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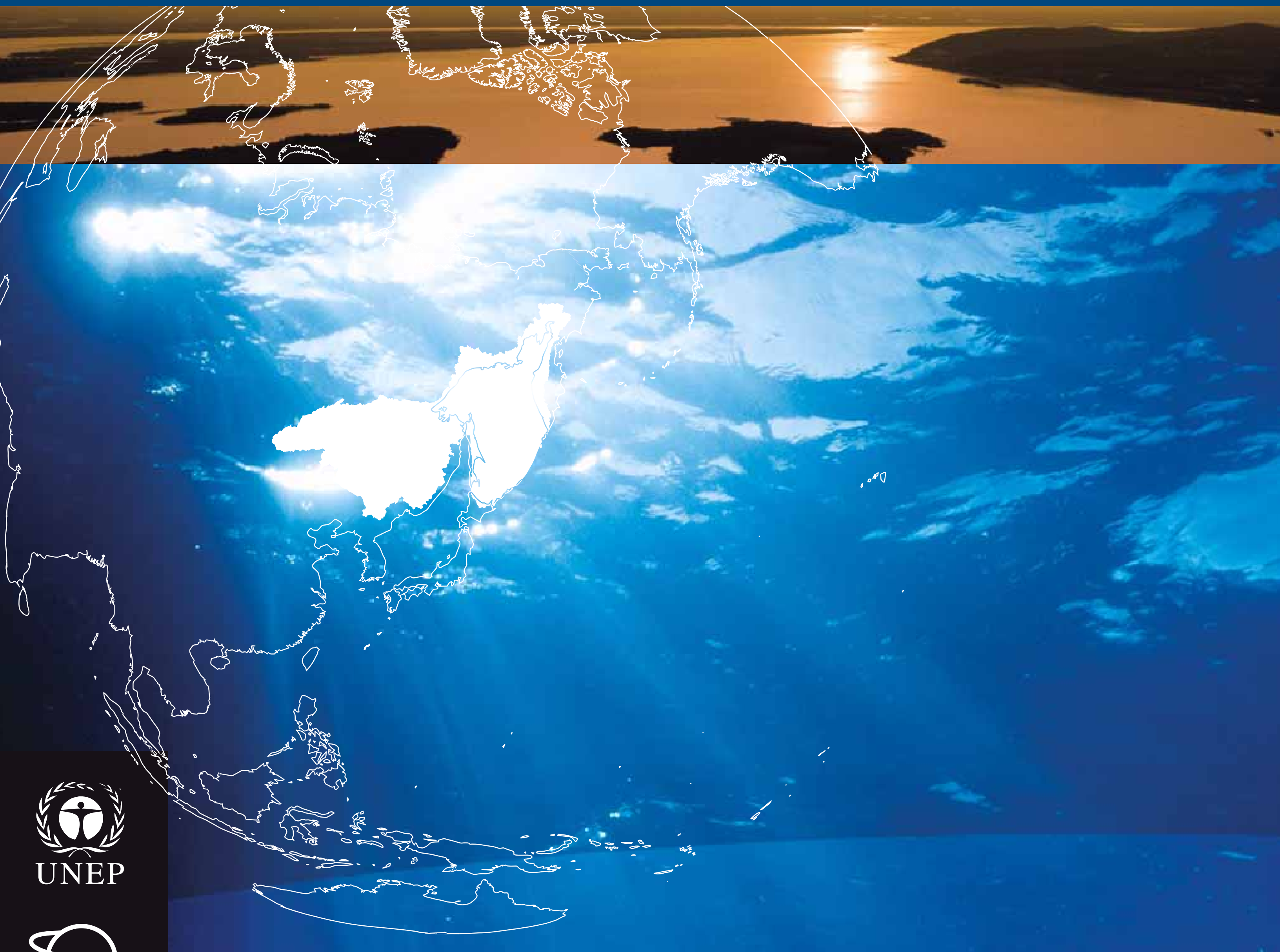

Sea of Okhotsk

GIWA Regional assessment 30

Alekseev, A.V., Baklanov, P.J., Arzamastsev, I.S., Blinov, Yu.G., Fedorovskii, A.S., Kachur, A.N., Khrapchenkov, F.F., Medvedeva, I.A., Minakir, P.A., Titova, G.D., Vlasov, A.V., Voronov, B.A. and H. Ishitobi

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Sea of Okhotsk

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Contents

Executive summary

The GIWA Sea of Okhotsk region comprises the Okhotsk Sea and its surrounding catchments, the largest of which, by far, is the Amur River Basin – a transboundary basin shared between China, Mongolia, Russia and North Korea. Other basins draining into the Okhotsk Sea include those of the Khabarovskiy Kray, Magadanskaya and Kamchatskaya oblasts in Russia.

For the purpose of this report, the Sea of Okhotsk region can be divided into two sub-systems: the Okhotsk Sea (marine) and the Amur River Basin (freshwater).

The Okhotsk Sea sub-system has an area of approximately 1.6 million km^2 and a coastline 10 460 km in length. More than 95% of the coast of the Sea lies within Russian territory, with Hokkaido Island (Japan) accounting for the remainder. The Sea contains over 50% of the Russian Far East's bio-resources and is regarded as the richest fishery region in the world, with approximately 340 fish species. Its continental shelves are rich in hydrocarbon resources. Although the majority of the Sea is within Russia's exclusive economic zone (EEZ), its centre is high seas (neutral zone), and its southeastern part, adjacent to Hokkaido Island, lies within Japanese territorial waters. The Sea's coast is generally characterised by mountainous relief which demarks the watershed – a narrow land belt 100-150 km wide.

The sub-system Amur River Basin – known in China as the Heilong Jiang – is one of the largest river systems in Asia, covering about 2 million km^2. The River is one of the ten longest in the world (approximately 4 345 km) and its course forms the boundary between Russia and China for 3 000 km. The average annual discharge of the Amur River is 369 km^3. The Amur River Basin hosts some of the world's most diverse and productive habitats and encompasses extensive areas of complex and unique ecosystems. The River supports more fish species than any other Russian river, with more than 120 species, 18 of which are endemic and eight endangered. The Basin's territory is socially, politically and economically diverse, with varying development patterns. These differences can be an obstacle to international cooperation in the Basin.

The population of the Okhotsk Sea sub-system is approximately 8.7 million, of which 2.7 million live in Russia and about 6 million in Japan. The Russian coast, except for Sakhalin Island, is sparsely populated, with a population density of approximately 1.5 people per km^2. The population of the Amur River Basin sub-system fluctuates between 70 and 80 million people, 5 million of whom live in Russia, 65-75 million in China and less than 50 000 in Mongolia. The North Korean part of the Basin is largely unpopulated. The Basin's average population density is 35 people/km^2, though 105 people/km^2 in the catchment of the Songhua River (a tributary of the Amur River in China) which includes large cities such as Harbin, Jilin and Mudanjiang.

This report presents the results of the UNEP/Global International Waters Assessment for the Sea of Okhotsk region (GIWA region 30). It is based on the outputs of three workshops, conducted in Vladivostok, Russia, in 2001, 2003 and 2004 respectively. The Task team consisted of local experts with various specialist backgrounds regarding environmental and socio-economic impact assessments in the Sea of Okhotsk region. The results are the consensus of the team and other participants of the workshops (see Annex I) and are substantiated using data obtained from a number of sources, including international and national programmes and projects operating within the region. For the Amur River Basin sub-system, this report assesses only the Russian territory and two of the riparian provinces of China (Heilongjiang and Jilin).

During the Scaling and scoping workshop, the experts prioritised the GIWA major concerns in the following rank order:

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

The priority concerns were identified as Pollution, specifically the issue of eutrophication (for the Amur River Basin sub-system) and oil spills (for Okhotsk Sea sub-system), and the Unsustainable exploitation of fish and other living resources (for the whole Sea of Okhotsk region).

In the Okhotsk Sea sub-system, oil and gas exploitation provides economic benefits for the region but discharges significant quantities of wastewater as by-products of drilling operations. Although only three major oil spills have occurred in the region since the 1990s, the future expansion of the oil industry in the region will increase the risk of spills. In the Amur River Basin, eutrophication has been attributed to nutrient enrichment caused by the discharge of domestic wastewater and surface run-off from the catchment area. It is expected to increase in severity over the next 20 years, with the communities of the lower Amur River Basin and Songhua River Basin experiencing the greatest socio-economic impacts. A significant proportion of chemical pollution originates from pesticides used in the agricultural sector, as well as heavy metals released by other human activities.

