceeded the MACs in Tiksi Bay (70 µg/l), Bugor-Khaya firth (a lane route) (130 µg/l), and in Olenek Bay (80 µg/l) (GOIN 1992). In 1992 the concentrations of petroleum hydrocarbons varied within narrow limits (12-39 µg/l) and only in Bugor-Khaya firth the maximum level (up to 200 µg/l) (GOIN 1996a). In 1993 the level of petroleum hydrocarbons in the Laptev Sea did not exceed the MACs (GOIN 1996b). The measurements carried out in recent years have found an average concentration of petroleum hydrocarbons of 17.1 µg/l in the open waters and up to 114 µg/l in Bugor-Khaya firth (GOIN 1996, Roshydromet 1997-2002).

The average concentration of petroleum hydrocarbons in the East Siberian Sea in 1991 amounted to 16 µg/l (a maximum of up to 50 µg/l was found in Chaun Bay) (GOIN 1992). In 1992 the PHs content somewhat increased (up to 27 µg/l), with maximum concentrations (up to 80 µg/l) observed near the Novosibirsk Islands and Wrangel Island (GOIN 1996b). Currently, oil pollution in the East Siberian Sea has stayed at approximately at the same level (GOIN 1996, Roshydromet 1997-2002).

In all the components of the Chukchi Sea ecosystems, benzo(a)pyrene (BP) - an indicator of carcinogenic polycyclic aromatic hydrocarbons (PAHs) - has been found. Some PAHs, for example BP, easily convert to mutagenic and carcinogenic epoxydiols, which interact with DNA. In the last few years the BP concentrations in Chukchi seawater have been 0.01-0.5 ng/l and 0.01-0.6 ng/l in the surface and bottom layers respectively. The average BP content of the bottom sediments has reached 2.28 mg/kg. However, the coefficients of BP accumulation in particulate matter and in biota have proved to be rather high (Izrael & Tsyban 1992, Tsyban 1999, Izrael & Tsyban 2000, Roshydromet 1997-2002).

The lowest mean oil pollution level for the Arctic seas, 7.2 µg/l, was observed in 1991, according to the data of the Roshydromet chemical monitoring network. In 1992 it amounted to 10.5 µg/l, the maximum of 20 mg/l was observed in the southern sea near the Chukchi Peninsula coast (GOIN 1996a). In 1993 near the settlement of Vankarem, the concentration of petroleum hydrocarbons amounted to 40 µg/l, although the general oil pollution level in the sea was low (GOIN 1996b). At the present time, the oil pollution in the different areas of the Chukchi Sea has remained at approximately the same level (GOIN 1996, Roshydromet 1997-2002).

A serious concern is also raised by the existing projects that involve the prospecting for and production of oil and gas on the Chukchi continental shelf. Exploration and industrial drilling for oil and gas production on the shelf result in a number of anthropogenic factors that affect the state of pelagic and bottom ecosystems, beginning with the hazardous consequences of seismic prospecting and the pollution of water and bottom sediments by drilling fluids and slurries, and ending with oil, copper and other metal pollution.

Socio-economic impacts

Economic impacts were considered slight in the Kara Sea sub-system. Economic impacts relate to the lack of funding needed to reconstruct and modernise water treatment plants to decrease the pollution of rivers of western and eastern Siberia. These problems are mainly linked to the general economic conditions in Russia, which are more problematic in the northern parts. After 1990, an abrupt decrease in production, reduction of investments, and an increase in consumer costs occured. A score of no known economic impact was assigned to the Laptev , East Siberian and Chukchi seas sub-system.

Health impacts were moderate and slight in the Kara and Laptev, East Siberian and Chukchi seas sub-systems respectively. The human health situation in the Arctic region in general is poor. Morbidity directly connected with chemical pollution of the catchments that drain to the Arctic seas (especially in the Kara Sea sub-system) is particularly troubling. Nowadays some Arctic regions (Pechenga-Nickel, Monchegorsk, Norilsk etc.) are referred to as ecologically unstable. Agricultural products and wild berries that come from these regions may contain higher-than-acceptable concentrations of heavy metals and other pollutants. Petroleum contamination and heavy metals spoil the quality of river and lake fish (Yevseev 1996).

The migration of pollutants in food chains (both terrestrial and aquatic) often results in the accumulation of these pollutants at a higher trophic level. For example, large numbers of deer meat deliveries from western Siberia to Scandinavian countries have been rejected as unacceptable because of higher-than-acceptable levels of heavy metals (Vilchek 1996).

The pollution problem is most acute in the region's large industrial cities such as Norilsk and Vorkuta. Residents of these cities, mostly children, are subject to chronic diseases such as bronchitis, pneumonia, lung cancer, bronchial asthma, and allergies. Women have had pregnancy complications. Heavy metals and PAHs are strongly mutagenic. In Norilsk the frequency of congenital defects in infants is 11.2 per 1 000 (the Russian average is 6 to 8). In addition to the unstable ecological situation, a decrease in living standards, a change for the worse in medical care, changes in the traditional way of life and nutrition patterns, all result in a growth in morbidity and mortality, including in children (Revich 1994). The mortality rate from different diseases in the region is 2.5 times higher than the Russian average. More detailed information is available in Annex V.

Other social and community impacts were assessed to be moderate in both sub-systems. Massive changes in the distribution of traditional indigenous populations are connected with the widening scope of oil, gas, and other resource production, transport routes and construction. Because lands are expropriated for industry and are tainted by industrial pollution, the rural population loses not only its pastures but hunting lands and fishing sites, as well as territories to collect wild berries and mushrooms. The indigenous population must therefore abandon historical residences and life styles.

It is important to note that most of the region's indigenous population (75%) is rural. Residence in multinational settlements and cities entirely changes indigenous peoples' lifestyles, resulting in many negative consequences. For example the death rate for the indigenous population is higher than for the immigrants. Additionally, traditional trades are largely unprofitable, which causes a serious unemployment problem. About 25-35% of the indigenous people in the region have no permanent job and survive only on the income from gathering berries and mushrooms. The unemployment level is especially high for women and young people. More detailed information is provided in Annex V.

Conclusions and future outlook

The open waters of the Arctic seas are clean, with the concentration of pollutants low or absent, and the state of the pelagic ecosystems as a whole is good. However, some of the shelf regions and essentially most of the coastal zones are considerably polluted and the state of a number of bays, gulfs and estuarine areas is as critical or even catastrophic. The ecological situation in these regions is aggravated by the presence in the bottom sediments of high concentrations of numerous contaminants of anthropogenic origin, which has accumulated for many years.

The character of marine pollution is specific to each of the regions of the Arctic seas and depends on the degree of anthropogenic loading and the specific features of pollution sources. The main contribution to pollution in the Russian Arctic region results from diffuse, non-point sources such as river run-off and long-range atmospheric transport as well as localised sources in the high latitudes or directly on the Arctic coast. Given their large catchment areas and run-off volumes, northern rivers exert a powerful influence on the character and level of pollution in the Arctic seas, particularly in the estuarine and shelf regions. More than half of the organic toxics (including phenols and chlorinated hydrocarbons), as well as nitrogen and phosphorus compounds, and the bulk of oil pollution that are exported from the Russian territory are carried by river flow to the Arctic Ocean. Practically all petroleum hydrocarbons and chlorinated hydrocarbons are transported to the Arctic seas by the run-off from the Ob and Yenisei rivers.

Air transport also contributes to the broad-scale pollution of the Arctic, especially in winter. As a result of long-range atmospheric transport, a substantial amount of contaminants from the industrial regions of Eurasia reaches the high latitudes and precipitates directly onto the surface of the Arctic seas.

Local coastal sources determine the specific distribution of pollution and its severity. Local fluxes of anthropogenic pollutants are mainly formed from the atmospheric emissions and wastewater produced by large cities, public services, industrial zones and transportation. The greatest number of point sources of contaminants is centred in the western Russian Arctic in the territories of the Murmansk and Arkhangelsk regions.

The major hazard for the Arctic seas results from oil and its components that enter marine ecosystems from sewage discharges, accidental spills, navigation, and gas and oil production, especially directly on the shelf. Trace metals and chlorinated hydrocarbons in combination with other contaminants undoubtedly constitute a threat to life in the Arctic seas. Pollution is one of the main problems in the Russian Arctic region. Chemical pollution and spills are the most alarming issues. Eutrophication, microbiological pollution, suspended solids, solid waste, thermal pollution and radionuclide have an unknown or slight effect in the region. Over the next 20 years, environmental impacts from oil pollution are expected to remain significant. Chemical pollutants such as chlorinated hydrocarbons, heavy metals are considered to pose a moderate threat.

Habitat and community modification

IMPACT **Kara Sea** IMPACT **Laptev, East Siberian and Chukchi seas**

This concern encompasses two environmental issues: losses of ecosystems or ecotones, and modification of ecosystems or ecotones. Because of the difficulties in the individual assessment of the two issues, and because the expertise did not fully cover all habitats, the decision was made in favour of a clumped assessment. The scores for each of the selected habitats were derived from educated guesses and estimations. Assessments were conducted only for habitats related to the Russian Arctic region.

Ecological indicators

Estimates of the state and the level of degradation in marine ecosystems are based on the results of the study and joint analysis of the following inter-connected problems (Tsyban 1999, Izrael et al. 2002). Box 1 shows the main functions of ecological indicators.

1. Study of chemical pollution in the marine environment.
2. Investigation of the rate of contaminant production-destruction processes, defining a balanced state for the formation and destruction of organic matter in the ecosystem, and with definition of the meaning of biomass of separate groups of organisms as well.
3. Study of the ecological consequences of anthropogenic impacts on the marine environment and determination of the extent of ecosystem degradation.
4. Study of natural processes, including those that result in the modification or elimination of polluting substances, and determining the stability of the marine ecosystem in view of anthropogenic impacts.

Environmental impacts

Loss and modification of ecosystems or ecotones

There are no records of serious habitat loss in the region. However, evidence of degradation of some habitats have been documented in the region. There is evidence of changes in species composition due to species extinctions or introductions. The changes are local in character. Changes in the region's marine and freshwater ecosystems and their degradation as a result of anthropogenic impacts can be manifested by: (i) decreased species diversity, changes in species and the dimensional structure of communities; (ii) decreases in the total number and biomass of organisms, especially of benthofauna; (iii) a pronounced predominance of species most resistant to pollution; and (iv) a decreased intensity and seasonal instability in biological processes,

Box 1 Main functions of ecological indicators.

Harmful changes in the natural environment are to some extent compensated for by the assimilative capacity of ecosystems, a capacity that in part determines ecosystem stability. The determination of standards for assimilative capacity is one of the most important problems posed by sustainable development. Included in this determination are economic, social, and ecological issues, as well as the demands of nature protection and other characteristics of the natural environment and society, all of which can be represented by indicators.

Indicators should be comprehensible and sufficient for the assessment of critical situations in natural ecosystems as well as economics, and should also be able to determine responses to negative impacts (Moldan & Billharz 1997). There are several definitions of indicators. All definitions agree that an indicator is a measure that sums up the information related to some phenomenon, parameter or a derivative of closely related parameters that describe the state of the phenomenon/process (Gallopin 1997).

The use of indicators is the most important goal in the assessment of stability of individual systems. This problem has not been adequately developed yet, but at present it is attracting more and more attention from the scientific community. According to current concepts (Moldan & Billharz, 1997), many factors and processes - from key natural phenomena to leading social problems - can be used as potential indicators. One cannot help but infer that the most important advantage in the use of indicators consists of the possibility of facilitating and expediting the taking of decisions at the national or regional level.

The main functions of ecological indicators are as follows (Gallopin 1997):

- To assess environmental conditions and process trends;
- To compare different natural situations;
- To assess environmental conditions with respect to a particular target;
- To provide an early warning system;
- To provide a system that can forecast the environmental state and variability of processes.

Taking into consideration modern approaches in the selection of stable development indicators and also considering the results of long-term interdisciplinary investigations and monitoring in the Russian seas and other region (e.g. Izrael, Tsyban, 1989, 1990, 1992, Gidrometeoizdat 1990, Izrael et al. 2000, Tsyban 1997, 1999), the GIWA Task team suggests the following ecosystem indicators to be used for the assessment of the stability and variability of marine ecosystems.

- Changes in the most important physical processes (temperature, wind, circulation and other regimes);
- Changes in the hydrochemical regime;
- The level of anthropogenic impact (chemical, biological, temperature, radioactive pollution, eutrophication, removal of renewable biological resources);
- The rate of changes in production /destruction processes;
- Changes in biodiversity;
- The rate of microbial degradation of organic contaminants;
- The rate of the flux of contaminants in the process of biogenic sedimentation;
- Adaptation at the organism level;
- Intensity of natural processes determining the stability of marine ecosystems that include deposition (biosedimentation) and destruction (microbial transformation) of organic matter (including toxics).

The activity of microorganisms is determined by environmental conditions (temperature, availability of easily assimilated organic compounds, oxygen regime, biotic factors, and particulate matter distribution). The functioning of the microbial population in the surface microlayers of the water column is particularly important. The complex of microorganisms that develops in these layers constitutes the first biological structure that performs the transformation and degradation of many chemical toxicants in the surface film of the ocean. Biosedimentation of particulate organic matter is the most important component of the process of photic layer purification of contaminants, especially from chemicals that possess a high bioaccumulative ability.

An ecosystem's ability to provide protection against alien intervention with the use of a spectrum of biological, physical and chemical processes is its natural immunity, which is measured by assimilative capacity. In this case any important perturbations of the structural and functional characteristics of marine biocenoses are accompanied by changes in their biogeochemical functions and reflect a change in the circulation of matter and energy in the marine ecosystem as a whole.

According to this approach, the GIWA Task team used the rating scale to reflect the extent of anthropogenic degradation of the marine ecosystem, as presented earlier. The main ecological indicators were taken into account in characterising the state of the marine environment. The scale includes the following stages:

- Stable ecosystem;
- Transient ecosystem;
- Crisis ecosystem;
- Disaster ecosystem.

In recent years many aspects of the anthropogenic impact on high-latitude marine ecosystems have been determined, these aspects include increasing levels of chemical pollution in near-shore waters (intensive pollution) and areas of chronic pollution by stable chemical compounds in low concentrations in open water (factors of low intensity). Both intensive pollution and factors of low intensity are hazards for the ecological safety of the Arctic seas.

especially of production/destruction. The overall score of slight impact was given to both sub-systems. For lagoons, estuaries and neritic systems in the Kara Sea sub-system, the environmental impacts were moderate. To characterise the activity of biological processes and assess the state of the Russian Arctic ecosystems data from the Roshydromet marine network (1997-2002) and Gidrometeoizdat (1990, 1992a, 1992b, 1993, 1996) have been used.

Kara Sea

Bacteriological observations included the determination of the total bacterial number, raw biomass, the number of heterotrophic, saprophytic, oil- and pheno-oxidising bacteria, and indices showing the relationships between the total number and the number of each of the above groups of bacteria in the offshore area. Note that the determination of indicator bacteria was carried out for the purpose of biological indication of chronic pollution of marine ecosystems.

Over the last few years in the Vega Strait near the settlement of Dickson the total number of microorganisms had an average of 200 000 cells/ml. Bacterioplankton biomass had an average of 0.34 mgC/m^3 in February. The seasonal dynamics of the total number and biomass of microorganisms was typical for the seas of the Arctic region. The maximum was observed in summer and early autumn, while the minimum occurred in winter. The dynamics of microbiological indices has remained constant during the last few years.

The number of heterotrophic and saprophytic bacteria ranged from 10 to 50 cells/ml, that of oil-oxidising bacteria ranged between 10 and 30 cells/ml. The quantitative indices of the development of indicator bacteria have not changed over the last years. The relationship between the total bacterial number and the number of saprophytic microorganisms (the coefficient of relationships) has changed in the range from 0.0001 to 1%.

The waters of the Vega Strait can be characterised by bacteriological indices as slightly polluted. In the Yenisei Bay, where observations were carried out from April to May, the mean values of the total bacterial number and biomass amounted to 195 000 cells/ml and 0.34 mgC/m^3. The maximum number of heterotrophic saprophytic bacteria was observed in April and amounted to tens of cells/ml. The minimum number fell in May. During investigations of all the areas studied, indicator microflora (oil-oxidising and phenol-oxidising microorganisms) were found.

The relationships calculated between the total bacterial number and that of indicator microorganisms makes it possible to characterise the waters of the Bay as slightly polluted. In the Pyasina Bay the total number of bacteria in April-May of 1993 to 230 000 cells/ml on average, and the mean bacterial biomass was 0.36 mgC/m^3. The mean number of saprophytic microflora turned out to be insignificant. Oil- and phenol-oxidising microorganisms were found over the entire water area studied, where their mean number ran into units of cells/ml. Pyasina Bay can be characterised as slightly polluted.

In Gydan Bay, the mean values of microbiological indices are as follows: the total bacterial number, biomass and the number of saprophytic bacteria were 210 000 cells/ml, 0.33 mgC/m^3 and units of cells/ml, respectively. Oil- and phenol-oxidising microorganisms were found in some cases. The waters of Gydan Bay can be placed, with respect of microbiological indices, in the category of slightly polluted. In 1993 the chlorophyll a content of the water in the offshore areas of the Kara Sea amounted to 0.8-22 mg/m^3. This value is five times greater than in the open sea. It should be noted that in the Ob Bay, in conditions of low water transparency and with a high concentration of biogenic elements, the physiological activity of phytoplankton was not high (Vedernikov et al. 1994).

The distribution and quantitative aspects of indicator microorganism development are indicative of the chronic pollution of water areas by low doses of persistent pollutants. The ecosystem state in the investigated regions of the Kara Sea as a whole is considered stable to transitional. The overall environmental impact for Habitat and community modification in the Kara sub-system was slight. However, for lagoons, estuaries and neritic systems, the environmental impact was moderate in the Kara Sea sub-system.

Laptev Sea

In the last few years in Balunkan Bight of Tiksi Bay the total number of bacteria has become as high as 1 million cells/ml, amounting to an average of 400 000-600 000 cells/ml. The dispersion of the concentration values of saprophytic bacteria has proved significant - from ten to hundreds of thousands of cells/ml, which also corresponds to the level of eutrophic waters.

Systematic studies of the distribution of indicator bacteria, i.e. of heterotrophic bacteria that have adapted to higher concentrations of toxic contaminants and acquired an ability to destroy persistent organic compounds, including non-natural substances, as a result of a change in the genotype, demonstrates mutations in microbial populations and reflects their dynamics and hence the variability of the ecosystem (Tsyban et al. 1992b). According to bacteria indicators, the waters of Tiksi Bay and Bulunkan Bight, where the Tiksi port is situated, can be placed into the category of eutrophic and chronically polluted waters. Indicator bacteria are widespread in the Bulunkan Bight. The maximum concentration of oil- and phenol- oxidising bacteria reached 1 000 cells/ml, which is indicative of the chronic pollution in that area of the sea. Over the rest of Tiksi Bay the total amount of microorganisms has also proved to be high (0.1-1.2 million cells/ml). The number of saprophytic bacteria has varied over a wide range (from 100 cells/ml to 600 000 cells/ml), amounting to an average of 10 000 cells/ml. The number of oil- and phenol-oxidising bacteria reached 1 000 cells/ml.