Over the past 15 years, total fish catches in the Sea of Okhotsk have drastically reduced. Catches of pollock – the major commercial species in the Okhotsk Sea sub-system – have decreased significantly, though estimating total catches is extremely difficult. In the Amur River Basin sub-system, stocks of salmon and sturgeon have declined as a result of overfishing and the degradation of spawning habitats. The problem is exacerbated by inappropriate fishing practices as well as adverse natural conditions. It is expected that salmon will continue to be overfished for the foreseeable future.

The concern of Habitat and community modification was assessed as having a slight impact. In the Okhotsk Sea, human activities have altered the habitats of pollock, Humpback whale and the endangered Gray whale, among other species. Whales are threatened by the increasing exploration and extraction of marine oil and gas reserves. Habitat and community modification is expected to increase in severity in the future due to further oil and gas development, which will also necessitate the development of bulk-oil complexes and harbours for large tankers. In the Amur River Basin, the extent of wetlands has declined in both Russia and China, threatening biological diversity and endangered species in the Basin, notably several migratory bird species.

The immediate causes of eutrophication in the Amur River Basin sub-system were identified as the considerable quantities of organic matter and biogenic material in domestic and industrial wastewaters and surface run-off. Run-off of fertilisers from agricultural areas also stimulates eutrophication. The sectors responsible for eutrophication were identified as industry, urbanisation, agriculture and aquaculture. Oil development on the Russian Sakhalin shelf has increased the intensity of oil-related marine traffic transiting the Okhotsk Sea. Although there have been relatively few incidents to date, there is always a risk of a spill through deliberate or accidental discharges. Oil is also discharged by the numerous fishing vessels operating on the Sea. Overfishing is affecting the ecosystems of the Sea of Okhotsk region. Fish catches have declined by one-third due to depleted fish stocks. The main cause of the stock depletion is overexploitation where the Total Allowable Catches (TACs) of Russia are exceeded by 2 to 10 times.

In the future, these aquatic concerns will remain the most significant anthropogenic threats to the region. Mitigatory actions should include: waste control and treatment in the Amur River Basin sub-system; the prevention of oil spills and the development of emergency response measures; and sustainable fisheries management.

In the Amur River Basin sub-system, there are a number of institutional weaknesses which are either promoting or failing to prevent transboundary pollution. While there is limited basin-wide cooperation, there is recognition of the need to work together to address transboundary issues. There is limited stakeholder involvement in the decision-making process and public awareness of pollution issues is rather rudimentary. A major hindrance for policy-makers when setting priorities for remediation is the lack of knowledge of the ecological characteristics and their reaction to human activities. A technical problem is the poor condition of wastewater treatment infrastructure.

In the Sea of Okhotsk region, overcapacity of the fishing fleet is a major factor in the overexploitation of the region's commercial stocks. The introduction of auctions of fish quota-rights, in addition to a burdensome tax system, has reduced the profitability of the fisheries, resulting in fishermen undertaking poaching and illegal fishing to supply a black market for fish products. Regional cooperation in combating illegal fishing is limited and national laws and regulations are undermined by deep-rooted corruption and weak enforcement. There is a lack of fisheries statistics and monitoring programmes, and fishermen lack awareness of the long-term impacts of overfishing.

Oil spills in the Okhotsk sub-system were considered to be a considerable future threat because, although there has been rather limited oil contamination to date, the extensive oil and gas development, particularly on the continental shelf of Sakhalin (Russia), and increased shipment of oil across the Sea, will significantly increase the risk of spills. While there has been considerable effort in rapidly developing the oil and gas industry in the region, progress in establishing emergency contingency plans was considered unsatisfactory.

The Policy options recommended to address the water-related problems of the Sea of Okhotsk region are based on the policies adopted at the United Nations Conference on Environment and Development (UNCED) and the World Summit on Sustainable Development (WSSD). Russian environmental and development legislation was also considered during their formulation. The measures discussed in the conclusions and recommendations of this report not only aim to preserve and rehabilitate aquatic ecosystems in the region, but also to prevent future eutrophication, oil spills and overexploitation of fish resources.

Abbreviations and acronyms

BOD	Biochemical Oxygen Demand
CCA	Causal Chain Analysis
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
DDT	Dichlorodiphenyltrichloroethane
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FEB RAS	Far East Branch of Russian Academy of Sciences
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIWA	Global International Waters Assessment
GRP	Gross Regional Product
HCCH	Hexachlorocyclohexane
IUCN	The World Conservation Union
MARPOL	International Convention for the Prevention of Pollution of Sea by Oil
PICES	North Pacific Marine Science Organization
RSFSR	Russian Soviet Federated Socialist Republic
SOC	Stable Organic Compounds
TAC	Total Allowable Catch
TINRO	Pacific Scientific Research Institute of Fisheries and Oceanography
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
USD	United States Dollar
USSR	Union of Soviet Socialist Republics
WSSD	World Summit on Sustainable Development
WWF	World Wildlife Fund

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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 Sea of Okhotsk region

The GIWA Sea of Okhotsk region comprises the Okhotsk Sea sub-system and its surrounding catchments (Figure 1), the largest of which, by far, is the Amur River Basin sub-system – a transboundary basin

Figure 1 Boundaries of the GIWA Sea of Okhotsk region.

100-300 km in width and shared between China, Mongolia, Russia and North Korea. Other basins draining into the Okhotsk Sea include those of the Khabarovskiy Kray, Magadanskaya and Kamchatskaya oblasts in Russia.

The Okhotsk Sea is situated at the margin of the northwestern Pacific Ocean between 43°43' and 62°42' N, and 135°10' and 164°54' E. It is separated from the open ocean by the chain of the Kuril Islands and the Kamchatka Peninsula. The Sea's limits are demarked by Hokkaido Island to the south and west, and the coast of Sakhalin and the Asian mainland to the east. The Sea's maximum length and width are 2 463 km and 1 500 km, respectively. It has an area of approximately 1.6 million km^2, a coastline 10 460 km in length and a total water volume of approximately 1.3 million km^3 (Arzamastsev et al. 2001). The Okhotsk Sea is connected to the Pacific Ocean by the numerous straits of the Kuril Islands, to the Sea of Japan by La Perouse Strait and to the Amur estuary by the Nevelskoy and Tatar straits. The depth of the sea averages 821 m but reaches a maximum of between 3 374 m and 3 521 m within the Kuril hollow (Alekseev & Bogdanov 1991, Dobrovol'sky & Zalogin 1982).

Physical characteristics

Approximately 70% of the region's land is characterised by mountains 1 000-2 000 m above sea level. Low-lying areas are found mainly in the Kamchatka coastal zone, the Penzhinskaya Gulf and in the middle and lower reaches of the Amur River. In these regions of low relief there are extensive swamps and marshes. The watershed of the Sea of Okhotsk region is formed by the Middle Ridge of the Kamchatka, Koryak and Kolyma highlands, and the Dzugdzur, Stanovoi and Yablonovy ridges. The Sikhote-Alin Mountains separate the Okhotsk Sea from the Japanese basins.

Okhotsk Sea sub-system

Climate and meteorological characteristics

The Okhotsk Sea sub-system is located within the monsoon climatic zone of the moderate latitudes. The northern region of the Sea is strongly influenced by the Arctic climate. Average July temperatures range from 8 to 16°C, while, in January, temperatures fluctuate between 8 and -32°C (Rostov et al. 2002). The Kamchatka coast, the western coast of the Okhotsk Sea and eastern Sakhalin form parts of the cold agroclimatic belt. The eastern portion of the Amur River Basin sub-system is within the monsoonal climate zone, whereas its western portion has continental climatic features.

Changes to the distribution and interactions of baric formations, as well as the Sea's position between continental Asia and the Pacific Ocean, are major factors forming the monsoonal climate and Sea's hydrological conditions. The dominant meteorological features that determine atmospheric circulation in the region are the Aleutian Low, North Pacific High and Siberian anticyclone in winter, and the Far-Eastern depression and Okhotsk anticyclone in summer. The generally monsoonal climatic conditions are often disturbed by cyclones which traverse the region from southwest to northeast. The winter, particularly in the northern Sea, is long and severe, with frequent wind and snow storms. In the summer, high precipitation rates, mist and fog are typical, whereas the spring and autumn seasons are short, cold and cloudy. The cold period lasts 120-130 days in the south and 210-220 days in the north of the region (Rostov et al. 2002). The cool, northern air masses have greater influence than the warmer air masses from the south, resulting in a negative heat exchange on the surface. As a result of these distinct meteorological characteristics, the Okhotsk Sea is the coldest of the Far-Eastern seas.

From May to September, light southerly winds (2-5 m/s) prevail. These winds can intensify to over 20 m/s up to four times a year as a result of cyclones and typhoons, with a maximum frequency from August to September. During the cold season, strong northerly winds with velocities of 5-10 m/s prevail. Wind speed and direction differ markedly in the various areas of the Sea. Maximum wind speeds reach 25-30 m/s in the northeastern and western parts of the Okhotsk Sea, 30-35 m/s in the central and eastern areas, and over 40 m/s in the south. The autumn-winter storm winds are characterised by greater strength and duration than those in the summer. The southern and south-eastern areas of the Okhotsk Sea are the most prone to unstable weather systems. The considerable spatial extent of the Sea, in combination with frequent and strong winds, allows intense seas and swell (waves are 4-11 m high) to develop (Rostov et al. 2002). The hydro-meteorological characteristics of the region create treacherous conditions for marine-based human activities.

Hydrology

The hydrological conditions of the Okhotsk Sea are determined by the particularities of its geographical location; its considerable meridional extent; its vulnerability to severe climatic conditions; the nature of vertical and horizontal circulation; the seabed relief, and its water exchange with the Pacific Ocean and Sea of Japan. The hydrology of the coastal waters is additionally influenced by continental discharges, tides and the geographic configuration of the coastline.

In general, the surface water temperature decreases from south to north except during certain summer months when a more mixed pattern is observed (August; Figure 3). Average annual temperatures in the north and south reach 5-7°C and 2-3°C, respectively. Significant annual variations of surface water temperatures exist throughout the Sea (10-19°C) which attenuate with depth. Between May and November, the average monthly water temperatures remain positive. The warmest waters are found in the southernmost part of the sea near the La Perouse Strait and Hokkaido Island. In October, the surface water temperature decreases approximately two-fold and in November changes to its winter spatial distribution. In February and March, surface water temperatures of -1.0 to -1.8°C result in a considerable part of the Sea being covered by ice (February; Figure 3) (Rostov et al. 2002). In the southeastern area of the Sea and to the northwest of the Kuril Islands, the water temperatures seldom register negative values (PICES 2004).

General cyclonic water circulation occurs around the periphery of the Okhotsk Sea (Figure 2). In addition, there are localised gyres and smaller eddies. Stable anti-cyclonic circulation is active over the TINRO hollow, to the west of the southern extremity of Kamchatka and in close proximity to the Kuril Hollow fall. The major currents in the region include the Penzhinskoye, Yamskoye, North-Okhotsk currents and counter-currents, and the East-Sakhalin, Middle and Soya currents.

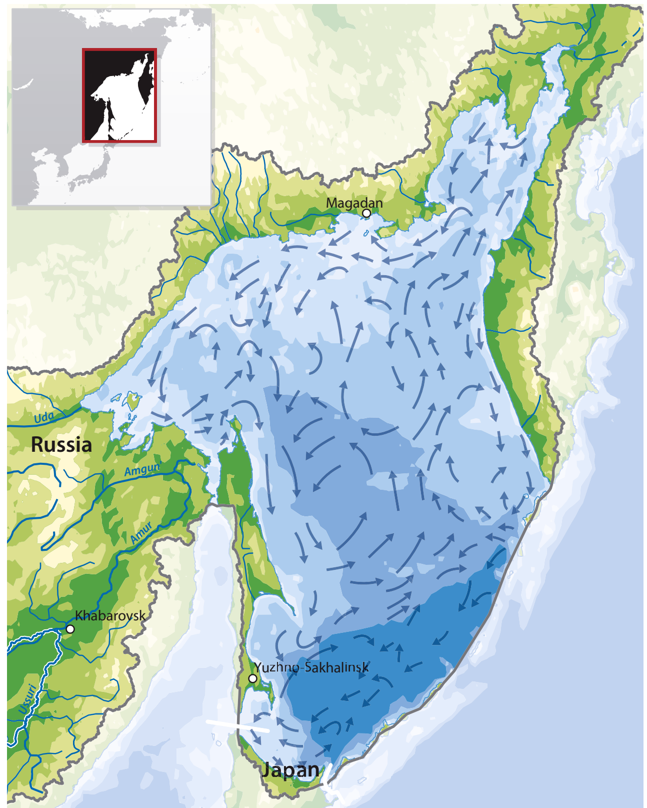

Figure 2 General water circulation.
(Source: Arzamastsev et al. 2001)

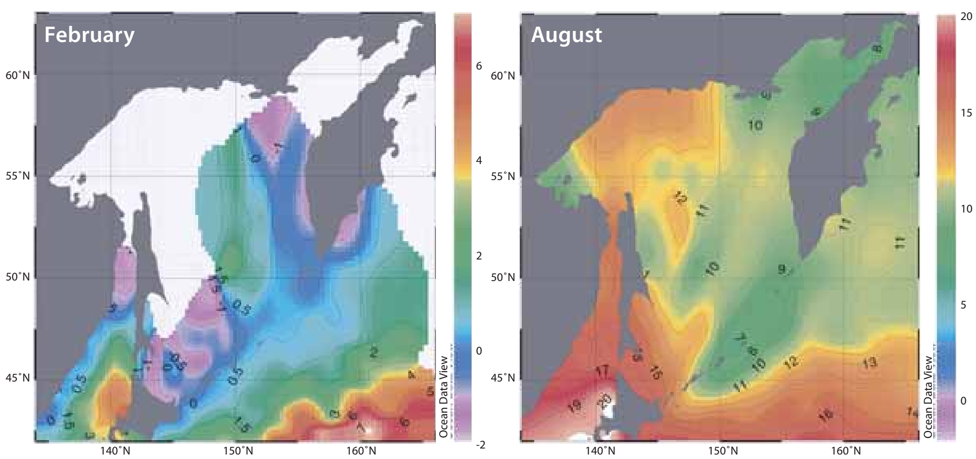

Figure 3 Sea surface water temperatures in February and August.
(Source: Arzamastsev et al. 2001)

The straits connecting the Okhotsk Sea to the Sea of Japan and the Pacific Ocean allow water exchange. The Nevelskoy and La Perouse straits are relatively narrow and shallow, which limits water exchange with the Sea of Japan. Conversely, the straits of the Kuril Islands ridge facilitate greater water exchange as they are approximately 500 km wide and are considerably deeper. The Bussol and Kruzenshtern straits are the deepest, 3 000 m and 1 900 m, respectively (Lapko & Radchenko 2000).

The general pattern of water circulation is subject to considerable seasonal variation. In autumn, the flow rates of the currents increase, and, in winter, currents flowing south and southwest are observed in areas free from sea ice. Periodic currents have greatest velocity in the south and around the periphery of the sea, including the coastal belt, bays, straits and narrow waters. Offshore tidal currents are weak, approximately 5-10 cm/s, while tidal currents near the coast, in bays and straits, and over submerged shoals are stronger (Zalogin & Kosarev 1999).

Severe winter frosts and sea ice cause intense cooling of sea surface waters. The sea ice is formed locally, and both stagnant and drift ice are present. The severity of ice conditions in the Okhotsk Sea is comparable to the Arctic seas (Lapko & Radchenko 2000). The annual ice period lasts for a maximum of 290 days, an average of 260 days in the northwest, 190-200 days in the north and the Sakhalin coasts, and 110-120 days in the south. During severe winters, ice cover can occupy up to 99% of the water area and, in milder winters, about 65%. Generally, ice formation begins in the northwestern part of the sea in November, but as early as October in areas with considerable water freshening. The ice cover gradually extends southwards along the western and eastern coasts, and eventually to the open sea. In December, the consolidated fast ice is formed in the bays and bights (Lapko & Radchenko 2000). In January and February, the ice fields occupy the northwestern and central parts of the sea. The drift ice reaches a great density and is subject to intense compression and hummocking.