In Neelov Bay, the total number of microorganisms has ranged from 0.1 to 1.4 million cells/ml, amounting to an average of 0.7 million cells/ml. The number of saprophytic bacteria has varied between 10 and 100 000 cells/ml, the average value being 10 000 cells/ml. The concentration of oil-oxidising bacteria in Neelov Bay has reached 100 cells/ml and remained at this level over the last few years. Neelov Bay waters can be placed, according to bacteriological indices, into the category of eutrophic and moderately polluted.

In Bulunkan Bight 36 species of phytoplankton were found (Table 17). The predominance of diatoms is indicative of a change in the phytoplankton community. In summer the species of green algae are also widespread in the Bight. The trend was a decrease in the total number and biomass of phytoplankton as compared with preceding years. The interseasonal long-term analysis of the phytoplankton community functioning in Bulunkan as a whole is indicative of its depressed state.

In the remainder of Tiksi Bay, 81 species of phytoplankton were found. In summer the phytoplankton number varied from 30 000 to 185 000 cells/l. The trend was for a decrease in the number and biomass as compared with the preceding years. In Neelov Bay a total of 137 species of phytoplankton were discovered. In summer the number of phytoplankton reached the maximum of 1 325 000 cells/l and the biomass 2.22 mg/l, at the expense of the active vegetation of the diatoms, green and blue-green algae (Table 17).

In Buor-Khaya Bay the phytoplankton diversity was very poor; 17 species were found, including 15 diatoms and 2 species of green algae. Over the last few years the quantitative indices of phytoplankton development have been extremely low: the maximum number and biomass were 110 000 cells/l and 0.12 mg/l, respectively. The mean values of the phytoplankton number and biomass amounted to 28 750 cells/ml and 0.07 mg/l, respectively, which is 5 times less than the mean

Table 17 Phytoplankton in the Laptev Sea.

Location	**Phytoplankton** (number of species)					**Phytoplankton**				**Zooplankton**		
	Diatoms	Green algae	Blue-green algae	Flagellates	Total	Number (cells/l)		Biomass (mg/l)		Number of species	Number (specimens/ m^3)	Biomass (mg/m^3)
						Variation	Average	Variation	Average			
Bulunkan Bight	31	3	1	1	36	65 000-285 000	ND	ND	0.23	18	7 440	467.3
Tiksi Bay	66	10	3	2	81	30 000-185 000	94 100	0.01-0.31	0.15	16	1 715	53.3
Neelov Bay	112	14	7	4	137	ND	576 600	ND	0.97	27	5 931	182.0
Buor-Khaya Bay	15	2	-	-	17	ND	28 750	ND	0.07	ND	ND	ND

Note: ND = No Data.

(Source: Roshydromet 1997, 1998, 1999, 2000, 2001, 2002, Gidrometeoizdat 1990, 1992a, 1992b, 1993, 1996)

values reported in 1992 (Table 17). The state of the phytoplankton in Buor-Khaya water is depressed and that there is a trend toward the degradation of important biotic components. In Olenek Bay the phytoplankton biomass also proved to be very low (0.02 mg/l). In Yana Bay the phytoplankton number and biomass amounted to 82 500 cells/l and 0.22 mg/l, respectively.

In the summer in Bulunkan Bight, 18 species of zooplankton were observed. Over the rest of the Tiksi Bay water area, 16 species of zooplankton were found, to be compared to 1992 when 19 species were found. Copepods formed a predominant group with 95% of the total number and 99% of the total biomass. The seasonal course of variation of the number and biomass of zooplankton in Buor-Khaya Bay was similar to that of 1992, however the absolute values varied substantially. In Neelov Bay, 27 species were revealed to be compared to 31 species in 1992. In summer the number and biomass of zooplankton were 5 931 specimens/m^3 and 182.0 mg/m^3, respectively, which is somewhat lower than the level of 1992 (Table 17). The species composition of benthos in Bulunkan Bight and Tiksi Bay has stayed at the same level in recent years, but is represented only by oligochaetes and amphipods. However the quantitative characteristics varied over wide limits. For example, in Bulunkan Bight the number ranged from 40 specimens/m^2 in September-November to 420 specimens/m^2 in January, and amounted to an average of 182.5 specimens/m^2. The total biomass varied from 1.2 g/m^2 in September-November to 8.0 g/m^2 in August, with mean values being equal to 3.7 g/m^2.

The maximum values for the total zoobenthos number in Tiksi Bay were observed in January and amounted to 3 000 specimens/m^2. The maximum zoobenthos biomass was observed in May (70 g/m^2) when its mean value was 18 g/m^2. In Buor-Khaya Bay, the highest quantitative indices were observed in July: the total number reached 4 850 specimens/m^2 and the total biomass was 38.5 g/m^2, while the mean values were 1 950 specimens and 28.3 g/m^2, respectively.

In Neelov Bay the highest values of the abundance and biomass of benthos were observed in March (840 specimens/m^2 and 10 g/m^2, respectively). The mean values were 191 specimens/m^2 and 5.4 g/m^2, which was at the level of 1992. In Olenek Bay, the maximum quantitative indices of zoobenthos development were also observed in spring. They reached 1 160 specimens/m^2 (the total number) and 18.9 g/m^2 (the total biomass), when the mean values were 780 specimens/m^2 and 18.4 g/m^2, respectively.

In Yana Bay and the Dmitry Laptev Strait, the species diversity of benthofauna remained unchanged, as in preceding years. The maximum values of the total number, 4 290 specimens/m^2, were observed in March in Yana Bay and 2 940 specimens/m^2 in the Dmitry Laptev Strait. The mean values were 1 657 and 1 900 specimens/m^2, respectively. The total zoobenthos biomass amounted on average to 17.7 g/m^2 in Yana Bay and to 30.5 g/m^2 in the Dmitry Laptev Strait.

Thus, changes in the biotic component of the coastal ecosystems of the Laptev Sea manifested themselves in the wide distribution of indicator microflora, low values of the total number and biomass of phyto-, zooplankton and zoobenthos, a decrease in the species diversity of benthofauna, and predominance in its composition of oligochaetes and polychaetes; hydrobionts-indicators of chronic chemical pollution of the marine environment. The state of the ecosystem in the open sea as a whole can be characterised as stable. In the coastal areas and in estuarine zones of large rivers, the ecosystems can be characterised as transient (Box 1).

East Siberian Sea

In the region of the Pevek tongue as a whole, the total number of bacteria varied from 60 000 to 7.6 million cells/ml. The seasonal variability of the total bacterioplankton number is only slightly expressed. The lowest values were observed in March and April, while the highest values occurred in September. The mean annual total number of bacterioplankton near the Pevek tongue amounted to 1.2 million cells/ml.

Saprophytic bacteria were found in all the East Siberian water studied. Their most probable number (MPN) varied within the limits of natural variability from 4 cells/ml in March to 500 cells/ml in January, amounting to 90 cells/ml per year on the average. Oil-oxidising bacteria were discovered during all seasons of the year. The maximum of their most probable number reached 250 cells/ml in April. Variations of the MPN of oil-oxidising microorganisms occurred within the range from 0 to 15 cells/ml. According to bacteriological data, the waters seaward of the Pevek tongue remain slightly polluted. In Chaun Bay, the total bacterial number varied from 270 000 cells/ml in May to 1.8 million cells/ml in September. The mean annual total bacterial number in Chaun Bay was 816 000 cells/ml.

The saprophytic microflora content also changed within the limits of natural variations from 0 to hundreds of cells/ml, amounting to 100 cells/ml per year on the average. The MPNs of oil-oxidising bacteria were within the range from 0 to some tens of cells/ml. The data obtained over the last three years confirm a trend toward stabilisation and even to some decrease in the values of saprophytic and oil-oxidising microflora in the Chaun Bay, pointing to some improvement of the ecological situation in the investigated areas.

According to microbiological data, the waters in the investigated areas remain slightly to moderately polluted. In the region of the Pevek tongue of Chaun Bay, 43 species - representing 14 large taxa of invertebrate animals and plants - were found in the benthos composition. The widest species diversity (16 species) was found in polychaetes. The average number of benthic organisms amounted to 7 783 specimens/m^2. The highest density of settlements was typical for oligochaetes. The predominant species were *Oligochaeta g.* sp., *Nereimyra aphroditoides, Cistenides granulata* and others. The average biomass reached 130 g/m^2. The benthos biomass was mainly formed by bivalves, e.g. *C. granulata, Leionucula inflata, Macoma incospicua,* and *Terebelioides stroemi*. The species composition and quantitative characteristics of the bottom biocenoses were within the limits of long-term variations, and the state of the benthos community remained stable (Box 1). It should be noted that the bottom sediments in this region are chronically polluted by inclusions of small pieces of coal, slag, and solid waste.

In the water of Chaun Bay, 17 to 56 species of macrophytes and invertebrate animals belonging to 25 taxonomic groups were discovered. Like in the preceding years, polychaetes (up to 21 species at a station) and bivalves (up to 9 species) remained the characteristic predominant groups. Polychaetes and bivalves predominated in number and in biomass, respectively, in most of the investigated areas of Chaun Bay. The number and biomass of benthos amounted to 4 400 specimens/m^2 and 195 g/m^2 respectively.

Judging from the species diversity and quantitative characteristics of the investigated biocenoses, the bottom ecosystems of Chaun Bay are in good condition. Based on these observations, it was determined that the benthos state in the coastal regions that were investigated of the East Siberian Sea is characterised as stable (Box 1).

The level of oil pollution in the investigated areas has been substantially reduced over the last decade, from mean values of 11-13 MAC to 1 MAC, and the waters are not polluted by synthetic surface active substances (SSAS), while contamination by metals and PCBs is insignificant. Hydrochemical characteristics of Chaun Bay waters make it possible to consider them clean as a whole, with appearance of zones with local pollution by some contaminants, like trace metals, petroleum, etc.

The state of microbial populations and bottom fauna in Chaun Bay has remained unchanged since the observations started in 1984. Variations discovered for the microbiological characteristics studied correspond to seasonal and inter-annual fluctuations. At the same time there has been a trend toward an improvement in the ecological situation. Based on microbiological indices, the waters in the studied areas of the sea may be defined as varying from relatively clean to lightly and moderately polluted (in local zones in summer). The zoobenthos state in Chaun Bay is stable (Box 1). In the light of the above facts, the state of the coastal ecosystems of the East Siberian Sea may be defined as not impacted.

Chukchi Sea

In further defining the negative consequences of Chukchi Sea chemical pollution, the partial biodegradation of chlorinated hydrocarbons by marine microorganisms must be taken into account. For example, from 8 to 45% of benzo(a)pyrene can be removed by microbial degradation. The greatest amount of microbial activity has been found in the southern Chukchi Sea (at the level of 80%). In the low-temperature waters of the Chukchi Sea, only low chlorinated PCB congeners (from mono- to pentachlorbiphenyls) are subject to microbial transformation. These congeners account for only 18% of the total amount, and the maximum level of their degradation, in 10 days, does not exceed 50% for dichlorbiphenyls and only 10% for tetrachlorbiphenyls. Highly chlorinated PCB components containing more than six chlorine atoms have proved to be resistant to microbial degradation at low temperature.

Microbial degradation of α- and γ-HCH in the Chukchi Sea was first studied in 1993. Unlike polychlorinated biphenyls, these compounds

Figure 14 The Fedor Matisen in the pack ice of the Chukchi Sea near Mechigmen Bay, Russia.
(Photo: Corbis)

are subject to more active microbial degradation. For example, in the southern Chukchi Sea, the microflora of the surface layers proved able to transform up to 40% of an HCH mass with an initial concentration of 40 ng/l in a period of five days. Thus, substantial proportions (from 40 to 100%) of persistent organic pollutants are capable of microbial transformation in Arctic sea conditions and actively accumulate in marine organisms and bottom sediments.

The negative ecological consequences of Chukchi Sea pollution also include the processes of bioaccumulation of pollutants possessing toxic, carcinogenic and mutagenic properties. The ecological situation in the Chukchi Sea as a whole can be considered as not impacted. However, continued chemical pollution will perturb the functioning of plankton communities, resulting in decreased biological diversity and continuing accumulation of hazardous pollutants in marine organisms of commercial value.

Socio-economic impacts

The overall socio-economic impacts of Habitat and community modification was moderate in both sub-systems. At the same time, the GIWA experts assigned a severe impact for the indigenous populations in the region. It is recommended that GEF considers combining the issues that concern the northern Russia's indigenous populations into a separate problem. The people who inhabit the Russian Arctic coast (including the old-settler Russians and the Yakut population) traditionally made their living by hunting, fishing, and reindeer husbandry. This lifestyle, which was common until the 1960s, promoted the development of a special type of cultural landscape, which, in the best case, appeared to outsiders as virgin lands, or more often, as waste lands, which did not need any land use regulation. Generations of experience allowed indigenous people to balance economic demands against the ecological capacity of the fragile environment. The specialisation and the structure of this type of nature management corresponded to the natural landscape structure, which provided stable functioning of its components and supported the ethnic groups who made their living from the land (Yevseev 1996).

Industrial development in the Arctic has been accompanied by severe natural resource losses. Nowadays, rivers, lakes and wetland ecosystems in the vast territories of the region have lost their value as a result of this development, which has affected the ability of indigenous populations to survive. Recent decreases in area and quality of reindeer pastures have resulted in decreases in herd size. For example, in the Yamalo-Nenets AD, the total area of reindeer pasture has decreased by 7.1 million ha in the last few years.

At the beginning of 1990s, the local population was no longer supported by the state as had been done under the old system of the planned economy. The combined effects of the destruction of natural ecosystems, along with the displacement of indigenous peoples from their traditional lands as a result of industrial development and the errors of economic reforms, caused huge damage to the local economy. After 1990, there was a one-third decrease in the harvest of fish, furs, and marine animals, and the gathering of berries, mushrooms, nuts, medical plants and algae nearly ceased. High transportation costs meant that around 60% of what is produced is lost since it cannot be shipped to markets.

Local products such as deer meet, fish and wild berries have traditionally occupied an important place in the nutrition of the indigenous and old settlers population alike. Thus, compared to the new arrivals, the indigenous population consumed 3-5 times more deer and wild animal meat, 8 times more marine mammal meat and fat, and 2-8 times more river fish. Both the indigenous peoples and new arrivals often eat local wild plants and marine fish. The raising of deer for slaughter accounts for almost half of the animal stock production in the region.

Nutritional imbalances, as a result of a decrease in local food consumption and the adoption of a European diet, mean that the population does not consume enough calories or foods rich in microelements. In view of the contamination of local products, the current situation contributes to a growth in morbidity and an increased death rate of the indigenous population.

The growth of poverty and the increasing unemployment levels on the Russian Arctic coast is closely connected with the destruction of natural ecosystems and the loss of traditional relationships with nature. Changes in employment opportunities for local populations and associated changes in social structures also contribute to the problem. These broad cultural changes have resulted in a loss of educational and scientific values, as well as a modification or loss of cultural heritages. More than 30% of deaths in the region are the result of violence. The suicides level is 3-4 times higher than the Russian average. Annex V contains more detailed information about health and social welfare in the region.

Conclusions and future outlook

Changes in the region's marine ecosystems, and their degradation as a result of anthropogenic impacts are manifested by the following negative effects: decreased species diversity, changes in species and the dimensional structure of communities, decreases in the total number and biomass of organisms, especially of benthofauna, a pronounced predominance of species most resistant to pollution, and a decreased intensity and seasonal instability in biological processes, especially of production/destruction.

Currently, the anthropogenic impact on the Russian Arctic marine ecosystems mainly consists of a more rapid arrival of contaminants at both local and regional scales. Thus, Habitat and community modification is an important issue for the Russian Arctic region. It is expected that over the next 20 years, the ecological situation in the Neritic ecosystems will experience changes. The major concern with regard to neritic ecosystems is linked to changes in the structure of the community, such as an increase in indicator bacteria, an increase in the quantity of tumour-like anomalies (TLA) in zooplankton, and a decrease of species diversity.

Unsustainable exploitation of fish and other living resources

IMPACT **Kara Sea** IMPACT **Laptev, East Siberian and Chukchi seas**

Fish catches and use of other aquatic resources harvested from the Arctic Ocean add up to about 950 000 tonnes annually or more than 20% of the total Russian catch (Anon. 2000). The businesses and organisations located in the Murmansk and Archangelsk regions are responsible for these catches as most of the harvest is from the Barents and White seas in the adjacent GIWA region Barents Sea. The number of species and the total stocks of biological resources in the the Kara, East Siberian, Chukchi and Laptev seas are limited. In these seas the fish stocks are not large enough to allow the establishment of a large industrial fishery. However, these coastal areas, along with fish stocks in the region's rivers, are of great importance in supporting the small settlements of the Arctic coastal zone.

As described above, the marine part of the region has a not known impact of unsustainable exploitation. The central and eastern Arctic seas do not have a significant fishing industry, except in a narrow band near coastal areas, and they are basically called "non-fishery seas" (Zenkevich 1977). Commercial fish are essentially unavailable in these seas, hence fishery production research is negligible.

However, the rivers of the region do have some valuable fish and are of great importance in providing fish for the local population. Therefore, the assessment of this concern is focused on the region's river systems. Generally, the Kara Sea sub-system was assessed to have slight environmental impacts of Unsustainable exploitation of other living resources, while the Laptev Sea, East Siberian Sea, Chukchi Sea sub-system had no known impact. Current harvesting practices show no evidence of excessive by-catch and/or discards. There is also no evidence of habitat destruction due to fisheries practices or impact on biological and genetic diversity. These issues are therefore not further discussed.

Environmental impacts

Overexploitation

Siberian rivers, particularly those of the Kara Sea sub-system, are historically of great importance in providing fish for the local population. Valuable roundfish such as whitefishes, sturgeons and nelma amount up to 40% of the total catch in the rivers of western Siberia. The average annual catch in Ob-Irtysh Basin was about 40 000 tonnes in the period from 1946 to 1989. In the 1990s, the average annual catch decreased to 12 000 tonnes. In the Yenisei Basin, the average annual catch during that period decreased from 4 000 to 1 500 tonnes. This data shows that catches in western Siberia rivers decreased by a factor of three in the 1990s as compared to the previous 40-year period. In the rivers of western Siberia that flow in the Arctic seas, the average annual catch decreased from 10 000 tonnes in 1946-1989 to 2 000 tonnes in the 1990s (Luzanskaya 1970, Anon. 2000).

However, scientists do not link this decrease solely to the overexploitation of fish stocks. Among the major causes is a total decrease in the catch intensity due to economic reasons. The river fishery has never been highly profitable and it was sometimes supported with subsidies. As a result of economic crisis many small fisheries went bankrupt. The other cause of the reduction in catches is due to the uncertainty in catch statistics. Some experts believe the volume of fish that are unaccounted for equals or exceeds the amount tallied in statistics.