Salinity

The salinity of the Okhotsk Sea is largely determined by the hydrological cycle in terms of the balance between precipitation and evaporation; the effect of sea ice formation and melting processes; continental discharges to the coastal zone; and water exchange with adjacent seas. The salinity of coastal surface waters in the northwestern part of the Sea has a large annual variance of 20-25‰ to 30-33‰. In summer and early autumn, the salinity of the Sea is less than in winter when it increases as a result of ice formation and a reduction in continental discharge (see Figure 4). Offshore and in the southwestern sea, salinity variations are less pronounced (31.0-33.5‰) (Rostov et al. 2002) due to water exchange via the La Perouse and Kuril straits. The seasonal fluctuations in salinity differ depending on location. There is a general trend of increasing salinity down the water column in all seasons and there are comparably few spatial and temporal variations.

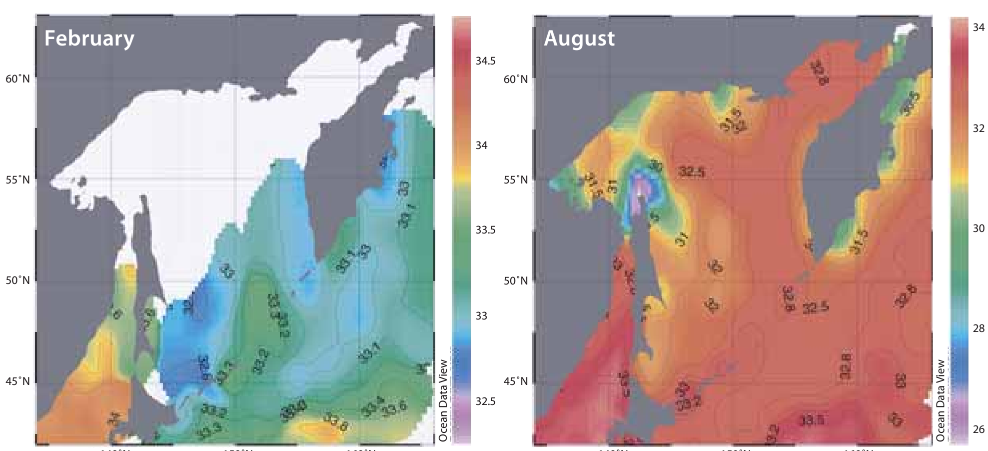

Figure 4 Salinity of surface water in February and August.
(Source: Arzamastsev et al. 2001)

Amur River Basin sub-system

The sub-system Amur River Basin, known in China as the Heilong Jiang, is one of the largest river systems in Asia, covering about 2 million km². The River is one of the ten longest in the world (approximately 4 345 km) and its course forms the boundary between Russia and China for 3 000 km. It originates from the Argun/Urgun (Russia-China border) and Shilka (Russia) rivers, is joined by the Songhua River (China), and later meets the Ussuri/Wusuli River (Russia-China border) and the Zeya and Bureya Rivers (Russia). The Amur then flows north until it reaches its mouth on the Tatar Strait from where it flows into the Okhotsk Sea.

Table 1 Basic hydrological and water quality characteristics of the Amur River

Characteristic	Value
Water run-off, average, long-term, km^3	369.1
Run-off maximum, annual, km^3	459.2
Run-off minimum, annual, km^3	135.0
Maximum water discharge, m^3/s	40 000
Minimum water discharge, m^3/s	153
Average annual flow of detritus, millions of tonnes	24.0
Average annual water turbidity, mg/dm^3	90.0
Maximum water turbidity, mg/dm^3	517.0
Average annual flow of dissolved matter, millions of tonnes	20.23
including Ca^{2+}	2.34
Mg^{2+}	0.74
$Na^+ + K^+$	1.60
HCO_3^-	10.40
SO_4^{2-}	2.10
Cl^-	1.10
Average annual flow of organic matter, millions of tonnes	5.3

(Source: Estimates of Institute of Water and Ecological Problems, FEB RAS)

The average discharge of the Amur River is 11 700 m³/s (369 km³/year). During spring and summer (April-September) almost 75% of the annual discharge is recorded, while only about 14-25% flows during autumn and winter (October-March). Among the major tributaries contributing to the Amur River's total discharge are the Zeya (17%), Ussuri/Wusuli (12%), Bureya (7.7%), Amgun (5.7%), Shilka (4.7%), Tunguska (3.5%), Argun/Urgun (2.9%), Anyui (1.9%), Gorin (1.6%) and Gur (1.4%). The smaller tributaries contribute between 0.1 and 1.0% to the annual discharge. The smaller river basins of Khabarovskiy Kray, Magadanskaya and Kamchatskaya oblasts also drain into the Okhotsk Sea. Table 1 shows the basic hydrological and water quality characteristics of the Amur River.

There are more than 60 000 lakes in the Amur River Basin sub-system, the largest being Khanka, Chukchagirskoye, Bolon, Udyl, Bolshoe Kizi, Evoron, Chlya (Voronov 2003). The Lake Khanka Basin, known as Lake Xingkai in China, is located in the upper part of the Ussuri/Wusuli River system. It is the largest freshwater lake in East Asia – shared by China (Heilongjiang province) and Russia (Primorskiy Kray).

Biodiversity and critical habitats

The Amur River Basin sub-system hosts some of the world's most diverse and productive habitats and encompasses extensive areas of complex and unique ecosystems. The Russian section of the Amur River Basin is situated in a temperate mixed broadleaved and coniferous forest zone, and forest steppe zone. The Amur River supports more fish species than any other Russian river, with more than 120 species (WWF 2001), 18 of which are endemic and eight are endangered, including Kaluga sturgeon (*Huso dauric*). There are also seven migratory salmon species (GEF Concept paper 2005). Lake Khanka and its surrounding wetlands have particularly high species diversity. The Lake's basin hosts 342 bird species which account for 65% of the total bird species found in Far-Eastern Russia and 48% in Russia. 12 species are included in the International Red Book. The variety of fish species in the Lake and its inflow and outflow (only Songacha) rivers represents 73% of the fish species in the Amur basin. The wetlands around the lake are used for a spring and autumn resting place for migratory species and for spawning grounds for commercial species, such as Predatory carp (*Erythroculter erythropterus*) and Mongolian redfin (*Erythroculter mongolicus*) (GEF Concept paper 2005).

About 61 species of mesopelagic fish belonging to 53 genera and 33 families have been recorded in the Okhotsk Sea sub-system (PICES 2004). There are known to be 16 species of squid – an important component of the food web of the Sea's ecosystem – belonging to nine genera and six families. Regarding groundfish, 50% are flatfish, 21% cods, and 11% sculpins. These three groups are a major determinant of the fish productivity of the Okhotsk Sea shelf. The Sea is home to 11 endangered species including the Western Pacific gray whale which is critically endangered in this region. At least 16 species of marine mammals inhabit the Okhotsk Sea sub-system. There are four species of the true seal (Phocidae) and two species of eared seal. Whales that inhabit the Sea include, among others, Gray whales (*Eschtrichtius robustus*), Southern baleen whales (*Eubalaena japonica*), Bowhead whales (*Balaena mysticetus*), Northern fin whales (*Balaenoptera physalus*), Little picked whales (Minke's) (*Balaenoptera acutorostrata*), Humpback whales (*Megaptera novaeangliae*), Baird's beaked whales (*Berardius baridii*) and Killer whales (*Orcinus orca*).

Socio-economic characteristics

Population

The population of the Okhotsk Sea sub-system is approximately 8.7 million, of which 2.7 million live in Russia and about 6 million in Japan. The Russian coast, except for Sakhalin Island, is sparsely populated, with a population density of approximately 1.5 people per km^2 (Figure 5). The only Russian cities with a significant population size (60 000-200 000 inhabitants) are Yuzhno-Sakhalinsk, Magadan, Nikolaevsk-on-Amur and Okha. The majority of the rural and urban population lives within the permafrost zone, tolerating severe or extreme natural conditions. The far eastern Russian economy experienced a severe and long recession in the 1990s which led to emigration and a decline in population. The largest decline in population out of all the Pacific coastal regions between 1991 and 2000 was observed in the Magadanskaya Oblast' (40% decline), Kamchatskaya Oblast' (20%) and Sakhalinskaya Oblast' (18%).