Scientists have also noted the sharp increase in poaching during the period of economic reforms. Poachers traditionally take the most valuable fish species, known as "Siberian delicacies". Stocks of major anadromous and catadromous fishes and populations of other valuable species are also stressed (Mikhailova 1995). The combination of these factors indicates that the most valuable fish species are overexploited.

Decreased viability of stock through pollution and disease

A slight impact was assigned to this issue in both sub-systems. The GIWA experts noted increased reports of parasitic infections in some fish but without evidence of widespread impacts on the main stock. The accumulation of high levels of pollutants has been noted in the tissues of marine organisms. It was concluded that the contamination in the Russian Arctic seas is not a problem for open water marine organisms. These marine organisms accumulate negligible quantities of chemicals (lower than anticipated as predicted by medical and biological estimates). Chemical pollution is more typically a problem for the European sector of the Arctic seas. However, oil and chemical pollution in Arctic coastal river systems, particularly in the Ob and the Yenisei, have resulted in morbidity and mortality in fish, along with a decreased viability of stock from pollution and (Mikhailova 1995).

Socio-economic impacts

The socio-economic impacts were assessed to be slight in the rivers of both sub-systems. A three-fold decrease in catches from the Siberian rivers during 1990s led to a loss of food sources for human or animal consumption. The overexploitation of valuable fish species and their death due to pollution has reduced the profitability of the catch and will require significant additional costs for the artificial restoration of valuable fish stocks. Because of the pollution of the Ob and other rivers by municipal wastes, as much as 60% of the Carp population and part of the Sig population is infected by opistharhosis and other helminth diseases, which make the fish dangerous for consumption (Anon. 2000). Other socio-economic impacts are for example bankruptcy of small fisheries, a growth in poaching and a conflict between user groups over shared resources, including space.

Conclusions and future outlook

Unsustainable exploitation of fish and other living resources is not a problem for the international waters of the region. Oil and gas extraction planned for the region will however increase the risk of anthropogenic impact on the region's river systems, which consequently will influence fisheries.

Global change

Kara Sea **Laptev, East Siberian and Chukchi seas**

Major physical and ecological changes are expected in the Arctic as a result of global climate change. Frozen areas will thaw and undergo substantial changes with warming. A substantial loss of sea ice is expected in the Arctic Ocean. As warming occurs, there will be considerable thawing of permafrost, leading to changes in drainage, increased slumping, and altered landscapes over large areas. Drainage systems in the Arctic are likely to change at the local scale. River and lake ice will break up earlier and freeze later. Polar warming probably will increase biological production but may lead to different species composition on land and in the sea. On land, there will be a tendency for northward shifts in major biomes such as tundra and boreal forest along with associated animals, resulting in significant impacts on species such as bear and caribou. However, the Arctic Ocean places a geographical limit on northward movement. Marine ecosystems will also move poleward. Animals dependent on ice may be at a disadvantage in polar areas. Figure 15 shows the annual winter temerature over Arctic during the period 1900 to 1996.

Environmental impacts

Changes in hydrological cycle and ocean circulation

The impact of this issue was slight in both sub-systems. A change in the hydrologic cycle due to global change will change in the distribution and density of riparian, terrestrial or aquatic plants but without influencing overall levels of productivity. There is some evidence of change in ocean and coastal currents due to global climate change, but without a strong effect on ecosystem diversity and productivity.

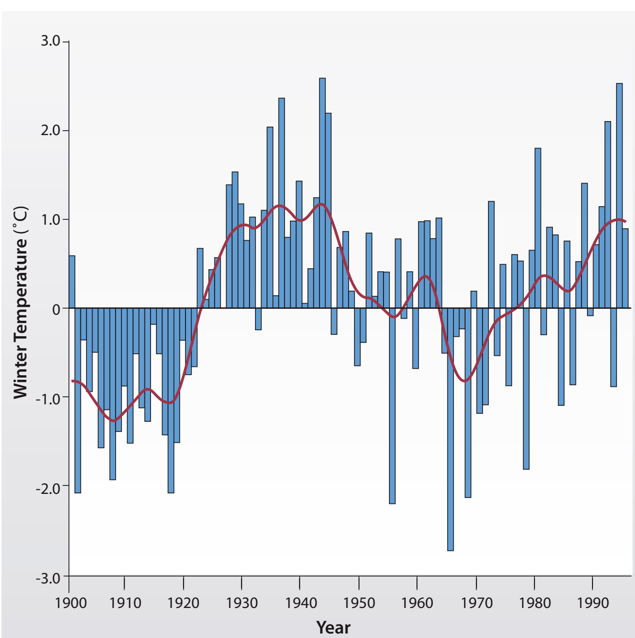

Figure 15 Annual winter temperature over Arctic 1900-1996.
(Source: IPCC 2001)

Sea level change

According to the IPCC (2001) there is no evidence of sea level change in the region. The issue was therefore assessed as having no known impact in the region.

Increased UV-B radiation as a result of ozone depletion

Ozone depletion and an associated increase in UV-B radiation have been observed in the Arctic over the past decade, and was assessed as having a slight impact in both sub-systems. This change may have a considerable effect on biological activity. Ozone depletion has occurred both as a steady decline and also in short, isolated areas with very low ozone (Watson et al. 1998). Climate change may increase ozone depletion. The cooling of the stratosphere is likely to increase this depletion with the current chlorine loading. However, chlorine loading can also be expected to decline considerably in the future. Some of the episodes of low ozone observed in the Arctic are not associated with chemical depletion but are due to the influx of low-ozone air from lower latitudes (Taalas 1993, Taalas et al. 1995). Whether these episodes will increase or decrease will depend on stratospheric circulation patterns near the Arctic; thus these episodes also may be influenced by climate change. The chemically induced and the dynamically induced episodes of low ozone that have occurred in the Arctic appear to be increasing in both frequency and severity (Taalas et al. 1997). These depletion events are most prevalent in the spring, when biological activity is highly sensitive to UV-B radiation. Increased levels are likely to affect human populations as well as aquatic and terrestrial species and ecosystems (Taalas 1993).

Arctic plants are also affected by increased UV-B radiation. In Arctic regions, UV-B radiation is low, but the relative increase from ozone depletion is large, although the ancestors of present-day Arctic plants were growing at lower latitudes with higher UV-B exposure. Over the past 20 years, stratospheric ozone has decreased approximately 10-15% in northern polar regions (Thompson & Wallace 2000). As a first approximation, a 1% decrease in ozone results in a 1.5-2% increase in UV-B radiation. The processes that damage organisms are temperature-independent, whereas repair processes are slowed by low temperatures. Hence, it is predicted that Arctic plants may be sensitive to increased UV-B radiation, especially because many individuals are long-lived and the effects are cumulative. In a study of responses by Ericaceous plants to UV-B radiation, responses varied from species to species and were more evident in the second year of exposure (Björn et al. 1997, Callaghan et al. 1998). For unknown reasons, however, the growth of the moss *Hylocomium splendens* is strongly stimulated by increased UV-B, provided adequate moisture is available (Gehrke et al. 1996). Increased UV-B radiation may also alter plant chemistry, which could reduce decomposition rates and nutrient availability (Björn et al. 1997, 1999). Soil fungi differ with regard to their sensitivity to UV-B radiation, and their response also will affect the processes of decomposition (Gehrke et al. 1995). Therefore, measurable effects of UV-B radiation can be detected with respect to the behaviour or appearance of some aquatic species, without affecting the viability of the population.

Changes in ocean CO_2 source/sink function

The impact of greenhouse gases including CO_2 was considered and based on the IPCC assessment (IPCC 2001) the impact is slight.

Socio-economic impacts

In the past, when population densities of indigenous people were lower and economic and social structures were linked only weakly to those in the south, northern peoples showed significant flexibility in coping with climate variability (Sabo 1991). Now, commercial, local, and conservation interests have reduced their options, and they may be less well equipped to cope with the combined impacts of climate change and globalisation (Peterson & Johnson 1995). Increasingly, the overall economy is tied to distant markets. For example, in Russia 92% of exported oil is extracted from wells north of the Arctic Circle (Nuttall 1998). The value of native, local harvests of renewable resources has been estimated to be only 33-57% of the total economy of some northern communities (IPCC 2001). However, harvesting of renewable resources also must be considered in terms of maintaining cultural activities. Harvesting contributes to community cohesion and self-esteem, and knowledge of wildlife and the environment strengthens social relationships (Warren et al. 1995).

Predicted climate change is likely to have impacts on marine and terrestrial animal populations; changes in population size, structure, and migration routes also are probable (Beamish 1995, Gunn 1995, Ono 1995). Careful management of these resources will be required within a properly consultative framework, similar to recent agreements that are wide-ranging and endeavour to underpin the culture and economy of indigenous peoples (Nuttall 1998). Langdon (1995) claims that "the combination of alternative cultural lifestyles and altered subsistence opportunities resulting from a warmer climate may pose the greatest threat of all to the continuity of indigenous cultures in northern North America." An alternative view is that northern people live with uncertainty and learn to cope with it; this view suggests that "for indigenous people, climate change is often not a top priority, but a luxury, and Western scientists may well be indoctrinating Natives with their own terminology and agenda on climate change" (BESIS 1999).

Exploration, production, transportation of oil and gas, and associated construction of processing facilities are likely to be affected by climatic change (Maxwell 1997). Changes in a large number of climate and related variables will affect on- and offshore oil and gas operations. Use of oil drilling structures or ice-strengthened drill ships designed to resist ice, use of the ice itself as a drilling platform, and construction of artificial islands are likely to give way to more conventional drilling techniques employed in ice-free waters (Maxwell 1997). These likely changes are not without concerns. Although the use of regular drill ships may reduce operating costs by as much as 50% (Croasdale 1993), increased wave action, storm surges, and coastal erosion may necessitate design changes in conventional offshore and coastal facilities (McGillivray et al. 1993). This may increase the costs of pipeline construction because extensive trenching may be needed to combat the effects of coastal instability and erosion, especially that caused by permafrost melting (Croasdale 1993, Maxwell 1997). Design needs for onshore oil and gas facilities and winter roads are strongly linked to accelerated permafrost instability and flooding. The impact of climate change is likely to lead to increased costs in the industry associated with design and operational changes (Maxwell 1997).

The impact of climate warming on transportation and communications in Arctic regions is likely to be considerable. Within and between most polar countries, air transport by major commercial carriers is widely used to move people and freight. Irrespective of climate warming, the number of scheduled flights in polar regions is likely to increase. This will require an adequate infrastructure over designated routes, including establishment of suitable runways, roads, buildings, and weather stations. These installations will require improved engineering designs to cope with permafrost instability. Because paved and snow-ploughed roads and airfield runways tend to absorb heat, the mean annual surface temperature may rise by 1-6°C, and this warming may exacerbate climate-driven permafrost instability (Maxwell 1997). Cloud cover, wind speeds and direction, and patterns of precipitation may be expected to change at the regional level in response to global warming. At present, the density of weather stations is relatively low in Arctic regions. Increased air and shipping transports under a changing climate will require a more extensive weather recording network and navigational aids than now exists.

The impact of climate warming on marine systems is predicted to lead to loss of sea ice and opening of sea routes such as the Northeast and

Figure 16 Road flooded by the Lena River outside Yakutsk, May 23, 2001.
(Photo: Corbis)

Northwest passages. Ships will be able to use these routes without strengthened hulls. There will be new opportunities for shipping associated with movement of resources (oil, gas, minerals, and timber), freight, and people (tourists). However, improved navigational aids will be needed, and harbour facilities probably will have to be developed. The increase in shipping raises questions of maritime law that will need to be resolved quickly. These issues include accident and collision insurance, which authority is responsible for removal of oil or toxic material in the event of a spill, and which authority or agency pays expenses incurred in an environmental cleanup. These questions are important because sovereignty over Arctic waters is disputed among polar nations, and increased ship access could raise many destabilising international issues. Increased storm surges are predicted that will affect transport schedules.

Increased levels of UV-B radiation are likely to affect the human populations (Taalas 1993). Episodes of extreme cold and blizzards are major climate concerns for circumpolar countries like Russia and Canada (IPCC 2001). However, the polar regions will remain cold, so the direct effects of global warming are likely to have little effect on human health. Potential indirect effects, such as changes in infectious diseases and vector organisms, are largely unknown. UV-B radiation is increasing, which can damage the genetic (DNA) material of living cells (in an inverse relationship to organism complexity) and induce skin cancers, as shown in experimental animals. It also may affect human health: UV-B radiation is implicated in causing human skin cancer and lesions of the conjunctiva, cornea, and lens; it also may impair the body's immune system (IPCC 2001).

Climate change and economic development associated with oil extraction, mining, and fish farming will result in changes in diet and nutritional health and exposure to air-, water-, and food-borne contaminants (Bernes 1996, Rees & Williams, 1997, Vilchek & Tishkov 1997, AMAP 1998, Weller and Lange 1999, Freese 2000). People who rely on marine systems for food resources are particularly at risk because Arctic marine food chains are long (AMAP 1997). Low-lying Arctic coasts of western Canada, Alaska, and the eastern Russian Arctic are particularly sensitive to sea-level rise. Coastal erosion and retreat as a result of thawing of ice-rich permafrost already are threatening communities, heritage sites, and oil and gas facilities (Forbes & Taylor 1994, Are 1999).

Along the coasts of the Bering and Chukchi seas, indigenous peoples report thinning and retreating sea ice, drying tundra, increased storms, reduced summer rainfall, warmer winters, and changes in the distribution, migration patterns, and numbers of some wildlife species. These populations say that they already are feeling some of the impacts of a changing, warming climate (Mulvaney 1998). For example, when sea ice is late in forming, certain forms of hunting are delayed or may not take place at all. When sea ice in the spring melts or deteriorates too rapidly, it greatly decreases the length of the hunting season. Many traditional foods are dried (e.g. walrus, whale, seal, fish, and birds) in the spring and summer to preserve them for consumption over the long winter months. When the air is too damp and wet during the "drying" seasons, food becomes mouldy and sour. The length of the wet season also affects the ability to gather greens such as willow leaves, beach greens, dock and wild celery. These accounts reflect the kinds of changes that could be expected as global warming affects the Arctic (Mulvaney 1998). As climate continues to change, there will be significant impacts on the availability of key subsistence marine and terrestrial species. At a minimum, salmon, herring, walrus, seals, whales, caribou, moose, and various species of waterfowl are likely to undergo shifts in range and abundance. This will entail local adjustments in harvest strategies as well as in allocations of labour and resources (e.g. boats, snowmobiles, weapons). As the climate changes, community involvement in decision-making has the potential to promote sustainable harvesting of renewable resources, thereby avoiding deterioration of common property. However, factors that are beyond the control of the local community may frustrate this ideal. For example, many migratory animals are beyond hunters' geographical range for much of the year, and thus beyond the management of small, isolated communities. Traditional subsistence activities are being progressively marginalised by increasing populations and by transnational commercial activities (Sklair 1991, Nuttall 1998).

The capacity of permafrost to support buildings, pipelines, and roads has decreased with atmospheric warming, so pilings fail to support even insulated structures (Weller & Lange 1999). The problem is particularly severe in the Russian Federation, where a large number of five-story buildings constructed in the permanent permafrost zone between 1950 and 1990 already are weakened or damaged, probably as a result of climate change. For example, a 2°C rise in soil temperature in the Yakutsk region has led to a decrease of 50% in the bearing capacity of frozen ground under buildings. It has been predicted that by 2030, most buildings in cities such as Tiksi and Yakutsk will be lost, unless protective measures are taken (Weller & Lange 1999). The impact of warming is likely to lead to increased building costs, at least in the short-term, as new designs are produced that cope with permafrost instability. Snow loads and wind strengths may increase, which also would require modifications to existing building codes (Maxwell 1997). There will be reduced demand for heating energy with warmer climate (Anisimov & Poljakov 1999).

Conclusions and future outlook

Changes in ecological situations and socio-economic activity caused by global climate change are expected. The hydrology of the Arctic is particularly susceptible to warming because small rises in temperature will result in increased melting of snow and ice, with subsequent impacts on the water cycle. There will be a shift to a run-off regime that is driven increasingly by rainfall, with less seasonal variation in run-off. There will be more ponding of water in some areas, but peatlands may dry out because of increased evaporation and transpiration from plants. In some areas, thawing of permafrost will improve infiltration. An expected reduction in ice-jam flooding will have serious impacts on riverbank ecosystems and aquatic ecology, particularly in the highly productive Arctic river deltas. Changes in Arctic run-off will affect sea-ice production, deepwater formation in the North Atlantic, and regional climate. A major impact would result from a weakening of the global thermohaline circulation as a result of a net increase in river flow and the resulting increased flux of freshwater from the Arctic Ocean.

Warming should increase biological production; however, the effects of increased precipitation on biological production are unclear. As warming occurs, there will be changes in species composition on land and in the sea, with a tendency for poleward shifts in species assemblages and loss of some polar species. Changes in sea ice will alter the seasonal distributions, geographic ranges, patterns of migration, nutritional status, reproductive success, and ultimately the abundance and balance of species. Animals that are dependent on sea ice, such as seals, walrus, and polar bears, will be disadvantaged. High-arctic plants will show a strong growth response to summer warming. It is unlikely that elevated CO_2 levels will increase carbon accumulation in plants, but plants may be damaged by higher UV-B radiation. Biological production in lakes and ponds will increase.

Climate change, in combination with other stresses, will affect human communities in the Arctic. The impacts may be particularly disruptive for communities of indigenous peoples following traditional lifestyles. Changes in sea ice, seasonality of snow, and habitat and diversity of food species will affect hunting and gathering practices and could threaten longstanding traditions and ways of life. On the other hand, communities that practice these lifestyles may be sufficiently resilient to cope with these changes. Increased economic costs are expected to affect infrastructure, in response to thawing of permafrost and reduced transportation capabilities across frozen ground and water.

Priority concerns for further analysis

Pollution and Habitat and community modification in the Kara Sea sub-system were ranked as the priority concerns for the Russian Arctic region. The analysis of the main issues and levels of pollution suggests that the waters of the Russian Arctic region are much cleaner than other European seas and the Barents Sea. However, two of the issues from the concern Pollution have been chosen for further analysis in the Kara Sea sub-system: chemical pollution and spills.

After the decline in production during the 1990s as a result of economic reforms, rapid growth in production in the Kara Sea sub-system is expected. Some estimates predict that the economy will develop mostly as a result of the development of hydrocarbon stocks. Economic development will also hinge on the planned growth in the production of chromite and titanium-magnetite ores from Yamal-Nenets AD, as well as growth in the production of nickel, cobalt, copper and other metals from the Norilsk industrial complex (Dolgano-Nenets AD, Taimyr). Therefore it is expected that the negative impacts from chemical pollution and spills will remain at their current levels or will increase in the future.

The second prioritised concern that may increase in severity in the future is Habitat and community modification. The most threatening issue here is the modification of ecosystems, primarily the neritic systems of the Kara Sea sub-system. Spills and chemical pollutants such as chlorinated hydrocarbons, heavy metals are actively bioaccumulating at significant levels in the bottom sediments and in marine organisms, thereby disturbing the natural balance in existing ecosystem.

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 on the methodology, please refer to the GIWA methodology chapter.

The issues identified in the assessment as having the highest priority for the region are chemical pollution, oil spills, and modification of neritic ecosystems, lagoons and estuaries in the Kara Sea sub-system. The aim of the Causal chain analysis is to determine the root causes of chemical pollution, oil spills and habitat modification, in order to enable policy makers to prioritise actions in the region. The identified root causes will form the basis for the Policy option analysis in the next section.

The increased water-borne inputs of chemical pollution and oil spills, atmospheric inputs of chemical pollutants are closely connected with oil and gas production, the mining and metallurgy industry, and sea and inland water transport. The modification of the Russian Arctic's ecosystems is a result of chemical pollution and oil spills.

Modification of neritic ecosystems in Kara Sea

Figure 17 shows the causal chain diagram for modification of neritic ecosystems in the Kara Sea sub-system.

Environmental and socio-economic impacts

Changes in the region's marine and freshwater ecosystems, and their degradation as a result of anthropogenic impacts, are manifested by the following negative effects; decreased species diversity, changes in species and the dimensional structure of communities, decreases in the total number and biomass of organisms (especially of benthofauna), a pronounced predominance of species most resistant to pollution, and a decreased intensity and seasonal instability in biological processes (especially of production/destruction).

Because lands have been expropriated for industrial uses and are tainted by pollution, the rural population has lost not only its pastures but also hunting lands and fishing sites, as well as territories where wild berries and mushrooms can be gathered. The indigenous population must therefore abandon their traditional lifestyles and places of residence. Serious conflicts with indigenous population and oil companies because of hunting and fishing sites have occurred (see Annex V).

The conditions in the Arctic region are unfavourable for human health. Morbidity can be directly connected with chemical and oil spills and the overall pollution in the catchments of the Kara Sea. The mortality rate in the region from different diseases is higher than the Russian average. Poverty and growth of unemployment is closely connected with indigenous peoples' loss of their traditional and sustainable relationship with the land. About 25-35% of the area's indigenous population are without a permanent job and survive only by gathering wild berries and mushrooms. The unemployment level is especially high for women

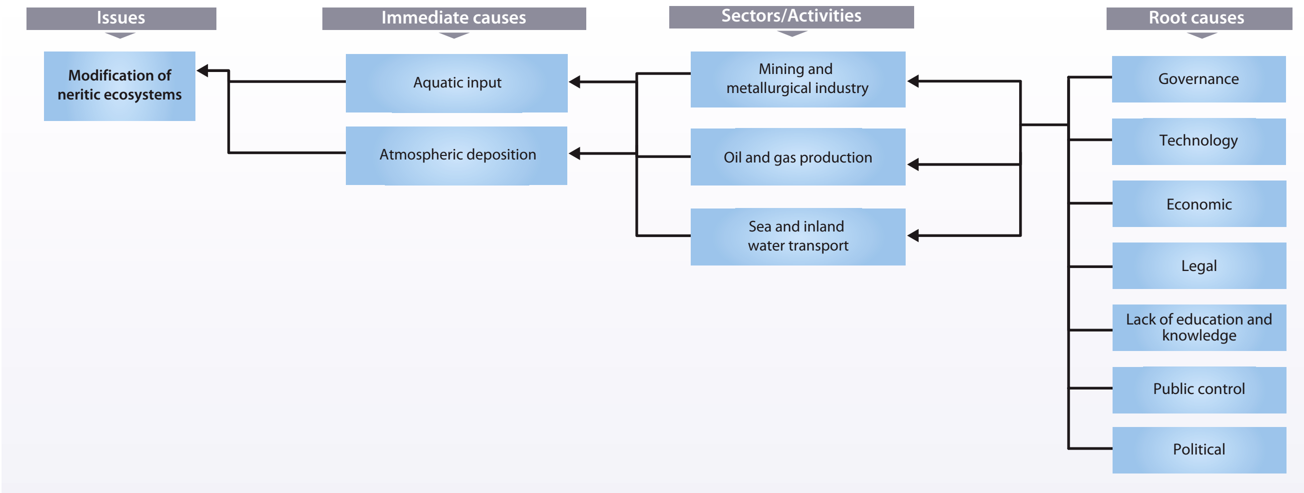

Figure 17 Causal chain diagram illustrating the causal links for modification of neritic ecosystems in Kara Sea.

and young people. As much as 15% of the unemployed indigenous population has stopped looking for a job.

Immediate causes

The immediate causes of the modification of the neritic, lagoons and estuarine ecosystems of the Kara Sea are: (i) Increased water-borne inputs of chemical pollution and oil spills; and (ii) Increased atmospheric inputs of chemical pollution. The following processes are mainly responsible:

- Pollution by petroleum hydrocarbons including polyaromatic ones (benzo(a)pyrene);
- Pollution by persistent organic pollutants (chlorinated hydrocarbons) of agricultural, industrial and community origin;
- Pollution by heavy metals, discharged into the environment by mining and metallurgy enterprises;
- Pollution by other chemical agents including oxides of sulphur, nitrogen and carbon, ammonium, hydrogen sulphide, phenols, nitrogen and phosphorus.

Sectors

The modification of highly vulnerable water ecosystems in the Kara Sea sub-system is a result of the rapid industrial development of the Russian Arctic region after the 1970s. The growth in oil and gas sector was facilitated by the construction of pipelines, roads and ports. Oil and gas development and extraction result in the following kinds of pollution: (i) release of drilling slurry; (ii) occasional and permanent leaks of fuel, lubricants, gas condensate, drilling and other washing liquids; (iii) chemical pollution of water and bottom sediments; (iv) construction of artificial structures (i.e. underwater pipelines); (v) noise and vibration caused by drilling rigs that scare animals; (vi) thermal impact on environment; and (vii) alterations in habitats for fish and migrant birds. All these factors cause serious damage to many natural resources. Many once-natural ecosystems have been affected by these impacts, which can be seen over a large part of the region (including sea, lake and swamp ecosystems).

Other sectors involved in the modification of neritic ecosystems are the mining and metallurgical industry as well as sea and inland water transports.

Root causes

Economy

Economic causes are linked with inadequate funding of environmental needs such as the reconstruction and modernisation of water treatment plants to control pollution discharged to Siberian rivers, treatment of industrial air discharges, restoration of natural ecosystems, and the provision of nature protection services (Andreev 2001). Poor integration of environmental protection problems with socio-economic planning also leads to water ecosystems degradation. A comprehensive monetary estimation of the natural resources potential (natural capital) in a single state accounting system has never been conducted. The result is a growth in corruption and illegal deals; income is hidden from taxation, which means there is less public money for social and economic needs; and corporate interests tend to dominate strategic problems (Barsegov et al. 2000). Other economic root causes of the modification of ecosystems are similar to the root causes of chemical pollution and oil spills.

Technology

Many of the oil, gas and mineral extracting and metallurgic companies use physically outdated equipment and technologies. Transport vessels are also outdated, which increases the risk of oil spills. Companies use outdated technologies to neutralise or control industrial wastes. (Andreev 2001).

Governance

In the Kara Sea sub-system control over environmental conditions is weakened due to low level of funding for control services, including funding for modern equipment. New owners of oil, mining, metallurgic and transporting companies that pollute reservoirs are not being forced by the government to completely follow environmental protection legislation and regulations, including paying compensation for damage done to the environment. The need to balance economic demands and the ecological capacity of fragile northern ecosystems is ignored by company managers (Andreev 2001).

Public control

Control over the activity of oil, mining, transporting and other industrial companies by the local population (especially indigenous peoples) is insufficient. The ability of non-governmental ecological organisations to influence decisions about new oil, gas and mineral field development and the construction of industrial infrastructures is extremely limited.

Lack of knowledge and education

Oil and gas administrators and the local population, particularly the rural and indigenous population have insufficient knowledge about current environmental legislation and the principles of sustainable development as described by Agenda 21. The problems caused by chemical and other pollution in Arctic seas ecosystems have been poorly studied. For example there has been little scientific examination of the ecological capacity of the fragile sea and freshwater ecosystems. There is a lack of information to allow the simulation of basic hydrological and ecological processes in Arctic seas, particularly with respect to the estimation of the possible consequences of petroleum product spills and other problems (Annex V) (Denisov 2002).

Legal and regulatory causes

Recently, a series of legislative acts, presidential decrees and long-term governmental programmes has been enacted to regulate the socio-economic and environmental situation in the Arctic and the Russian North (see Annex VII). However the existing legislation is not adequate for solving the region's problems. One of the main root causes of the negative trends in the socio-economic and environmental situation is that there are no regulations or legislation that reflect an agreed-upon definition of sustainable development in the region (Andreev 2001).

Political causes

The precepts of sustainable development have not yet been implemented in concrete international programmes and projects in the Arctic. Indicators of sustainable development that are common for all the Arctic countries have not been agreed to. These indicators should be aimed at reducing the total anthropogenic impact to an acceptable level.

Chemical pollution in Kara Sea

Figure 18 shows the causal chain diagram for chemical pollution in the Kara Sea sub-system.

Environmental and socio-economic impacts

Assessment analysis of the concern Pollution showed that the long-range atmospheric transfer of persistent toxic organic chemicals and pollution via river run-off are very harmful for the marine ecosystem. A decrease of the number and variety of macrophytes and zoobenthos, changes in ecological processes, changes in ethological reactions, bioaccumulation of toxic chemicals, pathological manifestations of contamination and increased mortality are the consequences of anthropogenic impact.

Increasing chemical pollution causes contamination of drinking water and local foodstuffs, such as deer meet, fish, and wild berries that have traditionally occupied an important place in the diets of indigenous and old settlers populations in the Russian Arctic. Different pollution-related illnesses result in a regional mortality rate that is 2.5 times higher than the Russian average. Costs for mitigating this problems are increasing. Because lands are expropriated for industrial uses and are tainted by pollution, the rural population loses its pastures, hunting lands and fishing sites, as well as territories where wild berries and mushrooms can be gathered. The indigenous population must therefore abandon their traditional lifestyles and places of residence, leading to increased unemployment.

Immediate causes

Pollutants are transported into the Kara Sea by currents from the Barents Sea, river run-off from industrial regions in its catchment area, and via long-range atmospheric transport from western Europe and the East. It is important to emphasise the sources of the different kinds of pollutants and to identify the ones that have the most influence. It is also important to define the kinds of activities in the territories of western Siberia that contaminate the Kara Sea sub-system. The

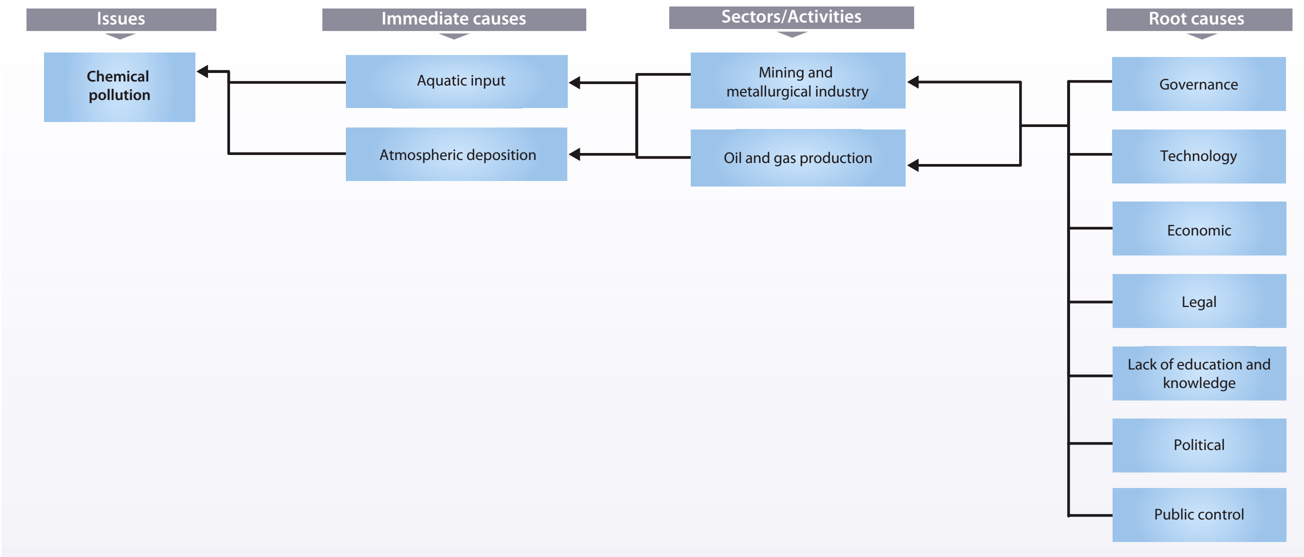

Figure 18 Causal chain diagram illustrating the causal links for chemical pollution in Kara Sea.

immediate causes of chemical pollution are increased aquatic inputs and atmospheric deposition.

Analyses have shown that the major source of contamination in Kara Sea is the mineral resource industry and oil and gas production. In the autonomous districts situated on the shores of the Kara Sea (Nenets, Yamal-Nenets and Taimyr (Dolgano-Nenets)), more than 95% of the industrial production is accounted for by the fuel industry, and the mining, and smelting and processing industry. Nowadays every fourth cubic metre of the world's gas is extracted in Yamalo-Nenets AD. Oil and gas development poses a significant threat to environment due to pollution from oil and gas extraction, and oil and gas spills from pipeline breaks.

However a much more dangerous threat to water bodies is posed by the chemical pollution from the mining and metallurgy industry. At present, the Norilsk industrial metallurgical complex, in the Taimyr Territory (Dolgano-Nenets) AD provides up to 20% of the world's nickel and cobalt, 65-70% of the copper and 100% the world's platinum metals (Anon. 1998). Point sources of pollution in Norilsk vent 31 different substances including sulphur dioxide; 40 000 tonnes of dust are vented every year, of which 18% is pure nickel. An estimated 5 kg of chemicals and contaminants falls on every square metre of Norilsk. These substances eventually find their way to the water.

The air emissions from the Norilsk industrial complex are nearly three times greater than those from all the shoreline industries in the region (Table 18). In fact, this industrial complex holds the dubious distinction of emitting the most amount of pollution of any industry or activity in all of Russia. The Norilsk region is currently considered to be ecologically unstable.

Table 18 Air pollution in the Russian Arctic region.

Administrative unit	1992	1995	2000	2001
Nenets AD	ND	24 000	8 000	8 000
Yamalo-Nenets AD	ND	757 000	576 000	587 000
Taimyr (Dolgano-Nenets) AD	ND	22 000	16 000	12 000
Republic of Sakha (Yakutia)	ND	120 000	134 000	130 000
Norilsk metallurgical complex, Taimyr Territory (Dolgano-Nenets) AD	2 208 300	2 041 400	2 149 100	2 114 800

ND = No Data.

(Source: Regions of Russia 2002, Goskomstat 2002)

Sectors

The main threat of chemical air and water pollution in the Kara Sea sub-system is posed by the mining and metallurgical industry (Norilsk industrial complex), particularly as a result of air emissions from the complex. All other industries in the region are undeveloped and tend to be of the service type. Transboundary atmospheric transport of chemicals poses a significant additional threat to Arctic seas. Oil and gas production industries in the region also contribute to pollution.

Root causes

Economy

Failures in market reform

The shock of the transition from a centralised state system to liberal market relations in Russia in 1992 hampered the creation of sustainable market structures and an adequate system for supporting communities in the north. When the reforms began many of the state supports for the population were eliminated. The failure of these reforms sharply decreased both production and tax incomes in Russia. But the most serious consequences of the crisis were in the north, where the very survival of the population was threatened. The abrupt decrease in production and the associated drops in tax incomes and business investments were combined with a dramatic increase in consumer costs after 1990. As a result, the financing of social and environmental needs has been greatly reduced.

The majority of newer state programmes dating from the mid-1990s and designed for the social and economic development of the northern Russia up to the year 2000 were never completed due to lack of money. Improvements in the socio-economic situation in the north were evident only after 2000. The reforms have meant that the financing of nature conservation measures has been drastic decreased (Regions of Russia 2002).

During the economic crisis, it was impossible for the state to regulate polluting industries and force them to clean up because to do so would have resulted in mass bankruptcies and a growth in social tensions. Additionally, a powerful industrial lobbying group hindered the Russian government in its efforts to toughening environmental protection and monitoring of mining operations. Industry has preferred to pay to pollute rather than to invest in clean-up and treatment technologies. Local authorities, under pressure from new business owners, have sometimes even decreased or eliminated pollution payments, even though this is prohibited by federal legislation. There are even cases in which these pollution payments have been used inappropriately on expenditures other than for the mitigation of industrial environmental impacts (Barsegov et al. 2000).

Strategic forecast failures

When market reforms were first introduced, the state had not performed complex long-term strategic forecasts for some time for socio-economic development in the north. Consequently, when northern industries were first purchased by new owners, the owners thought only about momentary gains, without concomitant spending on social and ecological needs.

Federal programmes from the mid-1990s onward were designed to encourage socio-economic development in northern Russia up until the year 2000, but these programmes did not establish a dependable system of environment protection.

The Russian government still does not accept a long-term federal strategy that would enable the Arctic zone to make the transition to an economy that is based on the principles of sustainable development. The main parts of the Arctic development strategy have already been created by the Council of Industrial Forces Relocation (Andreev 2001), but the strategy does not achieve the goals set by Agenda 21 and other international targets agreed to at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro 1992 and World Summit on Sustainable Development (WSSD) in Johannesburg 2002.

Technology

Many of the mining and metallurgical plants operated by Norilsk and other industrial complexes in the Kara Sea sub-system use aging and worn-out equipment and technologies that date from the 1940s and 1950s. This explains why more than 2 500 000 tonnes of pollution is discharged into the air and water every year. There is an urgent need for industrial renovation, pollution treatment facilities and wastewater treatment and recycling systems. However, these investments are very difficult to achieve due to lack of finances (Regions of Russia 2002, Barsegov et al. 2000).

Governance

The regulation of polluting industries in order to protect the environment is weak in the Kara Sea sub-system due to lack of financing for control systems, including the replacement of outdated equipment with modern equipment with pollution control systems. The payments that industries make to pollute the environment are unreasonably low and are not effective economic regulators (Barsegov et al. 2000).

Public control

The local population, particularly the indigenous population, has insufficient say or control over environmental protection issues. Non-governmental ecological organisations have virtually no effect on economic decisions (Barsegov et al. 2000).

Lack of education and knowledge

The local population, particularly the rural and indigenous population, know little about existing ecological laws and principles of sustainable development, such as are described in Agenda 21. It can be difficult for them to gain access to current, accurate environmental information in order to aid decision-making. Most parts of northern Siberia have no computer network with Internet access; indeed, a considerable part of the population has had difficulty getting access to newspapers and journals during the period of reforms. The overall levels of public education declined radically. Atmosphere and climate monitoring

Figure 19 Kara Sea.
(Photo: NASA)

services were cut back. Financing of ocean research expeditions was reduced, so that the long-term ecological monitoring data set was interrupted (Barsegov et al. 2000).