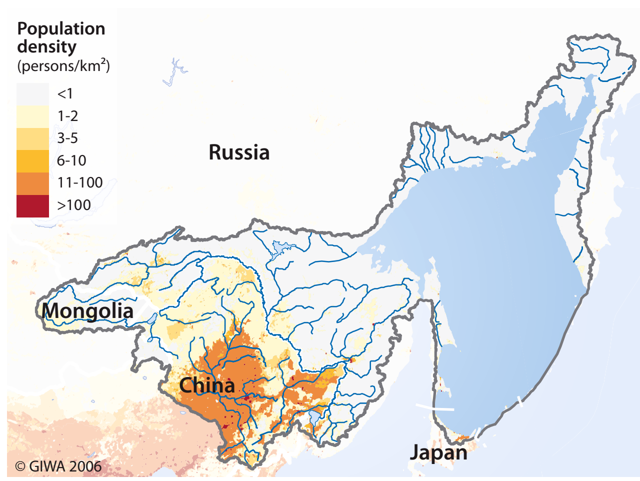

Figure 5 Population density of the Sea of Okhotsk region.
(Source: Data from ORNL 2003)

The population of the Amur River Basin sub-system fluctuates between 70 and 80 million people, 5 million of whom live in Russia, 65-75 million in China and less than 50 000 in Mongolia. The North Korean part of the Basin is largely unpopulated (Voronov 2003). The catchment of the Songhua River (a tributary of the Amur River) has a population density of 105 people/km^2 (compared to 35 people/km^2 in the whole of the Amur Basin) and includes most of the large cities in the Amur basin, such as Harbin, Jilin and Mudanjiang (GEF Concept paper 2005).

Economy

In the Russian coastal areas of the Sea of Okhotsk region there is a developed mining industry. The fishing industry is found in Kamchatka, Magadan, Okhotsk, Ayan and Nikolaevsk-on-Amur (Khabarovskiy Kray).

In Sakhalin, hydrocarbon is exploited and there are coal mining, and wood and pulp-and-paper industries. Figure 6 shows the distribution of industrial activities in the Okhotsk Sea sub-system. In the Amur River Basin sub-system, ship building and repair, carpentry, construction and coal mining are the predominant industries. Further, power generation using coal, gas and hydroenergy is a major sector. The sectoral structure of industrial output in the Far East of Russia in 2000 is shown in Table 3.

Table 2 Basic economic characteristics of the administrative regions of the Sea of Okhotsk basin.

Sectors of the Sea of Okhotsk basin	**Population in sector** (people)	**Share of total population of administrative territory** (%)	**Gross regional product** (million USD)	**Industrial output** (million USD)	**Volume of agricultural production** (million USD)	**Cost of basic assets of economics branches** (million USD)
Sakhalin and Kuril	335 000	61.24	722.9	615.8	38.1	2169.4
Magadan	125 000	68.41	286.6	244.6	8.5	1110.1
Khabarovsk	407 000	28.4	642.2	557.6	36.4	2931.5
Kamchatka	24 000	6.3	37.2	32.7	3.5	134.3
Japanese (Hokkaido Island)	310 000	6.1	10 200			

(Source: Russian Regions 2001)

Figure 6 Distribution of industries in the Sea of Okhotsk Basin.
(Source: Prepared by the authors using Russian Regions 2002)

During a period of market reforms between 1990 and 1998, there was a significant decrease in investment and industrial production. Since 1999, the Russian economy, including that of the Far East, has stabilised and industrial production has increased. GDP growth has averaged 5-7% for the period 2000-2004 (Lvov 2004).

According to the GIWA regional experts, the socio-economic development of the region has been determined by the following:

1. The collapse of economic relations with the western regions of Russia;
2. Aggravation of social problems. Transport tariffs increased by 10-12 times making voyages to the western regions of Russia unaffordable for most people;
3. Limited market in Far-Eastern Russia for primary and manufactured products;
4. Factors increasing the cost of production. For example, harsh natural conditions, remoteness of settlements and poor infrastructure development;
5. Marginal location of region; it is a considerable distance from the industrial centres of Russia, thus increasing transportation costs;
6. Periodic emigration from the region; and

Table 3 Sectoral structure of industrial output in the Far East of Russia in 2000.

Region	**Electric power industry**	**Fuel industry**	**Nonferrous metallurgy**	**Chemical and petro-chemical industry**	**Mechanical engineering including shipbuilding and ship repair**	**Wood, woodworking and pulp and paper industry**	**Food-processing industry including fish complex**	**Other**
Primorsky Krai	16.4	2.1	3.7	1.0	16.3	6.8	46.7	7.0
Khabarovsk Krai	8.5	7.9	8.4	1.6	50.4	8.0	8.5	6.7
Amur Oblast	34.4	4.7	29.6	0.1	6.3	5.7	10.2	9.1
Kamchatka Oblast	20.1	0.3	8.3	0.1	4.0	0.6	63.3	3.3
Magadan Oblast	15.3	1.1	66.4	0.0	1.5	0.3	14.0	1.4
Sakhalin Oblast	6.0	60.6	0.2	0.1	1.2	3.2	27.4	1.3
Jewish Autonomous Oblast	13.5	0.2	4.7	0.5	25.4	5.5	13.3	36.9
The Far East as a whole	11.4	13.2	29.8	0.6	16.7	4.1	19.8	4.4

(Russian Regions 2001)

7. The socio-economic conditions contrast with neighbouring countries in terms of population density, market characteristics and infrastructure development.

The Russian section of the Amur River Basin is one of the most developed territories in the Russian Far East. During the 18th and 19th centuries, development was concentrated on the north side of the Amur River. Economic development was further stimulated following the construction of the Trans-Siberian Railway in the 20th century, which crosses the Amur River. The Basin has an estimated 35% of the industrial potential and over 75% of the agricultural potential of the Russian Far East.

In Northeast China, the GRPs in 1999 of the Heilongjiang and Jilin provinces totalled 2.4 billion USD (14th position out of 32 Chinese provinces) and 1.4 billion USD (19th position), respectively (Baklanov et al. 2002a). As a result of economic reforms, there has been a shift in the employment structure of the region from the primary to the secondary and tertiary (service) economic sectors. This trend continued in subsequent years as a result of the state funded manufacturing industries of Northeast China (Baklanov et al. 2002a). There has also been significant investment in transport and communication infrastructure in order to stimulate trade with regions outside Northeast China. In Jilin, agriculture remains the largest sector, both in terms of production output and employment rates. There is major domestic and foreign investment in the Heilongjiang and Jilin provinces, particularly in agriculture, engineering and transport infrastructure.

Future economic development in the Sea of Okhotsk region will be based upon the exploitation of the region's mineral resources, such as oil, gas and coal, and possibly the development of hydropower. In addition, there are abundant forest resources and considerable land resources.

Economic sectors

Oil and gas industry

The Sea of Okhotsk region includes the Okhotsk oil and gas fields, making its hydrocarbon resources particularly important economically. Significant reserves of oil and gas are predicted to exist in the northeastern and northern shelves of Sakhalin, the western Kamchatka shelf and in the middle and lower reaches of the Amur River Basin. Only a small proportion of the large hydrocarbon reserves of the Russian Far East is exploited. The dynamics of oil production is shown in Figure 7. Although the volume of oil exploited continues to increase, with oil production reaching 3.4 million tonnes in 2004, only 20% of regional consumption is met by regional production.

An evaluation of hydrocarbon resources made by Dalmorneftegeofizika in 1994, concluded that the Sea of Okhotsk shelf has the equivalent of 14 462 million tonnes of fuel. In Sakhalin Island and on its shelf there are estimated to be 324 million tonnes of oil and 997 million tonnes of gas. By 2000, 23 oil and gas-oil, and 5 gas fields had been developed. Figure 8 shows the areas of prospective development of the oil and gas fields in the Sea of Okhotsk region.

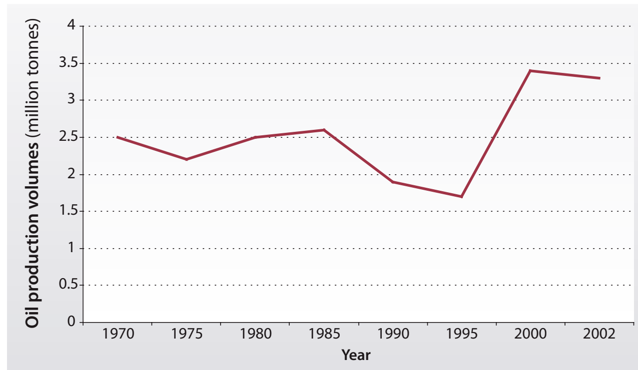

Figure 7 Oil production volumes.
(Source: Russian Statistical Yearbook 2001)

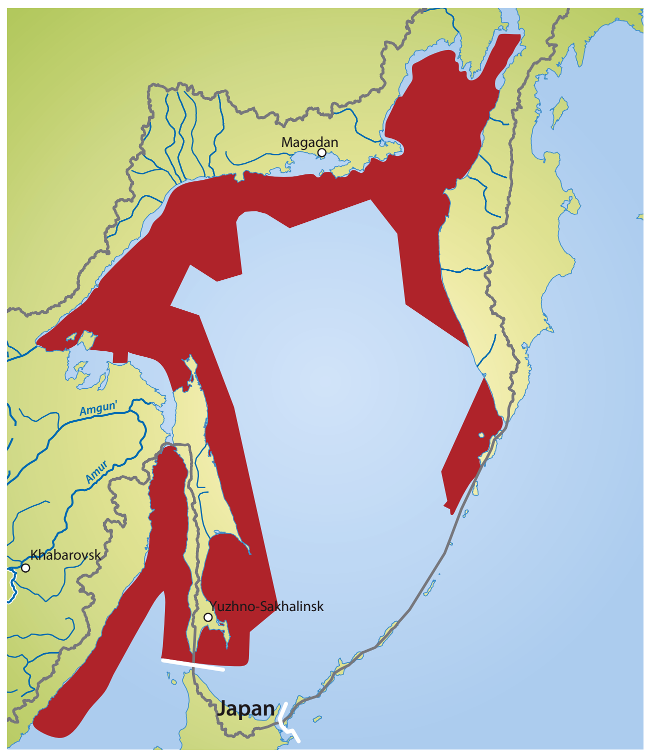

Figure 8 Areas of prospective development of the oil and gas fields in the Sea of Okhotsk region.
(Source: Alekseev et al. 2001)

Renewable resources

The region's renewable energy sector also has development potential. Shelikhov Bay and the Penzhinskaya Gulf have large tidal ranges of up to 10-12 m and are thus suitable for tidal energy projects. The Amur River and its tributaries, including the Zeya, Selemdzha and Burea rivers, have significant hydropower potential (Alekseev et al. 2001). In the Russian part of the watershed, there are hydroelectric plants such as the Somninskaya located on the watercourse of the Amgun and the Zeiskaya on the Zeya. Additionally, the Bureiskaya hydroelectric plant was recently constructed near the Talakan River mouth and further hydro-electric projects are planned for the Selemzha and Gilyui rivers. The region also has an abundance and diversity of wood resources.

Mineral resources

The Sea of Okhotsk region contains a wealth of mineral resources. In some of the region's mountains and river valleys, gold has been discovered and ferrous and non-ferrous metals and polymetallic ores are exploited. There is great mining potential in the coastal areas where substantial mineral reserves, particularly of boron, antimony and fluorspar, are found. Large reserves of brown and hard coal have been discovered in Sakhalin and in the Amur River Basin. In a zone adjacent to the lower reaches of the Uda, Amgun and Amur rivers there are considerable phosphorite reserves. Figure 9 shows the distribution of natural resources in the region.

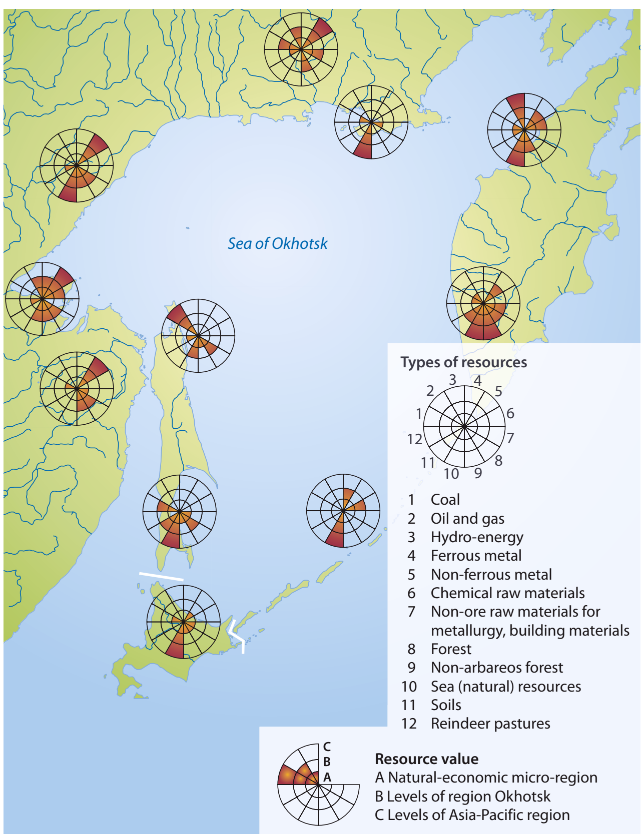

Figure 9 Natural resources of the Sea of Okhotsk sub-system.
(Compiled by the authors)

Agriculture

The agricultural sector (mainly grain and soybean production, and cattle-breeding) has been developed primarily in the middle and lower reaches of the Amur. In other areas of the Sea of Okhotsk region, deer-breeding, local arable farming and cattle-breeding are common, particularly in the south of Sakhalin and southwestern Kamchatka. The Amur River Basin sub-system is a major agricultural zone of the Russian Far East. The most fertile agricultural lands are located on the Zeya-Bureinskaya Plain and Lake Khanka lowlands.

Fisheries

The Okhotsk Sea sub-system is regarded as the richest fishery region in the world. The volume of biological resources in the Sea constitutes 46% of all marine biological resources in the northern Pacific. It has an estimated 11 million tonnes of biological resources, including approximately 7 million tonnes of cod, 2.5 million tonnes of herring and about 1.5 million tonnes of other seafood (e.g. molluscs and algae) (Shuntov 2001). Approximately 340 fish species inhabit the Okhotsk Sea (Froese & Pauly 2005). The main fish products are flounders, herring, capelin, halibut, pollock and crab. Walleye pollock (*Theragra chalcogramma*) is the most abundant commercial species in the Sea. Catch volumes average 1.2-1.5 tonnes per km^2, but in productive years reach between 8 and 22 tonnes per km^2 on the western Kamchatka shelf. In comparison, fisheries production is about 0.7-1.1 tonnes per km^2 in the North Atlantic (The Seas 1998). Russian catches of commercial fish between 1992 and 2003 in the Okhotsk Sea are given in Figure 10.

Until recently, numerous vessels from various countries fished intensively in the Okhotsk Sea. The Sea's non-Russian fishery has been closed since 2003 with the exception of Japanese gill net fishing for Pacific salmon. In 2005, the foreign fleet was not allocated any quotas for fish in the Okhotsk Sea sub-system (Governmental Resolution 2004).

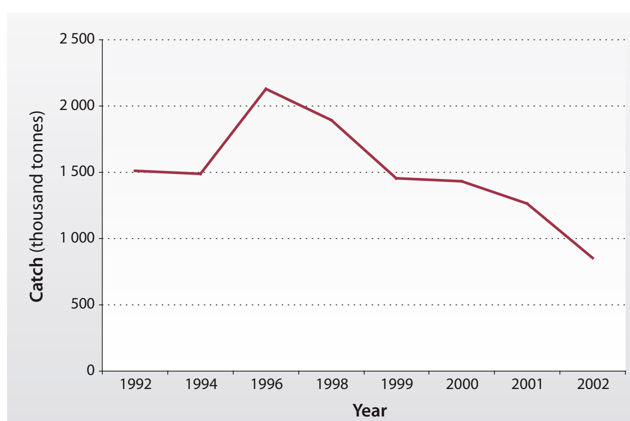

Figure 10 Catches of commercial fish by the Russian fleet in the Okhotsk Sea.
(Source: Barushko 2005)

In 2000, the fishing industry contributed 1.2 billion USD to the economy of the Russian Far-East. It accounted for 18.2% of gross regional product (GRP) in 1999, and as much as 63.5% in the Koryak Autonomous Region, 49.3% in Kamchatka, 27.3% in Primorskiy Kray, and 18.3% in Sakhalinskaya Oblast'. The fisheries industry therefore plays an important role not only for the local economy, with one fisherman creating 6-7 workplaces onshore, but also in the development of the social and cultural characteristics of the region and the distribution of fishing settlements.