Legal

Recently a series of legislative acts, presidential decrees and long-term governmental programmes have been enacted to regulate the socio-economic and environmental situation in the Russian Arctic (see Annexes III and IV). However these efforts are insufficient in terms of sustainable development in the Arctic because there is no agreed-upon approach to sustainable development for the Russian Arctic region. It testifies to absence of system approach of the legislative base of the Russian legislation conformably to Arctic from the point of the sustainable development (Andreev 2001).

Political

A large part of chemical pollution of the Arctic seas comes from European and Asian countries as well as the US as a result of transboundary air and water flows. The annual amount of sulphur and nitric oxides transported to the Arctic from Europe amounts more than 400 000 tonnes, and from Siberia, the Far East, Kazakhstan, China and Middle Asian countries, the amount is estimated to be as much as to 230 000 tonnes (Barsegov et al. 2000). International efforts and multinational cooperation will be required to limit this flow of pollution to the Arctic.

Conclusion

This causal chain analysis demonstrates the clear links between environmental and socio-economic impacts, immediate causes and root causes underlying the increase of chemical pollution in the Kara Sea sub-system and other Arctic sea basins. These links are shown in Figure 18. The root causes of chemical pollution that have been identified as a result of this assessment cannot be overcome over the short-term. Time and significant resources will be required.

Oil spills in Kara Sea

Figure 20 shows the causal chain diagram for oil spills in the Kara Sea sub-system.

Environmental and socio-economic impacts

The exploitation of oil fields in the Kara Sea sub-system and the transport of this oil, whether by boat or pipeline, have increased

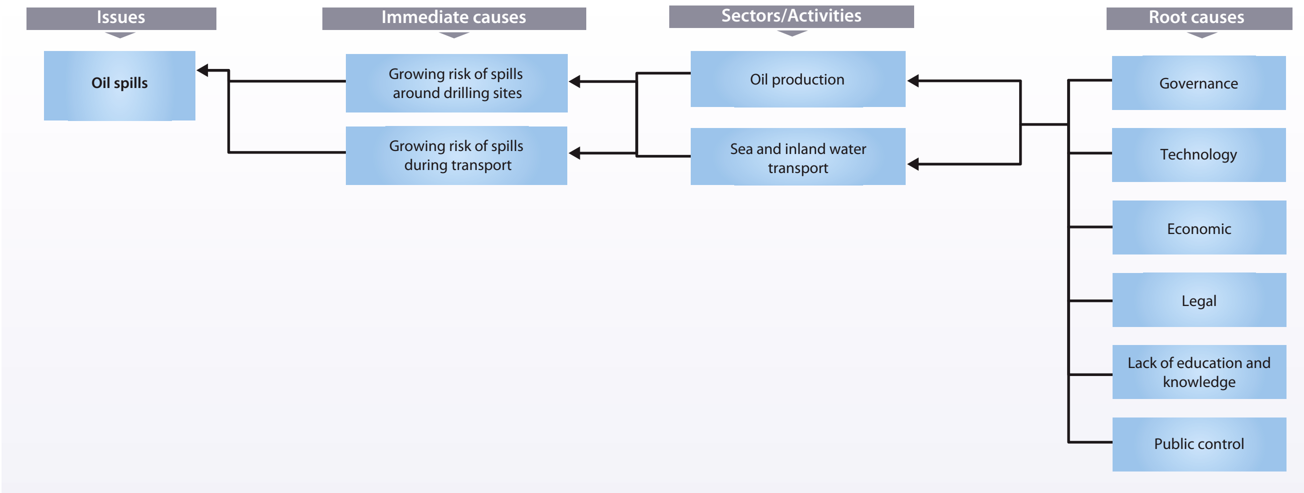

Figure 20 Causal chain diagram illustrating the causal links for oil spills in Kara Sea.

the risk of oil spills, which are harmful for marine communities and organisms. The larger spills result in injury and death of birds and mammals in the vicinity of the spill (Borisov et al. 2001). The microbiological population changes both in number and genetic characteristics as a result of oil spill pollution. Furthermore, bioaccumulation of hydrocarbons, and changes in behaviour of fish and benthic organisms occurs. Finally, the ecosystem's functioning is disturbed.

The high concentration of petroleum products in the region's waters destroys the quality of river and lake fish, and can affect berries and mushrooms (Yevseev 1996). Because lands have been expropriated for industrial uses and are tainted by pollution, the rural population has lost not only its pastures but also hunting lands and fishing sites, as well as territories where wild berries and mushrooms can be gathered. The indigenous population must therefore abandon their traditional lifestyles and places of residence. About 25-35% of the area's indigenous population traditionally survived due to gathering wild berries and mushrooms. The generally unprofitable nature of traditional trades worsens the unemployment problem. Oil pollution is also attributed with the higher-than-average levels of morbidity and mortality in the population. The mortality rate from different diseases in the Russian Arctic region is significantly higher than the Russian average. Additionally, the mortality of indigenous population exceeds the mortality of newer arrivals to the region.

Immediate causes

Several kinds of oil pollution disturb the Kara Sea sub-system, divided into two main immediate causes:

- The increasing risk of oil spills near and around drilling sites as well as occasional and permanent leaks from ground-based (near-shore) and undersea oil fields ;
- The increasing risk of spills during transportation such as pipeline accidents, occasional or deliberate release of dirty water, lubricating fluids and fuel from all kinds of transport into the sea and river ports and when transporting cargo along the Northern Sea Route NSR, accidents with cargo vessels (tankers) and equipment.

The intense development of oil fields in the Kara Sea sub-system began in the early 1970s. Until recently, oil wells have been land-based, and the oil is mainly transported via pipelines. Oil spills often occur during drilling, which results in soil pollution of soil and ultimately rivers and lakes. The peak extraction levels were reached by the end of 1980s. From 1992-2000 extraction decreased by about 1.5 times. During the same period transport along the NSR dropped nearly to zero; the number of sea transporting vessels in the Arctic decreased by five times, while the number of trips decreased two-fold. Researchers have noted that the drop in oil production has led to an improvement in water quality in Siberian rivers and restoration of fish stocks (Anon. 2000).

But the goal of the "Energy strategy for Russia until 2020" from the Russian Federal Council (2002) is for an increase oil extraction, including drilling on Arctic continental shelf. The plan also calls for a growth in sea and river transportation, particularly for oil transport, which makes the threat of oil spills more real. Different statistical sources report that an average of 130-160 tonnes is lost for every million tonnes of oil transported (Borisov et al. 2001). The energy strategy also calls for increases in the level of oil extraction in the Kara Sea sub-system to 40-

50 million tonnes in 20 years. This means as much as 8 000 tonnes of oil could be lost in transport, or an amount that is equivalent to what could be lost in a large tanker accident. But unlike a tanker accident, these spills will occur over a long period and will be spread along the vast area of the Arctic seas. In sum, the main pollution threat to the Kara Sea sub-systems from the oil industry and associated sea and river transportation.

Root causes

Economy

Failures in market reforms

The shock of the transition from a centralised state system to liberal market relations in Russia in 1992 hampered the creation of sustainable market structures in the oil industry. The economic crisis caused by failures during this transition period sharply decreased the levels of both oil extraction and tax incomes at. As a result, financing for social and environmental needs was greatly decreased. The export-oriented Russian economy is sometimes perceived as the main reason for the press to increase in oil and gas exploitation and transportation in the Arctic seas without an adequate attention to ecological safety. As a result, the risk of accidents and oil spills may increase (Barsegov et al. 2000, Lvov 2002).

Corruption

Even though it has been over 10 years since the introduction of market reforms, there still is no effective state regulation of the monopolies that exploit publicly owned oil, coal and mineral fields. The profits from these privately owned companies, which are estimated to be in the trillions of US dollars, are hidden from taxation, and company owners profited greatly. The magnitude of these profits was evident even in the earliest years of market reforms when a huge disparity in incomes was common. This situation jeopardises for sustainable development. More than half of Russia's population had to struggle to survive. The natural resources extraction sector became highly corrupt (Lvov 2002).

Domination of corporate control over strategic problems

Most of the Russian oil companies allow short-term profits to dominate over the long-term ones. These companies do not put sufficient investments into the kinds of infrastructure that allow for clean oil extraction and transportation, nor do they fund environment protection measures, such as information centres, emergency services, and monitoring systems. The absence of a long-range well-coordinated plan for the development of petroleum production in the Russian Arctic prevents oil companies from investing in programmes for environmental protection. Instead, when the oil wells run dry, oil companies leave nothing but destroyed ecosystems and social crises.

A similar situation exists with respect to transport services, which have been transferred to private ship-owners, who are not interested in modernising their aging fleets. This increases the threat of oil spills. There is no single Arctic policy designed to solve the problems posed by the use of the Northern Sea Route (NSR). Such a policy was implemented under the planned economy but currently the state does nothing to support the NSR, even though it is a very significant route for the Russian Arctic.

Technology

Many oil companies use outdated equipment and technologies (pipelines in particular). The different Russian Arctic emergency services are equipped with the equipment to clean up relatively small oil spills (up to 500 tonnes) not far from the Arctic coastline. However, these organisations are unable to cope with large-scale oil spills in remote ice covered Arctic seas (Patin 2001).

Governance

The sustainable development of the Arctic is impossible without reliable data, including the monitoring of natural systems, hydrometeorological conditions and ecological situations. An arctic monitoring network must include stationary research stations and other structures, research vessels and satellites for remote monitoring. However in the 1990s, financing for the environmental monitoring network in the Kara Sea sub-system was severely cut back. Air quality observations were cut by nearly five-fold, and the sea hydrometeorological network was cut by more than 30%. This reduced the quality of the forecasts for storm and ice conditions, ship-icing and consequently increased the risk of dangerous situations, including oil spills (Andreev 2001). New owners of oil and transport companies that cause oil spills are not forced by the government to follow the ecological legislation and regulations or to pay compensation for the damage done to the environment (Barsegov et al. 2000).

Public control

The public has insufficient control over the environmental impacts from the level of activity of oil extraction and transport companies. The local population has little or no control or influence over the conditions and restrictions on new oil field development.

Lack of knowledge and education

The local population, particularly the rural and indigenous populations, does not have enough information about existing environmental protection legislation and the principles of sustainable development as described in Agenda 21. Gaining access to this information is also difficult. Tanker transportation in Arctic conditions entails a complex of natural factors (polar night, seasonal ice, frequent storms). All this presupposes special knowledge and skills on the part of the crew. With the decrease of cargo traffic along the NSR, the lack of experience in large-tonnage tanker navigation in Arctic conditions is more and more evident (Andreev 2001).

Legal

Recently, a series of legislative acts, presidential decrees and long-term governmental programmes has been enacted to regulate the socio-economic and environmental situation in the Arctic and the Russian North (see Annexes III and IV). But these efforts are insufficient in terms of sustainable development in the Arctic because there is no agreed-upon approach to sustainable development for the region. It testifies to absence ot system approach of the legislative base of the Russian legislation conformably to Arctic from the point of the sustainable development (Andreev 2001). Environmental Impact Assessments (EIA) procedures for providing emergency clean-up equipment for complex oil and gas installations are not common practice in Russia.

Conclusion

Sustainable development in the Arctic will require the balanced coordination of economic, social and ecological aspects of development, with an emphasis on human welfare, particularly because threats to the environment also threaten the well-being of indigenous minorities. Because the Arctic environment is extremely vulnerable, the capacity of the environment to absorb or withstand the negative effects of pollution must be taken into account during oil and gas production. However, until now, the Russian government has not adopted a long-range state strategy to allow the transition of the Russian Arctic region to sustainable development, even though the main components of such a strategy have already been created by the Council of Productive Forces Relocation (Andreev 2001).

As rapid industrial development is predicted for the region, the adoption of this strategy should be given priority. The existence of the strategy demonstrates that the Russian government has the ability to meet the sustainable development goals set by Agenda 21 and other international targets agreed to at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro 1992 and World Summit on Sustainable Development (WSSD) in Johannesburg 2002. Nonetheless, Arctic countries must also participate in defining a strategy for Arctic sustainable development given the fragile ecosystems and unique cultural heritage. Russia has in principle declared support for the concept idea of sustainable development in decrees from the president and the government (see Annex IV). At the same time the living conditions in Arctic are so extraordinary, that the practical realisation of sustainable development will require not only special national programs, but international efforts.

Policy options

This section aims to identify feasible policy options that target key components identified in the Causal chain analysis in order to minimise future impacts on the transboundary aquatic environment. Recommended policy options were identified through a pragmatic process that evaluated a wide range of potential policy options proposed by regional experts and key political actors according to a number of criteria that were appropriate for the institutional context, such as political and social acceptability, costs and benefits and capacity for implementation. The policy options presented in the report require additional detailed analysis that is beyond the scope of the GIWA and, as a consequence, they are not formal recommendations to governments but rather contributions to broader policy processes in the region.

Definition of the problem

The previous causal chain analysis identified the most significant immediate causes, sectors and root causes of problems in the region. According to the results of the Assessment and Causal chain analysis, the following priority issues have been chosen for the Policy option analysis:

- Chemical pollution
- Oil spills
- Modification of ecosystems

The Causal chain analysis showed that the root causes of the three issues are quite similar. Therefore a single Policy option analysis can be carried out for all three issues combined. The completed analysis showed that the threats from these issues are evident in: (i) the rapid degradation of fragile Arctic ecosystems; (ii) the increase in the scale of exploitive consumption of natural capital; (iii) changes in the way of life and culture of indigenous peoples; and (iv) decrease in social safety nets, standards of education and life spans. At the same time, corruption, crime rates and other social problems have increased. During the 1990s, the total pollution load to the water bodies decreased in Russia as a result of economic slowdowns and production setbacks. In spite of this, ecological systems have tended to continue to degrade, partly as a result of the accumulation of pollutants from earlier activities. All of these facts are evidence of unsustainable development inthe Russian Arctic region and demonstrate that socio-economic and ecological problems in the northern Russia are interrelated. These problems cannot be solved using the principle of "patching holes". Solving these problems will require a comprehensive approach at the national level, as well international cooperation for the control of transboundary atmospheric and water pollution.

In Russia, a long-term federal programme for sustainable development of the Arctic region is still not accepted, although the concepts for this approach has been worked out and used for the substantiation of Russian Arctic policy (Andreev 2001). There is a huge threat to the region's economic and environmental stability by powerful monopolies. These monopolies, as Russian President Vladimir Putin has said "have become a hostile enclave that doesn't follow common rules and laws" (Putin 2004). The monopolies evade taxes, exploit and undervalue natural capital and thereby undermine the financial basis of the nature conservation efforts (Barsegov et al. 2000, Gaffney et al. 2000, Lvov 2002).

The concept of sustainable development has not taken shape as concrete international programmes and projects in the Arctic region. There is an absence of indicators of sustainable development that can be used in common in all Arctic countries. These indicators should be aimed at limiting human impact.

Political and organisational framework

The design of solutions for these problems has as its underlying principle the protection of the rights of the small indigenous populations and strengthening their role in achieving sustainable development, as has been identified as an international priority (for example, Agenda 21, part III, §26). One of the principal aims of the national and international policies of the Arctic region's governments should be the harmonisation of the relationship between people and nature by matching the scopes of industrial development with the capacity of natural ecosystems and improving of the quality of life of the indigenous population. To achieve this, local policy should not be administratively isolated, but should draw on the transboundary consolidation of efforts and cooperation between the ethnically-related native populations.

The legal basis for the various policy options should be the declarations of the World Summits on Sustainable Development held in Rio de Janeiro 1992 and in Johannesburg 2002. The main principles from other International conventions and Russian environmental protection legislation and sustainable development should also be used. One of the main legislative reasons behind the effort to improve the environmental situation in the Russian sector of the Arctic is the Russian Federation Constitution, which guarantees a right to a healthy environment and access to reliable information about its condition (asset 42). A list of international conventions, russian federal laws and other federal acts is provided in Annexes III and IV.

After enduring a setback in industrial production in the Russian Arctic in the 1990s, there has now been a resumption of industrial production since 2000. Future forecasts predict an increase in the production of hydrocarbon and other mineral resources for the period to 2020 (Andreev 2001). In this context, clean-up and control efforts should be aimed at the gradual reduction of existing pollution levels as well as the gradual rehabilitation of natural ecosystems, along with an increase in the quality of life of the native populations. During the reforms some decrease in the anthropogenic load on sea and freshwater ecosystems in the Russian Arctic region has been observed. It is necessary not only to preserve this improvement but also to make certain the trend continues.

Current Russian legislation contains the legal basis for the ownership, use and administration of lands and other natural resources by minority indigenous populations, and also forms the basis for future socio-economic development and environmental preservation. Since 2000, the Russian economy is becoming more stable and federal programmes for the socio-economic development of the Russian Arctic are being better enforced. In 2002, the Russian government approved "The general requirements for the development of plans on prevention and elimination of oil-spill accidents" for the prevention of oil spills and passed "Urgent measures to minimise the risk of oil-spill accidents", Nr. 240 from 15.02.2002) as a resolution (see Annex VI).

Arctic people have seen an increase in incomes and industry is being restored, and with this, additional tax revenue and growth of spending on environmental protection can be expected. In July-August 2004 (for the first time since the beginning of 1990s) the Russian government has declared its intention to support Arctic research expeditions, to rebuild the hydrometeorological network for monitoring the state of the Arctic environment, and to assist in the development of the northern shipping route. The government projects are to shift from annual planning to short-term (3-5 years) to long-range (10-20 years) forecasting. Long-range industrial development planning for the Arctic is now being carried out in the context of the Russian World Ocean Programme. Since 2004, the government has indirectly begun to support different patterns of business ownership businessmen. These measures emphasise the need to modernise the transport infrastructure in respect to ecological safety (ports, water routes, hydrographs, ice-breakers, navigational aids, qualified personnel, and scientific study of the Arctic region) and the need for enhanced control of environmental conditions.

Targets and measures aimed at reducing the negative impacts of chemical pollution, oil spills and the modification of ecosystems in Russian Arctic seas have been crafted according to the document entitled "Major directions of transition of Russian Arctic Zone to sustainable development". This document was prepared by the Council for Industrial Forces Relocation under the Russian Federation's Ministry of Economic Development and Trade and the Russian Academy of Sciences (Andreev 2001). Its practical realisation will help eliminate the root causes of chemical pollution, oil spills and the modification of ecosystems in Russian Arctic region.

The main goal of the Russian Arctic region's stated environmental improvement policy is the creation of proper conditions for preserving the critical functions of the biosphere and sustainable development based on the balance between socio-economic growth and the capacity of natural ecosystems. Other goals of this policy are:

- That all administrative decisions in the Russian Arctic region be made according to the environmental capacity of natural systems;
- The refinement of federal and regional environmental protection legislation, ecological criteria and standards;

- The strict legislative enforcement of the mutual responsibility of federal, regional and local governments to protect the environment in the region;
- The combination of administrative and economic methods to prevent environmental degradation and pollution;
- The creation of a scientific basis for the sustainable development of Arctic ecosystems;
- Effective participation in international cooperative efforts to incorporate principles of sustainable development in the Arctic zone, regional, transboundary and global.

Construction of policy options

The following policy options are based on previously described root causes and existing conditions. The policy measures that can eliminate the threats to Arctic waters are listed below. The measures are presented from the perspective of fundamental causes: economic, technological, governance, public control, education and knowledge, and legal or political improvements. At the same time it is necessary to note that elimination of economic and legislative deficiencies is a priority because implementing sustainable development in the region depends on them. To finance the elimination of the technological and other fundamental causes of chemical pollution, oil spills and modification of ecosystems, to solve the social problems of the indigenous population and to increase their role in decision-making for environmental management, to extirpate corruption, to improve the supply of information, and to finance nature conservation measures, the following policy options are recommended.

Figure 21 Gas drilling on the Yamal Peninsula.
(Photo: Arcticphoto)

Option 1: Economy actions

In order to decrease the pollution and modification of ecosystems the following economic actions are suggested:

- In the sphere of resource exploitation:
    - Reformation and development the regional system of accounting and monetary valuation of natural resources, and the development of a system to limit and license consumptive resource use on the basis of natural resources cadastres,
    - Gradual reformation of the local and regional taxation system with the goal of increasing the share of natural resource payments into appropriate budgets,
    - Improvement of economic and financial mechanisms for sustainable natural resources, economic encouragement for the effective use of natural resources, development of a labour and service market in the sector of resource use,
    - Transition from short-term to long-range forecasts for economic development, taking into account the need for natural systems to recover from their current degraded state, and recognising the need to improve the quality of life for indigenous populations.

- In the sphere of environmental protection:
    - Identification of ecological capacity of the Russian Arctic region according to regional ecological and economic realities,
    - Development of methods of the economic assessment of negative ecological impacts according to conditions in the region,

- Improvement of economic and financial mechanisms for environmental protection,
- Creation of the mechanism for insurance, the liquidation of ecologically dangerous industries and requirements for the payment of compensation for environmentally harmful activity,
- Improvement of economic stimulation of activity that protects natural resources,
- Development of a service market for environmental protection.

Option 2: Technology actions

In order to improve existing technology the following actions are suggested:

- Development of new methods and technologies in the sphere of protection, reproduction and rational use of natural resources; the stimulation of use of energy and resource conservative technologies (for example, use of wind power or biomass energy from wood wastes accumulated at timber and lumber companies in Siberia) as well as growth of natural resources reuse and level of waste recycling;
- Modernisation of the Northern Sea Route transport infrastructure (ports, icebreaking and other fleet in recognition of Arctic ice conditions);
- Modernisation of oil and gas production technologies to improve pollution prevention, with a priority on the enterprises that pollute the most in the Russian Arctic Zone as listed in Annex VII;
- Restoration of a local transport infrastructure, including air routes.

Option 3: Governance actions

The following governance actions are suggested:

- In the sphere of improving long-term forecasting using the principles of sustainable development and a gradual transition to economic development that is based on these principles:
  - Elaboration of and acceptance at a governmental level of a strategy and programmes for sustainable development for the Russian Arctic region;
  - Creation of ecological and economical zoning along the coasts of the Arctic seas and strict regulation of industry and commercial activities to protect the environment;
  - Financial and methodical support for local initiatives and programmes based on the principles of sustainable development;
  - Perfection of a system of governance for the administration of natural resource use in the region;
  - Coordination of all the activities in the region based on the demands of environmental protection and sustainability.
- In the sphere of improving monitoring and information:
  - Restoration and modernisation of an observation network in the Russian sector of Arctic based on the principles of sustainable development;
  - Creation of a national information network, integrated into a uniform world information system of oceans;
  - Development and implementation of effective administrative systems to control environmental protection programmes at various industries;
  - Development of systems of territorial ecological control and environmental monitoring including industrial ecological monitoring;
  - Maintenance of ecological information by all interested administrative and public organisations.

- In the sphere of rehabilitation of ecologically damaged territories, the concrete measures in this sphere could be the following:
  - Establish the location of zones of ecological instability and ecological disasters and rehabilitate them;
  - In areas of oil and gas extraction, mining, non-ferrous metallurgy and other dangerous industries, provide site clean-up and aid to affected populations;
  - Restore degraded elements in the sea, biological resources, coastal ecosystems;
  - Tally and safely store environmentally harmful weapons and ammunition;
  - Increase activity designed to protect the biological diversity of Arctic ecosystems and landscapes; develop a network of protected natural territories and areas with unique natural resources and features; and expand zones where resource exploitation is limited.

- In the sphere of protecting human health, measures aimed to prevent or reduce the effects of pollution on the health of the population should provide:
  - Regulation of drinking water quality at standards protective of human health;
  - Regulate air quality at standards protective of human health;
  - Provision of safe healthful food;
  - Reduction of the negative impact of contaminated soils;
  - Provision of environmentally healthful communities;
  - Protection of the population from radiation;
  - Regulation of working conditions at standards protective of human health.

To achieve the goals listed above and in accordance with Russia's responsibilities as stated by the Helsinki Declaration on Environment and Health Protection, a regional plan for the Russian Arctic region regarding human health and the environment is needed.

Option 4: Public control actions

Actions to improve public control are financial, methodological and legal support from different levels of authorities, non-governmental and other public organisations in establishing local control over the ecological situation in the region, i.e. help in organising the public oversight groups, and opening ecological information to the public.

Option 5: Education and knowledge actions

Actions to improve access to education and knowledge:

- Creation of a system to educate indigenous and migrant populations about the environment, develop an ecological culture and ideology with priority given to minority indigenous peoples;
- Creation of and support for regional state structures and public institutes that oversee environmental protection;
- Disseminate credible and timely information about environmental conditions via the mass media;
- Secure free access to environmental information for citizens and corporations; provide access to experts from the Russian Naval Fleet about Arctic conditions;
- Provide support for regional and global public environmental movements and attract non-governmental organisations to analyse and formulate solutions for the unique environmental problems of the Russian Arctic;
- State support for scientific research to create the scientific basis for sustainable development of the Arctic, along with the development of sustainable development indicators.

Option 6: Legal and political actions

- Adoption of legislation to implement a strategy for sustainable development in the Arctic;
- Creation of a regulatory and legal basis for making administrative decisions in the Russian Arctic region according to ecological capacity of natural systems;
- Toughening requirements so that industries operate in a clean, responsible manner in the Arctic region and a shut-down of illegal, polluting industries responsibility for faces accepting solution on accommodation industrial production in the Arctic region and supposing unlawful operations in the sphere of nature exploitation;
- Creation (with participation of military experts) of measures to reduce the impact of military activity on the environment;
- State support for social and ecological programmes and projects to protect the health of the population in the Arctic region;
- Legislative support for the traditional use of natural resources by indigenous populations;
- Legislative protection for the rights of the indigenous population, based on the concept of sustainable development, and with help in organising groups for monitoring and the provision of access to ecological information;
- Regulation of transportation in the region;
- State support for local self-sufficiency (territorial self-management, and help for local budgets).
- Evaluation of foreign experience to determine how best to protect the indigenous population.

Moreover, actions on the international level are needed. Policy options at the international level are: development of a single strategic approach for sustainable development, so that Arctic countries can have a common, integrated strategy for management and protection of Arctic resources, and development of a forum or mechanism so that the populations of all Arctic Ocean coastal countries can discuss common actions that will achieve a transition to sustainable development.

Performance of policy options

The performance of the policy options is evaluated as to their effectiveness, efficiency, equity, political feasibility and ability to be implemented.

Effectiveness

The policy options can be highly effective in solving the problems of pollution and modification of water ecosystem in the Arctic region, and will help the region's economies move toward sustainable development.

Efficiency

The likelihood of accomplishing goals depends on following aspects:

- The Russian government's adoption of the strategy and the programme of sustainable development of the Arctic region and the subsequent implementation of the programme measures;
- Survey sources of stable financing for the environmental and socio-economic problems that have been identified in this analysis. This approach is linked with the solution of another highly complex problem, the elimination of corruption and implementation of requirements that the oil and gas industry pay appropriate taxes;

- Raise the level of awareness in the population regarding principles of sustainable development;
- Create a system for the effective public oversight of environmental pollution and industrial activities.

Equity

The responsibility for environmental degradation will be linked to the obligation to pay for the rehabilitation of the environment or to alter production techniques (or cease them).

Political feasibility

Non-polluting producers as well as the population in general will support the proposed policy options. However, it will be necessary to limit the action of business lobbying groups to carry out this policy. In parallel with this, the influence of the public sector should be strengthened to make this policy feasible. To carry out this measure, governments must be supported by company owners, especially in the oil and gas production.

Implementation capacity

The proposed policy options are required to improve the region's economy and to create a modern monitoring system in the Arctic. Support for or opposition to this approach will entirely depend upon how environmental education is carried out.

Conclusions and recommendations

The GIWA region Russian Arctic extends from Novaya Zemblya on its western boundary to the Mys Dezhneva (East Cape) on the eastern one. As a result of human activities such as industrial, urban and agriculture, pollutants enter the Arctic seas via river run-off from the large river basins situated in the region. Harmful persistent pollutants are also transferred via long-range atmospheric transportation from western Europe and the East.

The assessment, as carried out in accordance with the GIWA methodology, has identified pollution, mainly from chemicals and oil spills, and habitat and community modification of neritic, lagoon and estuarine systems as the most important concerns for the Russian Arctic region. The analysis of the level of impact of these GIWA issues in the Kara, Laptev, East Siberian and Chukchi seas showed that the problems are more significant in the Kara Sea sub-system. Therefore, the Causal chain and Policy options analysis focused on identifying the root causes of the problems in the Kara Sea sub-system, and evaluated possible options to mitigate them.

Successful implementation of the policy options discussed in this report can be only be provided based on the principles of sustainable development. In the short term, priority should be given to:

- Beginning the work to create a strategy for sustainable development in the Russian Arctic and in legislation as well as in long-term socio-economic and ecological programs for development of the Arctic region;
- Deepening of market mechanisms and stabilisation of the economic situation to create a sustainable financial basis for solving ecological and social problems;
- Development of a single strategic approach for sustainable development, so that Arctic countries can have a common, integrated strategy for management and protection of Arctic resources;

In the long-term, priority should be given to:

- Sequential implementation of the strategy of sustainable development;
- Deepening of international coordination in terms of Arctic ecosystem conservation and recreation.

The stabilisation of the Russian economy after 2000 and the increase in interest in the problems of Arctic by the government allow hope that the ecological and social situations in Russian Arctic region will improve in the next two decades. The measures proposed can be effective provided the relevant political measures are taken. Political measures should also be directed against corruption, taxes on the oil and natural gas industry profits will create the financial assets needed to solve the environmental and socio-economic problems in the region.

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Annexes

Annex I
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Name	Institutional affiliation	Country	Field of work
Authors			
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Annex II
Detailed scoring tables: Kara Sea

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	0	N/a	Freshwater shortage	0
2. Pollution of existing supplies	1	N/a		
3. Changes in the water table	0	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small (0) 1 2 (3) Very large	1	N/a
Degree of impact (cost, output changes etc.)	Minimum (0) 1 2 (3) Severe	1	N/a
Frequency/Duration	Occasion/Short (0) 1 2 (3) Continuous	1	
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small (0) 1 2 (3) Very large	1	N/a
Degree of severity	Minimum (0) 1 2 (3) Severe	1	N/a
Frequency/Duration	Occasion/Short (0) 1 2 (3) Continuous	1	N/a
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small (0) 1 2 (3) Very large	0	N/a
Degree of severity	Minimum (0) 1 2 (3) Severe	0	N/a
Frequency/Duration	Occasion/Short (0) 1 2 (3) Continuous	0	N/a
Weight average score for Other social and community impacts		**0**	

N/a = Not applied

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	0	N/a	Pollution	2
5. Eutrophication	0	N/a		
6. Chemical	2	N/a		
7. Suspended solids	0	N/a		
8. Solid wastes	1	N/a		
9. Thermal	0	N/a		
10. Radionuclides	1	N/a		
11. Spills	2	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small (0) 1 2 (3) Very large	1	N/a
Degree of impact (cost, output changes etc.)	Minimum (0) 1 2 (3) Severe	1	N/a
Frequency/Duration	Occasion/Short (0) 1 2 (3) Continuous	1	N/a
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small (0) 1 2 (3) Very large	2	N/a
Degree of severity	Minimum (0) 1 2 (3) Severe	2	N/a
Frequency/Duration	Occasion/Short (0) 1 2 (3) Continuous	2	N/a
Weight average score for Health impacts		**2**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small (0) 1 2 (3) Very large	2	N/a
Degree of severity	Minimum (0) 1 2 (3) Severe	2	N/a
Frequency/Duration	Occasion/Short (0) 1 2 (3) Continuous	2	N/a
Weight average score for Other social and community impacts		**2**	

N/a = Not applied

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	1	N/a	Habitat and community modification	1
13. Modification of ecosystems or ecotones, including community structure and/or species composition	1	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	N/a
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	2	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	N/a
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	3	N/a
Degree of severity	Minimum 0 1 2 3 Severe	3	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	N/a
Weight average score for Health impacts		**3**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	3	N/a
Degree of severity	Minimum 0 1 2 3 Severe	3	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	N/a
Weight average score for Other social and community impacts		**3**	

N/a = Not applied

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	2	N/a	Unsustainable exploitation of fish	1
15. Excessive by-catch and discards	0	N/a		
16. Destructive fishing practices	0	N/a		
17. Decreased viability of stock through pollution and disease	1	N/a		
18. Impact on biological and genetic diversity	0	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	N/a
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	2	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	N/a
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	1	N/a
Degree of severity	Minimum 0 1 2 3 Severe	1	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	N/a
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	1	N/a
Degree of severity	Minimum 0 1 2 3 Severe	1	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	N/a
Weight average score for Other social and community impacts		**1**	

N/a = Not applied

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	N/a	Global change	1
20. Sea level change	0	N/a		
21. Increased UV-B radiation as a result of ozone depletion	1	N/a		
22. Changes in ocean CO_2 source/sink function	1	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	N/a
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	N/a
Degree of severity	Minimum – Severe 0 1 2 3	0	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	N/a
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	N/a
Degree of severity	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	N/a
Weight average score for Other social and community impacts		**1**	

N/a = Not applied

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts: Environmental score – Present (a)	Environmental score – Future (b)	Economic score – Present (a)	Economic score – Future (b)	Human health score – Present (a)	Human health score – Future (b)	Social and community score – Present (a)	Social and community score – Future (b)	Overall score	Rank
Freshwater shortage	0	0	1	1	1	1	0	0	0.5	5
Pollution	2	2	1	1	2	2	2	2	1.8	2
Habitat and community modification	1	1	2	2	3	3	3	3	2.3	1
Unsustainable exploitation of fish and other living resources	1	1	2	2	1	1	1	1	1.3	3
Global change	1	1	1	1	0	0	1	1	0.8	4

Annex II
Detailed scoring tables: Laptev, East Siberian, Chukchi seas

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	0	N/a	Freshwater shortage	0
2. Pollution of existing supplies	0	N/a		
3. Changes in the water table	0	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	N/a
Degree of severity	Minimum – Severe 0 1 2 3	0	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	N/a
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	0	N/a
Degree of severity	Minimum – Severe 0 1 2 3	0	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	N/a
Weight average score for Other social and community impacts		**0**	

N/a = Not applied

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	0	N/a	Pollution	1
5. Eutrophication	0	N/a		
6. Chemical	1	N/a		
7. Suspended solids	0	N/a		
8. Solid wastes	0	N/a		
9. Thermal	0	N/a		
10. Radionuclides	0	N/a		
11. Spills	1	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	0	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	0	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	N/a
Weight average score for Economic impacts		**0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	N/a
Degree of severity	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	N/a
Degree of severity	Minimum – Severe 0 1 2 3	2	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	N/a
Weight average score for Other social and community impacts		**2**	

N/a = Not applied

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	1	N/a	Habitat and community modification	1
13. Modification of ecosystems or ecotones, including community structure and/or species composition	1	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	1	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	1	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	N/a
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	3	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	3	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	N/a
Weight average score for Health impacts		**3**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	3	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	3	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	N/a
Weight average score for Other social and community impacts		**3**	

N/a = Not applied

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	1	N/a	Unsustainable exploitation of fish	0
15. Excessive by-catch and discards	0	N/a		
16. Destructive fishing practices	0	N/a		
17. Decreased viability of stock through pollution and disease	1	N/a		
18. Impact on biological and genetic diversity	0	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	1	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	1	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	N/a
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	1	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	1	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	N/a
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	1	N/a
Degree of severity	Minimum – Severe (0 1 2 3)	1	N/a
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	N/a
Weight average score for Other social and community impacts		**1**	

N/a = Not applied

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	N/a	Global change	1
20. Sea level change	0	N/a		
21. Increased UV-B radiation as a result of ozone depletion	1	N/a		
22. Changes in ocean CO_2 source/sink function	1	N/a		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	N/a
Weight average score for Economic impacts		**1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	N/a
Degree of severity	Minimum – Severe 0 1 2 3	0	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	N/a
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	N/a
Degree of severity	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	N/a
Weight average score for Other social and community impacts		**1**	

N/a = Not applied

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score	Rank
	Environmental score		Economic score		Human health score		Social and community score			
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Freshwater shortage	0	0	1	1	0	0	0	0	0.3	5
Pollution	1	1	0	0	1	1	2	2	1.0	2
Habitat and community modification	1	1	1	1	3	3	3	3	2.0	1
Unsustainable exploitation of fish and other living resources	0	0	1	1	1	1	1	1	0.8	4
Global change	1	1	1	1	0	0	1	1	0.8	3

Annex III
List of important water-related programmes

International programmes and projects

Arctic Environmental Protection Strategy (AEPS) 1991

Main issues:

- Protect the Arctic ecosystems, including humans;
- Provide for the protection, enhancement and restoration of environmental quality and sustainable utilisation of natural resources, including their use by local populations and indigenous peoples in the Arctic;
- Recognise and, to the extent possible, seek to accommodate the traditional and cultural needs, values and practices of indigenous peoples as determined by themselves, related to the protection of the Arctic environment;
- Review regularly the state of the Arctic environment, identify, reduce and, as a final goal, eliminate pollution.

The five programmes established under the AEPS are:

Arctic Monitoring and Assessment Programme (AMAP)

An international organisation established to implement components of the AEPS. AMAP has responsibilities to monitor the levels of, and assess the effects of, anthropogenic pollutants in all compartments of the Arctic environment, including humans. AMAP is now a programme group of the Arctic Council, and its current objective is "providing reliable and sufficient information on the status of, and threats to, the Arctic environment, and providing scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants".

Conservation of Arctic Flora and Fauna (CAFF)

The Programme for the Conservation of Arctic Flora and Fauna, under the AEPS, was established to address the special needs of Arctic species and their habitats in the rapidly developing Arctic region. CAFF has responsibilities to facilitate the exchange of information and coordination of research on species and habitats of Arctic flora and fauna.