The riparian population of the Amur River has depended throughout history on fishing and hunting as its major source of food supply. The Amur River Basin sub-system contains one of the largest inland fishing industries in Russia. The most important commercial fish species in the Amur are the migratory salmons (Humpback, *Oncorhynchus gorbuscha* and Chum, *O. keta*), sturgeons (Amur, *Acipenser schrenckii* and Kaluga, *Huso huso*), smelt, and lamprey (*Lethenteron* sp.). Sturgeon fishing is an important part of the regional fish industry but, due to the depletion of stocks, bans were enforced on Kaluga sturgeon between 1976 and 1991. The Amur is one of the richest rivers for salmon in the world; in 1910 the total catch of salmon was over 100 000 tonnes. The majority of catches of salmonids consist of Humpback salmon (Novomodny et al. 2004).

Aquaculture

In Russia, aquaculture is poorly developed. According to the GIWA experts, only 40 fish breeding factories operate in the entire Russian Far East which release 0.5 billion juvenile fish. In comparison, Japan has 350 factories which release approximately 2 billion juvenile fish. Most commonly, Chum salmon, Humpback salmon and other species of salmon are bred, mainly in Sakhalin. Most enterprises have become obsolete as they failed to achieve their anticipated production capacities due to poor management. Only 1% of the total output of the fisheries industry is produced by aquaculture (Baklanov et al. 2002b).

Water use

There is an irregular distribution of water resources in the Basin between the oblasts and krays of Russia and the territories of Mongolia and China. The majority of freshwater originates from Khabarovskiy Kray (34%), Amurskaya Oblast' (22%) and from China (28%). Water resources in the basin are extensively used for agricultural, industrial, energy production and domestic purposes. In Khabarovskiy and Primorskiy krays and Priamurye, more than 80% of the total water abstracted is used for production and domestic purposes. In other regions, irrigation and domestic supply are the most significant consumers. In Chitinskaya Oblast', within the watersheds of Argun/Urgun, Onon and Ingoda rivers, as well as practically all the administrative districts of Primorskiy Kray, more than 90% of water resources are used for these purposes. Table 4 shows how water consumption generally decreased in the Russian administrative regions during the 1990s.

Table 4 Consumption of freshwater in the Russian adminstrative regions of the Okhotsk sea.

Region	1991 (million m^3)	1995 (million m^3)	2000 (million m^3)	2001 (million m^3)
Khabarovsk Kray	714	558	465	467
Kamchatka Oblast	309	276	261	252
Magadan Oblast	144	137	90	96
Sakhalin Oblast	455	376	275	273

(Source: Russian Regions. 2002. Moscow, 2002.)

International cooperation

The three riparian countries of the Amur River Basin sub-system have established bilateral cooperation agreements in the field of protection and use of transboundary water resources. These include:

- Agreement between the USSR and China on joint research operations to determine the natural resources of the Amur River Basin and the prospects for development of its productive potentials and on planning and survey operations to prepare a scheme for the multi-purpose exploitation of the Argun River and the Upper Amur River, 1956;
- Agreement between the governments of Russia and China on cooperation in the field of conservation of transboundary water resources.
- Agreement between the governments of Russia and China on cooperating in the preservation of the environment, 1994.
- Agreement between the governments of Russia and China on cooperating in the conservation, regulation and protection of living aquatic resources in the boundary waters of the Amur and Ussuri Rivers, 1994.
- Agreement between the governments of China and Mongolia on the protection and utilisation of transboundary waters and environmental management (1994); and
- Agreement between the governments of Mongolia and Russia on the protection and use of transboundary waters, 1995.

International treaties relevant to the Okhotsk Sea sub-system:

- The international convention for the regulation of whaling, 1946;
- The international convention for the prevention of pollution of the sea by oil, 1954;
- The convention on the continental shelf, 1958;
- The Ramsar convention on wetlands, 1971;

- The convention on international trade in endangered species of wild fauna and flora, (CITES), 1973;
- The convention on the prohibition of military or any other hostile use of environmental modification techniques, 1977;
- The United Nations convention on the Law of the Sea (UNCLOS), 1982; and
- The agreement for the implementation of the United Nations convention on the Law of the Sea of December 10, 1982, relating to the conservation and management of straddling fish stocks and highly migratory fish stocks, 1995.

Regional agreements relevant to the Okhotsk Sea sub-system

- The agreement between the governments of USSR and Japan about mutual relations in the sphere of fishery at coasts of both countries, 1984;
- The agreement between the governments of USSR and Japan about cooperation in the sphere of fishery, 1985;
- The agreement between the governments of USSR and North Korea about cooperation in the sphere of fishery, 1987;
- The agreement between the governments USSR and Chinese about cooperation in the sphere of fishery, 1988;
- The agreement between the governments USSR and South Korea about mutual relations in the sphere of fishery, 1991;
- The convention for the conservation of anadromous stocks in the North Pacific Ocean, (Russia, United States, Canada, Japan, South Korea), 1992;
- The North Pacific Marine Science Organization (PICES), (Russia, Canada, United States, Japan, China, South Korea), 1992; and
- The agreement between the governments of Japan and Russia on matters of cooperation in the field of fishing operations for marine living resources, 1998.

Protected areas – case of Lake Khanka

The two Lake Khanka basin riparian countries, Russia and China, initiated specific measures to protect species and their habitats, particularly the wetland areas around the lake. Two protected areas were established for this purpose: Lake Xingkai National Nature Reserve (China) and Khankaisky National Nature Reserve (Russia). The Russian side of the lakeshore wetlands have been designated as a Ramsar site. However, the national legislations and restricted activities applicable to them differ, and it is expected that more harmonised management and regulations for the protected areas will be developed between the two national nature parks.

Assessment

Table 5 Scoring table for Sea of Okhotsk.

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

- 0 No known impacts
- 1 Slight impacts
- 2 Moderate impacts
- 3 Severe impacts

The arrow indicates the likely direction of future changes.

- ↗ Increased impact
- → No changes
- ↘ Decreased impact

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

* 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.

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 5 and Annex II.

The Sea of Okhotsk region is a large and complex system which, for the purpose of this report, can be divided into two sub-systems: the Okhotsk Sea (marine) and the Amur River Basin (freshwater). Only the sub-system most relevant to each of the GIWA concerns is assessed. For the Amur River Basin, this report assesses only the Russian section and two of the riparian provinces of China (Heilongjiang and Jilin). These provinces of China impact the Okhotsk Sea sub-system via the Amur River.

IMPACT 1 Freshwater shortage

Freshwater shortage was analysed for the Amur River Basin sub-systems.

Environmental impacts

The environmental impacts of Freshwater shortage were assessed as slight. The issue of changes in the water table is not further discussed as there were no known impacts.

Modification of stream flow

The construction of dams and reservoirs for hydroelectricity production has been a major factor in altering the regime of the Amur River. In the late 1940s, the Fynman hydroelectric station was constructed on the Songhua River (China) and, in 1975, construction began on the Zeiskaya hydroelectric station in the Zeya River Basin (Russia). Changes in stream flow have been detected (Birdlife International 2003). Hydropower development has reduced the average annual water level variations by 1.0-2.3 m along the Blagoveshchensk-Khabarovsk section of the river. In addition, stream flow has increased during winter (Shcheka 2005); the average minimum low water levels in winter rose by 0.3-0.6 m and in the Maly Khingan by more than 1.2 metres.

The water regime of the Amur River and its tributaries has also been altered by the abstraction of freshwater for industrial and agricultural purposes as well as logging and ditching (Novomodny et al. 2004), the release of water to reclaim swamps, and increased surface run-off due to a loss of vegetation caused by deforestation and fires (Shcheka 2005). As a result, downstream wetlands have been depleted (Birdlife International 2003, GEF Concept paper 2005) and the frequency of flooding has increased (Jen 2003, Shcheka 2005).