Emergency Prevention, Preparedness and Response (EPPR)

Established as an expert forum to evaluate the adequacy of existing arrangements and to recommend necessary systems of cooperation.

Protection of the Arctic Marine Environment (PAME)

PAME addresses policy and non-emergency response measures related to protection of the marine environment from land and sea-based activities. PAME has responsibilities to take preventative and other measures, directly or through competent international organisations, regarding marine pollution in the Arctic, irrespective of origin.

Sustainable Development Working Group (SDWG)

Established by Arctic Ministers in 1998. The objective is to protect and enhance the economies, culture and health of the inhabitants of the Arctic, in an environmentally sustainable manner.

Arctic Climate Impact Assessment (ACIA)

An international project organised under the auspices of the Arctic Council to evaluate and synthesise knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences.

International Arctic Science Committee (IASC)

IASC is a non-governmental organisation to encourage and facilitate cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic region. The IASC member organisations are national science organisations covering all fields of Arctic research.

Arctic Environmental Impact Assessment (ARIA)

The purpose of the project is to develop Guidelines for EIA in the Arctic. A circumpolar ad hoc group, whose task was to evaluate a proposal for an electronic information system supporting Arctic EIAs, has recommended that an electronic network on the internet should be established.

AMAP's Assessment: State of the Environment Report

During its initial phase of operation (1991-1996), AMAP designed and implemented a monitoring programme and conducted its first assessment of the State of the Arctic Environment with respect to pollution issues. A special group (the AMAP Assessment Steering Group) was established to oversee the preparation of the AMAP Assessment, which is based on input from several hundred scientific experts. Two Assessment reports were produced to present the results of the AMAP assessment firstly to decision makers and the general public (the SOAER; full text), and secondly to fully document the scientific basis for the assessment (the AAR). This first AMAP Assessment was presented in 1997.

GEF Projects in the region

UNEP-GEF-International Waters

Support for the National Plan of Action in the Russian Federation for the Protection of the Arctic Marine Environment from Anthropogenic Pollution.

The project will focus on pre-investment studies of identified priority hot spots with known significant transboundary consequences. Additional activities will include the necessary support in the development of legal, institutional and economic measures.

UNEP-GEF-Biodiversity

An Integrated Ecosystem Approach to Enhance Biodiversity Conservation and Minimise Habitat Fragmentation in the Russian Arctic.

Other actors and initiatives

- European Commission Report on the Northern Dimension, November 1998.
- Conclusions of the Foreign Ministers Conference on the Northern Dimension, November 1999.

Russian programmes and projects

Federal programme

Economic and social development of northern minorities up to 2000 year (1996)

Includes the following sub-programmes:

- *Economy and culture development of northern minorities*:
  State support of the production of local natural food production is stipulated. Clubs for 16 800 visitors will be constructed; investments for the development of trades, publishing of manuals and belles-lettres in the languages of northern minorities, scientific research work connected with their history and culture are planned in the federal and local budgets.
- *Medical and health care*:
  Permanent regional health monitoring will be organised. Mobile special medical care will reach all remote northern settlements. Building of hospitals for 3 500 patients and the construction of 101 obstetric and doctor assistants clinics, along with the modernisation of health transport are stipulate).

World Ocean

includes the following subprograms:

- Development and use of the Arctic region;
- Creation of high-tech installations, machines and equipment for marine production of oil, gas and development of hydrocarbon deposits on the continental shelf of the Arctic from 2004-2012 (Shelf).

Economic and social development of northern minorities up to 2011 year

Reduction of differences in socio-economic development of regions of Russian Federation (2002-2010 and up to 2015).

Annex IV
List of conventions and specific laws that affect water use

International Conventions

United Nations Convention on the Law of the Sea (UNCLOS)

1982, UN Documents A/CONF. 62/122

United Nations Conference on Environment and Development (UNCED)

Rio de Janeiro, 1992

Rovaniemi Declaration on the Protection of the Arctic Environment

Rovaniemi, 1991

Convention on Biological Diversity (CBD)

Rio de Janeiro, 1992

World Summit on Sustainable Development (WSSD)

Johannesburg, 2002

Convention on Long-Range Transboundary Air Pollution (LRTAP)

The purpose of the UN Economic Commission for Europe's LRTAP Convention is to prevent, reduce, and control transboundary air pollution from both existing and new sources. This regional, binding agreement and the five related protocols represent the most appropriate instrument for addressing relevant components of the Arctic pollution problem. Current negotiations in LRTAP include efforts to conclude a new protocol on photochemical pollution, acidification, and eutrophication, and to prepare new protocols on heavy metals and persistent organic pollutants.

Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR)

OSPAR was developed under the Oslo and Paris Commissions to update two existing Conventions (the 1974 Paris Convention for the Prevention of Marine Pollution from Land-based Sources, and the 1972 Oslo Convention for the Prevention of Marine Pollution from Ships and Aircraft). The 1992 OSPAR Convention is currently one of the most applicable international agreements for addressing Arctic marine pollution from various sources.

The International Convention for the Prevention of Pollution from Ships (MARPOL)

From 1973 and modified by the Protocol of 1978 (MARPOL 73/78): This convention is a combination of two treaties adopted in 1973 and 1978. It covers all the technical aspects of pollution from ships, except the disposal of waste into the sea by dumping, and applies to ships of all types. It has five annexes covering oil, chemicals, sewage, garbage, and harmful substances carried in packages, portable tanks, freight containers, etc.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention)

The London Dumping Convention is the primary international agreement regulating ocean dumping of wastes. It has direct significance for several aspects of environmental protection of the Arctic, particularly in relation to radioactive waste disposal issues. All eight Arctic countries are Contracting Parties and have signed a recent comprehensive revision and restructuring of this Convention.

Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances that Deplete the Ozone Layer

The Vienna Convention of 1985 identified the threat to ozone in the atmosphere and resulted in the adoption of the 1987 Montreal Protocol, which limits the production of substances responsible for stratospheric ozone depletion. Compliance with the protocol including its amendments is the primary mechanism for protecting stratospheric ozone.

United Nations Framework Convention on Climate Change (UNFCCC)

Adopted at the Rio Conference in 1992, the United Nations Framework Convention on Climate Change provides an international framework to discuss greenhouse gases, especially carbon dioxide. A ministerial declaration at a meeting of parties at the convention in June 1996 includes instructions to negotiate binding agreements to reduce emissions.

UNEP Global Programme of Action

The 9th session of the UNEP Governing Council decided to establish a negotiating committee before July 1, 1998 to prepare a global, legally binding agreement on at least persistent organic pollutants, and to finish its work before 2000. This fulfils a ministerial agreement within UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities.

Russian-specific federal laws and other federal acts

- The law of the Russian Federation "About natural environment conservation" (1992, 2002)
- The law of the Russian Federation "About natural protected territories" (from 14.03.1995)
- The Water Code of Russian Federation (from 16.11. 1995 with additions in 2001, 2002)
- The Land Code of Russian Federation (from 25.10. 2001)
- The law of the Russian Federation "About the continental shelf of the Russian Federation" (1995)
- The law of the Russian Federation "About the Exclusive Economic Zone of the Russian Federation" (from 17.12.1998)
- The law of the Russian Federation "About Earth's interior" (1992)
- The law of the Russian Federation "About fundamentals of state regulating of social and economic development of the Russian Federation North" (from 19.06.1996).
- The law of the Russian Federation "About state guarantees and compensations for people living and working at the Far North and similar territories" (from 19.02.1993).
- The law of the Russian Federation "About territories of traditional use of natural resources by the small indigenous peoples of North, Siberia and Far East of Russian Federation " (2000)
- The law of the Russian Federation "About the distribution of housing subsidies to the citizens leaving from Far North regions and similar territories» (from 25.07.1998)
- The Ukase of the President of Russian Federation "About the State Strategy of the Russian Federation on the Protection of Environment and Ensuring of Sustainable Development" (No 236 from 04.02.94).
- The Ukase of the President of Russian Federation "About of the Concept of Transition of the Russian Federation to Sustainable Development" (No 440 from 01.04.1996).
- Federal government regulations "About the statement of organisation of delivery and carriage of production (goods) for maintenance of a national economy and population of Far North regions and similar territories" (No 207 from 06.01.93 and No 450 from 05.05. 95).
- Resolution of lower house of Russian Parliament (State Duma) "About ensuring the sustainable development of Far North regions and similar territories" (2000)

Annex V
The health and social welfare of the Arctic indigenous population in Russia

The modern regional demographic situation

The indigenous population of the Russian North belongs to 30 northern minorities (about 200 000 people). These minorities live in the territories of 27 regions of the Russian Federation. Eleven of these minorities live in the Arctic region: the Saami, the Enets, the Nenets, the Khants, the Nganasans, the Dolgans, the Evens, the Evenks, the Chukchi, the Eskimos and the Yukagirs. Minorities that live in the adjacent regions are the Selkups, the Chuvans, the Mansi, the Kets and the Koryaks. On January 1, 2001, 1 854 800 people lived on the Arctic coastline of the GIWA region Russian Arctic region. The indigenous population comprises about 3.4% of this total. Population numbers and the ethnic structure of the indigenous peoples in the region are presented in Table 1.

The indigenous population comprises 60.6% of the Sakha Republic, and in the autonomous okrugs: 60% in the Nenets, 66.2% in the Yamalo-Nenets, 64.2% in the Taimyr (the Dolgano-Nenets), and 67.7% in the Chukchi. For the majority of northern minorities, the female population is slightly larger than the male population (by 8%). The female percentage of the population is lower only for the Kets, the Saami, the Enets, and the Yukagirs. The overall economic crises, which were more serious in the north, led to a decrease in the population of the Arctic zone both because of natural decreases and emigration processes.

Table 1 Rural indigenous population in the Russian Arctic region.

Minority	Sakha Republic (Yakutia)	Taimyr AO (Dolgano-Nenets)	Murmansk	Nenets AO	Yamalo-Nenets AO	Chukchi AO
Nenets	6	2419	127	474	297	18
Khants	1	-	-	10	7 009	-
Mansi	1	-	-	-	68	-
Evenks	12 914	-	2	3	65	38
Koryaks	-	-	-	-	-	39
Chukchi	403	-	-	-	-	11 605
Saami	-	-	1 130	-	-	-
Enets	-	130	-	-	-	-
Nganasans	-	20	-	-	-	-
Dolgans	871	4 872	-	-	-	-
Yukagirs	560	-	-	-	-	-
Even	6 304	-	-	-	-	115
Eskimo	4	-	-	-	-	1219
Selkups	-	3	-	1	1 616	-
Chuvan	-	-	-	-	-	520
Kets	-	-	-	1	1	-
Total	21 064	7 444	1 259	489	9 056	13 557

Note: AO = Autonomous Okrug

For the first time in 1994, a natural decrease in the general population was recorded for the regions where northern minorities live. The population decrease in 1995 as compared to 1994 was marked for the Saami (-14), the Nganasans (-6), the Kets (-3), the Enets (-1). Other minorities have shown a slight natural population increase. The growth in migration from economically depressed northern regions of Russia after the collapse of the USSR was accompanied by the abandonment of settlements and has had serious social consequences for the indigenous population, because it has led to a decrease in the availability of in food, paid services, and medical care.

The major part of the indigenous population (more than 90%) of the region is rural. The percentage of the population that is urban is relatively high for the Nenets (17.1%) and the Chukchi (10%). Residence in multinational settlements and cities entirely changes the indigenous peoples' lifestyle, resulting in many negative consequences. Large shifts in the traditional distribution of the indigenous population are mainly connected with the development and exploitation of mineral deposits, transport routes and construction. This disturbs pastures, hunting lands, productive fishing areas and undermines the indigenous peoples' natural resources base.

Population health

Morbidity structure

The health of people living in the Arctic region is poor. A general decrease in living standards, a change for the worse in medical care, changes in the traditional way of life and nutrition patterns combine to increase morbidity and mortality, even in children. Four of the most common diseases, per 1 000 people, are: infectious and parasitic diseases 54.5, nervous system diseases 56.9, respiratory diseases 301.2, traumas and poisoning 74.2. The mortality rate from different diseases is 2.5 times higher than the Russian average. Thus, because of inadequate medical care, infant mortality from infectious and parasitic diseases in the Taimyr (Dolgano-Nenets) AD is 60% higher than in Norilsk. Indigenous infants often are infected with opistharhosis during the first year of their life. 95% of the population experiences hypovitaminoses.

After 1990, the frequency of active tuberculosis grew by 23%; for the indigenous population this rate is 2-3 times higher than for the rest of the region's residents. (The Federal programme "Urgent measures for tuberculosis control in Russia in 1995-1999" has resulted in special measures for indigenous peoples.) There is a marked tendency towards alcoholism and alcoholic psychosis growth. After 1990, alcoholism grew by 39% in the Taimyr (Dolgano-Nenets) AD, by 51% in the Yamalo-Nenets AD, and by 37% in the Chukchi AD (37% growth). Venereal diseases are also problematic.

Morbidity directly connected with environmental pollution is of special concern. This problem is most acute in the large industrial cities of the region, such as Norilsk and Vorkuta. Chronic illnesses in these cities are common, particularly in children. These include bronchitis, pneumonia, lung cancer, bronchial asthma, and allergies. Women have pregnancy complications and other reproductive problems. Heavy metals, PAHs and other have a strong mutagenic effect. In Norilsk the frequency of congenital defects for infants is 11.2 per 1 000 (the Russian average is 6-8), including the Daun 1.05 (as compared to the far from ecologically clean Krasnoyarsk 0.87).

Human life span and mortality

Recent changes in the lifestyles of the indigenous populations have appeared to be greatly adverse for these peoples' overall well-being. The average life span in the north is 3-4 years less than the Russian average, while for indigenous people the number is 10-11 years lower. The following data shows why indigenous population numbers tend to decrease: their general mortality rates are 1.7 higher than the average, and infant mortality 2 times higher than for the region's population in general. The marital status of men has decreased, while the number of unmarried indigenous women with children is increasing. Non-traditional families are 25-35% of the total number. About 50% of reindeer herders remain unmarried. In 1990-1993 the birth rate had decreased by 34% and mortality had increased by 42%, which caused a ten-fold decrease in the population.

Nutritional imbalances have resulted because of the adoption of European diets, and these diets also mean that not enough calories are consumed, and the foods that are eaten are poor in microelements. This is why an increase in the consumption of traditional foods, such as reindeer meat, fish, wild berries and mushrooms not only solves food problem, but also solves a problem of population ethnic survival. The poor physiological state of northern minorities, along with their poor physical condition is one of the causes of their shortened life spans. Poverty is closely connected with the lost reliance on natural resources as a basis for traditional lifestyles. More than 30% of deaths are violent. The suicides level is 3-4 times higher than the Russian average.

Every twentieth death in the indigenous population is a child one year or younger, a statistic that is five times higher than the Russian average. The highest infant mortality is found in the Chukchi AD. The mortality rate of the able-bodied indigenous population is also 3-4 times higher than in the non-indigenous population.

Measures to improve overall health in the population

The socio-economic basis for improving the health of the people in the region has been mapped out by "Economic and social development of northern minorities up to the year 2000 ", a federal programme developed in 1996. A special section was directed at the improvement of health in the northern minority population. Permanent regional health monitoring will be organised. Mobile special medical care will be created to reach all remote northern settlements. Regional problems concerning morbidity of the Arctic zone population will be solved by "Northern minorities health", a programme that is currently being developed.

Socio-economic situation

The social structure of the Russian Arctic region has been built within the framework of the industrial development of northern territories. The food supply, along with the supply of and industrial products, transportation and energy, were provided through connections with the parent state. This is why the social structure has developed unequally, with relatively good services in cities and big industrial enterprise sites and poor services in rural zones. This is also why it is very vulnerable to economic downturns and weakened links with the more populous and developed south.

Professional occupation and unemployment rate

The immigrant population of the Russian Arctic mainly works in industry, while the indigenous population is employed in agriculture, hunting and fishing. There are 154 farms in the region, covering 12 000 ha. They are concentrated mostly in the Nenets AD, where there are 29 farms, with 31 farms in the Chukchi AD, and 39 farms in both the Tyumen region and the Sakha Republic (Yakutia). The average size of farms varies greatly from 1 ha in the Taimyr (Dolgano-Nenets) AD to 141 ha in the Sakha Republic (Yakutia). The average size is 49 ha. Traditional land management is the most important historical component of northern ecosystems, as it provides ecologically sound forms of nature management. It is an important source of raw goods for the market. Thus, 96% of the reindeer herd is concentrated in the region; hunting provides 52% of the bulk fur purchases and 58% of wild animal meat.

The decrease in production, reduction of investments, and increase in consumer costs drastically influenced socio-economic situation, because it resulted in a growth in unemployment, reduction in indigenous peoples' incomes, and disruptions in the consumer goods and services supply. About 25-35% of the indigenous population has no permanent job and survives only by gathering berries and mushrooms gathering. The unemployment level is especially high for women and young people. 15% of the unemployed indigenous population has stopped looking for a job.

Medical care

The current declines in caloric intake and overall living standards, combined with the great difficulties in transportation of sick people to hospitals has led to a growth in both morbidity and mortality. The existing forms of medical care do not meet the demands of population because there are relatively few numbers of settlements scattered over vast territories, and because of the nomadic way of life of indigenous people, which is inadequately factored into health care programmes. Because of the decrease in the highly educated non-indigenous population in the region, there is a tendency for the numbers of doctors and clinics to decrease. Only two-thirds of the medical services that are typically found in other regions of Russia are available in the territories where the indigenous population is found.

In order to improve medical care, its offerings must be enlarged, and aspects of this care must be made more efficient, such as the transportation of the sick to larger hospitals. The medical system must also improve prophylactic care and the availability of medicines. More indigenous people must be trained as medical personnel, and the use of traditional treatment methods should be expanded. Sanitary and veterinary services should also be offered. Some of these priorities are reflected in existing programmes (Children of Russia), new programmes (Economic and social development of northern minorities up to 2000 year" and projects (Women of Russia etc.). For example, in the Federal programme "Urgent measures to fight tuberculosis in Russia in 1995-1999", 13 mobile medical groups for examining and treatment of active tuberculosis are planned, as well as 10 ambulances for prophylactics and personnel training from indigenous people. The Federal programme "Economic and social development of northern minorities up to 2000 year" plans the construction of hospitals for 3 500 patients, 101 obstetric and doctor' assistants clinics, along with the modernisation of health transport vehicles, with the purchase of 20 helicopters, 60 automobiles, 10 boats and 5 four-wheel drive transports.

Education and culture

The education level of the region's immigrant population does not greatly differ from the Russian average, but the indigenous population differs greatly from the average. Only 10-15% of indigenous children has completed 10-11th grade (Table 2). The majority of the population that have not completed a secondary education are without jobs. Recently the number of school children studying native languages increased. Aside from high school, higher education is available to northern minorities in ethnology, ethnopolitics, economy and ecology at the Polar Academy in St.-Petersburg, which offers programmes that are directed at training high-level specialists for work in the Arctic and the creation of a new generation of intellectuals.

Table 2 Indigenous people education level.

Region	Nenets AO	Yamalo-Nenets AO	Taimyr (Dolgano-Nenets) AO	Chukchi AO	Sakha Republic (Yakutia)	Murmansk region
Primary education (%)	40	50	50	20	38	40
Secondary and special education (%)	45	40	40	70	40	45
Higher education (%)	15	10	10	10	12	15

Note: AO = Autonomous Okrug

The federal programme "Economic and social development of northern minorities up to 2000 year" envisions the construction of clubs for 16.8 thousand visitors, investments that will help in the development of trades, the publishing of manuals and belles-lettres in the languages of northern minorities, scientific research work connected with their history and culture. Inadequate attention has paid, however, to the study of the history and culture of the old settlers population and their part in the Russian national heritage.

Importance of conservation of the marine environment

Because marine environments are closely connected with their terrestrial counterparts, the conservation of the Arctic seas is important not only for maintaining a stable ecological situation in the region, but as a basis for the continued existence and development of the ethnocultural northern minorities. It also supplies the region with its living environment, from which products are derived. A clean environment also supplies a place for the recreational activities of the local population and migrants.

Preservation of northern minorities ethnocultural formations

The traditional occupations of the peoples who inhabit the region, including the Russian old settlers Russian and the Yakut population, have been hunting, fishing, and reindeer herding. This last has resulted in the development of a special type of cultural landscape that in the best case is perceived as untrammelled virgin lands, but unfortunately more often as waste lands that do not need any protection. Generations of experience allowed indigenous people to balance economic demands against the ecological capacity of the fragile environment. Specialisation and structure of nature management corresponded to zonal-landscape structure The specialisation and the structure of this type of nature management corresponded to the natural landscape structure, which provided stable functioning of its components and supported the ethnic groups who made their living from the land. Local ecological crises of the past have been caused by fires, cutting of northern taiga, and overgrazing, but the scale of these disturbances has never been so large as to prevent the ecosystem from rebounding.

In recent times, the damage to natural ecosystems in these vast territories of the region has destroyed their ability to support the resource-based activities of indigenous peoples. In particular, industrial development in the Arctic is accompanied by severe losses of many natural resources. Recently, such development has resulted in a huge decrease in the area available for reindeer pastures and its quality, resulting in a two- to three -old decrease in forage, and a concomitant decrease in the reindeer herd. In the European North, the total area of reindeer pastures has decreased by 3.6 million ha since 1970, while in the Yamalo-Nenets AD it has decreased by 7.1 million ha.

Other causes of the decrease in available pasture lands were fires and overgrazing. Because lands have been expropriated for industrial uses and are tainted by pollution, the rural population has lost not only its pastures but hunting lands and fishing sites, as well as territories where wild berries and mushrooms can be gathered. Thus in the Tyumen region alone, 1200 small and 250 big rivers were lost, including more than 20 former fishing sites, including 20 thousand ha of fish reproduction territories. Pollution of the Ob caused a 10-fold reduction in salmon harvesting over the last 15 years and 2-fold decrease in the total number of fish caught. Because the Ob and other rivers are polluted by municipal wastes, as much as 60% of the carp population and a part of the sig population has been infested with opistharhosis and other helminth diseases, which are dangerous for the population. In the Yenisey mouth, the catch rate has dropped by 1.5-2 times.

During the reform years, the harvest of fish, furs, and marine animals dropped by one-third, while the gathering of berries, mushrooms, nuts, medical plants and algae nearly stopped. Because of high transportation costs 60% what is produced is not shipped to market and is wasted. A lack of local processing facilities for deer meat, fishing and hunting products means that these traditional branches of economy have become cheap sources of raw materials for other industries. The lack of profitability in the traditional trades has caused a serious unemployment problem.

The destruction of collective farms and loss of public property, which was the structure of all deer husbandry and hunting farms and that provided prosperity for the workers associated with these farms, resulted in serious problems for the rural population. The loss of these traditional economic activities has destroyed the basis for of the distinctive indigenous population culture. Changes caused by the social-economic situation, changes in nutrition patterns and the decrease in caloric intake, along with the continued spread of European culture at the expense of traditional forms and spiritual institutions of indigenous peoples has worsened the outlook for their survival .

Food production

The Arctic is an important region for natural food production, not only for the local population, but also, for some items, for the whole of Russia. Local products - deer meat, fish, and wild berries have traditionally occupied an important place in the nutrition of both the indigenous and old settlers population. Thus, compared to the newcomer population, the indigenous population consumed 3-5 times more deer and wild animal meat, 8 times more marine mammal meat and fat, and 2-8 times more river fish. Both the indigenous and newcomer population often eat local wild plants and marine fish (Table 3). The production of deer for slaughter makes up nearly half of all stock production in the region.

Table 3 Production of meat and fish.

Region	**Meat and meat products** (kg)	**Fish and fish products** (kg)	**Potatoes** (kg)
Yamalo-Nenets autonomous okrug	82.0	21.3	27.9
Taimyr (Dolgano-Nenets) autonomous okrug	40.8	90.9	-
Nenets autonomous okrug	30.6	28.4	60.4
Sakha Republic (Yakutia)	31.6	56.5	8.8

The Federal programme "Economic and social development of northern minorities to the year 2000" includes support for local food production. Thus, 24 deer slaughterhouses, 25 meat and wastes processing factories, 48 processing facilities for wild berries, mushrooms, 20 fish processing plants, 28 plants for the processing of marine mammals harvest., 5 for marine products processing and 5 hatcheries for valuable fish species. Many Arctic regions continue to produce natural products although their volumes have been reduced recently. But the continuing expansion of territories occupied by oil and gas production sites and pipelines, combined with the activities of environmentally harmful enterprises in the big Arctic river basins (the Yenisey, the Ob, the Northern Dvina) and the transport of pollution (oil, radionuclides) by the North Atlantic current are harmful for this production. Some Arctic regions (Pechenga-Nickel, Monchegorsk, Norilsk etc.) are currently referred to as ecologically unfavourable, and agricultural products, along with gathered products, like wild berries that come from these regions may contain higher-than-acceptable concentrations of heavy metals and other pollutants.

The migration of pollutants up through food chains (both terrestrial and aquatic) often results in the accumulation of the pollutant at a higher trophic level. Thus, concentrations of organochlorine pollutants (PCBs, etc.) in tissues of fish-eating gulls and other birds may be 50 thousand times higher than is found in plankton. Though DDT compounds and pesticides pollution is more typical for the non-Russian Arctic, increased concentrations of these compounds have been measured in the tissues of marine mammals from the White and the Barents seas. The following fact is illustrative: large numbers of dear meet shipments from western Siberia to Scandinavian countries have been rejected as unacceptable because of higher-than-acceptable concentrations of heavy metals and radionuclides.

Recreational demands

The Arctic region possesses various recreational resources, providing a basis for recreation activities for both locals and visitors from other regions of Russia. The interest in recreation development in northern regions is stimulated by a necessity to diversify income from the region's natural environment, the reduction of popular recreation territories in Russia (particularly in the Baltic sea region, the Carpathians region, and the Caucuses), the increase in recreational costs as compared to the decrease in the Russian standard of living, and the worldwide growth in non-traditional recreation.

The following types of recreational activities are the most promising for the Arctic region of Russia: health-promoting(natural, hiking and ecotourism), cognitive (excursion and industrial tourism), sports recreation including hunting and fishery. Currently, the recreational resources of the Russian Arctic are being used and exploited without controls, which often leads to conflicts with indigenous population over the use of hunting and fishing sites. Preliminary studies of the recreational resources of the Russian Arctic have shown there is a value in the coastal zone for marine cruises. This activity has been actively developed in the Murmansk region, which hosts between two to seven days of marine excursions with tourists from neighbouring Scandinavian countries. Traditional folk festivals involving the northern minorities in the Murmansk region and the Chukchi AD (Sireniki) are also attractive as tourist activities. Tourism that involves hunting or gathering of wild foods is the most popular for Russia's urban population (the gathering of berries and mushrooms, fishing and hunting).

The recreational development of the Arctic region depends on healthy natural environments, which are attractive to residents of overcrowded cities and industrial areas. Unique natural phenomena, such as the aurora borealis and nesting bird colonies are also of interest to tourists. Nature conservation in the Russian Arctic sets the stage for this kind of recreational use, which in its turn may help to solve several serious social-economic and ecological problems with the development of a nature reserves system, a reduction in industry, the development of folk trades and cultural centers. All of these developments have the potential to provide new jobs for the local population, particularly women in the service sector, while broadening opportunities for professional employment for the young.

Annex VI
General requirements for development of plans on prevention and elimination of oil spill accidents

Requirements were approved by governmental resolution "Urgent measures to minimise the risk of oil spill accidents", No 240 from 15.02.2002. According to the resolution, oil spills are classified as an emergency and are to be eliminated according to the legislation of the Russian Federation.

Depending on the size and volume, the oil spill accidents are classified as follows:

- Local - the volume of oil spill is up to 500 tonnes;
- Regional - from 500 to 5 000 tonnes;
- Federal - more than 5 000 tonnes.

Depending on the location of an oil spill and hydrometeorological conditions, the category of emergency may be increased. The plan on the prevention and elimination of oil spill accidents is developed on the basis of the existing regulations allowing for the maximum possible volume of an oil spill.

The plan encompasses:

- Monitoring of the possible oil spill accidents;
- Number of forces and facilities needed for the liquidation of an oil spill accident, their correspondence to the tasks of liquidation activities;
- Organisation of cooperation between forces;
- Composition and dislocation of forces and facilities;
- System of control and warning;
- Securing of constant readiness of all forces, appointing the organisations responsible for their upkeep;
- System of the information exchange;
- Immediate actions right after the emergency alarm;
- Geographic, navigational, hydrographic, hydrometeorological and other features of the area of an oil spill accident, which should be taken into account when planning the liquidation activities;
- Safety of the population, provision of medical aid;
- Technical, engineering and financial provision.

When defining the number of facilities and forces needed for the liquidation of an oil spill accident, the following aspects should be taken into account:

- The maximum possible volume of leakage;
- The area of an oil spill;
- The year when the damaged object was brought onto operation and the year of the last overhaul;
- The maximum volume of oil kept at an object;
- Physical and chemical properties of the spilled oil;
- Hydrometeorological, hydrogeological and other conditions influencing the spreading of an oil spill;
- The presence of terminals for the transport, storage and processing of oil wastes;
- The transport infrastructure in the area of an oil spill accident;
- The time needed for the transport of liquidation forces to the area of an oil spill accidents;
- The time of oil spill localisation, which should be less than 4 hours for an accident at sea and less than 6 hours for an accident on land.

Annex VII
Urgent measures for environmental protection

Urgent measures for environmental protection are necessary in the following impact regions of Russian Arctic:

- Pechenga (heavy metals pollution);
- Murmansk (petroleum, organic compounds, heavy metals pollution, potential pollution by radionuclides);
- Archangel-Severodvinsk (petroleum, organic compounds, heavy metals pollution, potential pollution by radionuclides);
- Ob'-Yamal (petroleum pollution);
- Norilsk-Enissey (heavy metals, organic compounds, petroleum pollution);
- Lena (petroleum, heavy metals pollution);
- Chaun (petroleum, heavy metals pollution, potential pollution by radionuclides).

Urgent measures of environmental protection to implement NPA-Arctic should be carried out for the following objects:

- Oil producing and oil transporting complexes of West Siberia and Timan-Pechora provinces;
- Oil storage and oil treatment sites for all ports of the Arctic coast of Russia;
- "Pechenganickel" and "Norilsk nickel". It is known, that reconstruction of "Pechenganickel" requires about 256 million USD and "Norilsk nickel" requires about 2 billion USD. However even before full scale reconstruction one can improve the treatment installations and exclude the discharges of untreated waters;
- Archangel and Solombala PPM. In pulp processing it is necessary to replace chlorination with ozonation. As preliminary step one can consider improvement of treatment facilities for existent technologies;
- Ob' and Enissey region wood producing combines;
- Mining and enrichment combines of Sakha-Yakutia and Chukchi regions;
- Development of modern sewage treatment systems for towns and settlements on the Arctic coast of Russia;
- Unloading of spent nuclear fuel from laid off nuclear submarines and construction of new storage places for the fuel;
- Development of the system of treatment of liquid and solid radioactive waste at Kola Peninsula and Severodvinsk and construction of regional disposal sites.

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Russian Arctic region. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF"*.

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: *"GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference*".

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

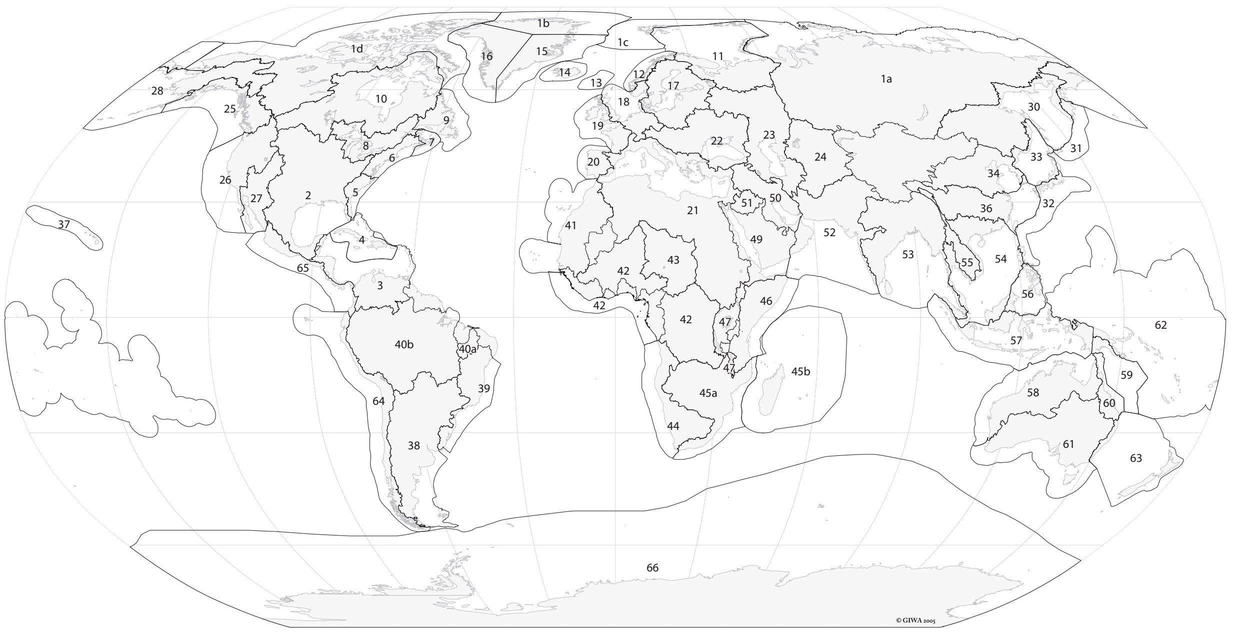
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1a Russian Arctic (4 LMEs)
1b Arctic Greenland (LME)
1c Arctic European/Atlantic
1d Arctic North American
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands (LME)
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal Sea (LME)
21 North Africa and Nile River Basin (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan (LME)
34 Yellow Sea (LME)
36 East China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Northeast Brazil Shelf (2 LMEs)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
49 Red Sea and Gulf of Aden (LME)
50 Euphrates and Tigris River Basin
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal
54 South China Sea (2 LMEs)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Pacific Islands
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific (LME)
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as

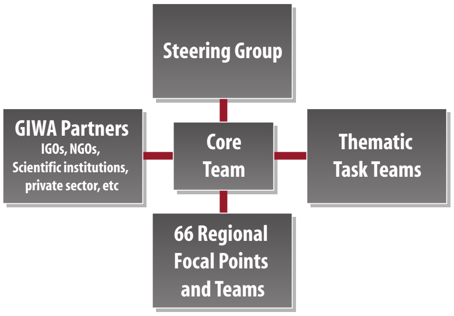


Figure 2 The organisation of the GIWA project.

universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;
(b) Raising awareness of the importance and consequences of unsustainable water use;
(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;
(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;
(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

Global International Waters Assessment

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO_2 source/sink function	**V Global change**

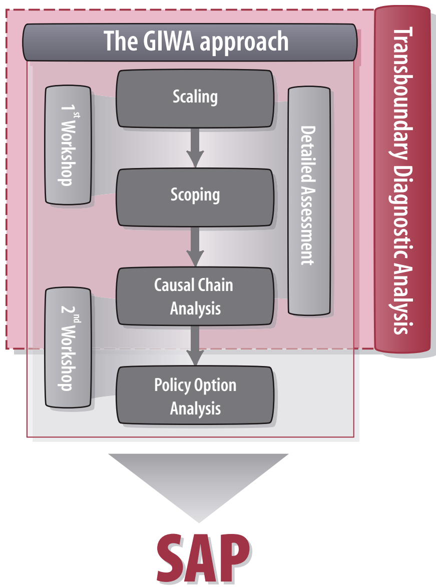

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: *"Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades."* The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern. In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small – Very large 0 1 2 3	2	50
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Environmental score		Economic score		Human health score		Social and community score		Overall score
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

(Types of impacts)

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

Global International Waters Assessment

Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of all the world's transboundary waters that recognises the inextricable links between freshwater and coastal marine environment and integrates environmental and socio-economic information to determine the impacts of a broad suite of influences on the world's aquatic environment.

Broad Transboundary Approach

The GIWA not only assesses the problems caused by human activities manifested by the physical movement of transboundary waters, but also the impacts of other non-hydrological influences that determine how humans use transboundary waters.

Regional Assessment – Global Perspective

The GIWA provides a global perspective of the world's transboundary waters by assessing 66 regions that encompass all major drainage basins and adjacent large marine ecosystems. The GIWA Assessment of each region incorporates information and expertise from all countries sharing the transboundary water resources.

Global Comparability

In each region, the assessment focuses on 5 broad concerns that are comprised of 22 specific water related issues.

Integration of Information and Ecosystems

The GIWA recognises the inextricable links between freshwater and coastal marine environment and assesses them together as one integrated unit.

The GIWA recognises that the integration of socio-economic and environmental information and expertise is essential to obtain a holistic picture of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

The GIWA indicates priority concerns in each region, determines their societal root causes and develops options to mitigate the impacts of those concerns in the future.

This Report

This report presents the results of the GIWA assessment of the Russian Arctic region, which is occupying a large part of the Russian Federation and is including the Kara Sea, Laptev Sea, East Siberian Sea as well as the Russian section of the Chukchi Sea. The region contains significant stocks of natural resources, like oil and gas. The exploitation of these resources leads to severe environmental impacts, where the issues chemical pollution, oil spills and modification of ecosystems were identified as having the highest priority. The past and present status and future prospects are discussed, and the transboundary issues are traced back to their root causes. Policy options have been identified not only to preserve and restore the aquatic ecosystems and to reduce pollution, but also to aid the local population to deal with the environmental and socio-economic concerns.

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