Pollution of existing supplies

Urban areas are the major source of freshwater pollution in the Amur River Basin but agricultural contaminants are also a concern. In Khabarovskiy Kray, more than 400 million m^3 of wastewater is discharged into the Amur every year, 70 million m^3 of which is untreated and 173 million m^3 is inadequately treated. The Amur River suffers from transboundary pollution from agrochemicals, phenol, heavy metals and untreated wastewaters (GEF Concept paper 2005). Agricultural land use has intensified resulting in the increased use of fertilisers and pesticides (Jen 2003). The deterioration of water quality in the Amur and its large tributaries has decreased the quantity of potable water in near the Amur River in Priamurye (Jen 2003). A considerable proportion of the population is forced to use low quality and often contaminated water, especially during the summer floods and in winter (Baklanov et al. 2002b). The Songhua River in China experienced a large release of benzene in 2005 which threatened the freshwater supply of millions of people (UNEP 2006).

Socio-economic impacts

The economic impact of Freshwater shortage was assessed as slight. Freshwater shortages have not had any significant influence on human activities in the Basin, although the GIWA regional experts have found that pollution had increased the costs of water treatment. Additionally, increased flooding has damaged property and human life and temporarily disturbed productive agricultural land (Shcheka 2005).

The health impacts associated with Freshwater shortage were considered slight. Only a minor proportion of the regional population is occasionally affected by seasonal water shortages (Baklanov et al. 2002a) and there appear to be no associated health problems of great significance. The pollution of freshwater supplies has, however, caused some public health concerns in urban areas. There have been reports of diarrhoea and other infections linked to the poor water quality of the Amur River system (Baklanov et al. 2002a).

Conclusions and outlook

The Amur River and its tributaries have been modified during the 20^{th} century. The major hydroelectric plants on the Songhua and Zeya rivers have altered the discharge of these tributaries into the Amur River. As a consequence, flow rates and seasonal discharge patterns have been modified, which has changed the chemical composition of water bodies and altered aquatic habitats. Pollution in the Amur River has increased water treatment costs and, in urban areas, the prevalence of diseases. Freshwater shortage, however, is not presently a major problem for the Sea of Okhotsk region. Therefore, its overall impacts were assessed as slight. There is currently no agreement between China and Russia on the flow rates and discharges of the transboundary rivers in the region. Economic development and population growth, particularly in China, will result in greater demand for water resources, the further diversion of rivers to supply human uses, and increased pollution loads.

IMPACT Pollution

The following contaminants are found in the Amur River: organic substances (BOD_5), oil products, phenols, ammonium nitrogen, nitrate nitrogen, iron, copper, zinc and lead (Chudaeva 2002). Studies by the Far-Eastern Hydrometeorological Institute between 1997 and 2000 found that water quality had deteriorated in the lower reaches of the Amur River. Between 50% and 90% of the contaminants entering the lower reaches of the Amur River are discharged by the Songhua River, including ammonium ions, phosphates and other ions (Table 6). The Songhua River has experienced rapid agricultural, urban and industrial development which has resulted in the degradation of its water quality. There is a lack of measures aimed at reducing the quantities of pollutants entering the Songhua River (China) despite its impact on the water quality of the Amur (Kondratyeva 2000, Kondratyeva 2001,

Table 6 Water discharge and chemical composition of water near the mouth of the Amur River

Discharge (10^9 m^3/year)	HCO_3^- (mg/l)	SO_4^- (mg/l)	Cl^- (mg/l)	Ca^{++} (mg/l)	Mg^{++} (mg/l)	K^+ (mg/l)	Na^+ (mg/l)
400-800	29.0	5.1	0.76	5.8	1.9	2.7	0.6

(Source: Chudaeva, 2002 and Russian Hydromet Service)

Shesterkin & Shesterkina 2004). The largest sources of pollution are the cities of Khabarovsk and Komsomolsk-on-Amur, which account for 37% of the total wastewater discharged into the Amur. About 60% of the total contaminated wastes are discharged by enterprises in Khabarovskiy Kray. Monitoring performed by the state of Khabarovskiy Kray did not assess all potentially dangerous contaminants in the Amur, including organo-chemicals and heavy metals, and their possible impacts on aquatic ecosystems and human health.

Environmental impacts

The environmental impacts associated with pollution were considered slight. The main impacts are caused by eutrophication, chemical pollution, suspended solids and oil spills. Solid wastes, and thermal and radionuclide pollution have not been assessed due to a lack of information.

Eutrophication

Eutrophication was assessed only in the Amur River Basin sub-system.

Considerable quantities of organic matter and biogenic material enter the Amur River via domestic and industrial waste waters and surface run-off from the basin (particularly during periods of heavy rainfall). The abundance of microbe communities suggests that large quantities of untreated or inadequately treated industrial and domestic effluents are discharged into the River and its tributaries. Eutrophication, caused by the nutrient enrichment of the River basin's aquatic ecosystems, increases the growth of phytoplankton and zooplankton. Microscopic organisms (bacteria, fungi, yeast, protozoans and algae) thrive on the decaying plant matter and deoxygenate the freshwater. Aquatic organisms are subsequently affected and often migrate or are eradicated from an area. The benthic bacterial community structure is modified as the anthropogenic loads increase (Dzyuban 2002). The greater biomass also increases the turbidity of freshwater ecosystems which prevents light penetration, thus reducing the productivity of riverbed photosynthetic plants. This impacts the food web and has reduced species diversity in the Amur River Basin. According to Jen (2003), fish in the Amur River are poisoned as a consequence of algal blooms.

Eutrophication is most severe in the Amur River Basin during periods of low water in both the summer and winter. Based on the composition of zoobenthos in the bed of the Lower Amur, the water quality was classified as IV-VI, i.e. contaminated, polluted or heavily polluted. Analysis of the long-term dynamics of benthos communities suggests an intensification of eutrophication in the Amur River. The River's ecosystem is now being disturbed not only during periods of low water in summer and autumn but also during the period of ice formation. In March 1998, for the first time, the production of aquatic plants in the lower reaches of the Amur was comparable to the summer and the water was classified as 'very eutrophic' (Yur'ev et al. 1999). Studies by Shesterkin & Shesterkina (2004) from 1980 to 1997 established that the water quality in the lower reaches of the Amur has been considerably decreased as a result of changes to the composition of the benthic communities. Further, the Amur River discharges 400 million tonnes per year of organic material to the Okhotsk Sea (Schlesinger et al. in Seki et al. 2006) with unknown consequences.

Chemical pollution

The Amur River has been contaminated by a range of heavy metals, as shown in Table 7, and by stable organic compounds (SOC), including chlorine-containing organic substances. The polychlorinated dibenzo-dioxins and dibenzofurans are highly toxic. These chlorinated organic substances are only formed by human controlled processes (Chudaeva 2002). When these substances bio-accumulate they can cause mutagenic and carcinogenic effects. Minute concentrations of SOCs are present within the aquatic environment in the form of organic micro-impurities. Because they accumulate in bottom sediments, maximum concentrations of SOC were found in benthic fish (e.g. bream and sheat-fish).

Table 7 Concentrations of various dissolved and suspended metals in the Amur River

	Fe	Mn	Zn	Cu	Pb	Cd	Ni
Dissolved forms (μg/l)	2-116	0.2-22	0.1-6.9	0.8-4.5	0.0-1.9	0.04-0.11	0.2-1.1
Suspended forms (ppm)	8 000-51 400	357-1 507	80-2 113	6-113	23-224	1.3-3.7	6-673

(Source: Chudaeva, 2002)

There has been considerable chemical pollution resulting from the application of pesticides in the catchment of the Amur. In 2001 and 2002, the muscle tissue of fish caught in the Amur contained as much as 0.0008-0.0120 μg/kg of dichlorodiphenyl-trichloroethane (DDT) and 0.0019-0.0249 μg/kg of the gamma-isomer of hexachlorocyclohexane (HCCH). These concentrations are comparable to fish caught in English rivers during a period of intensive and uncontrolled agro-chemical application. Further, freshly frozen fish caught in the Lower Amur in 1997 exceeded the maximum permissible concentrations of cadmium, mercury, zinc and arsenic.

The transboundary significance of chemical pollution was recently illustrated when a benzene spill in the Jilin province of northeast China severely polluted the Songhua River. Experts estimated that approximately 100 tonnes of pollutants containing benzene and nitrobenzene flowed into the river. The water supply to millions of people in cities along the river was interrupted. Harbin, a city with over 3 million inhabitants, was unable to withdraw water from the river for four days after the incident. The concentrations of nitrobenzene exceeded national standards by 100-fold. The polluted water in the Songhua flowed into the Amur affecting downstream communities in Russia (UNEP 2006).

In the Okhotsk Sea sub-system, there is concern over the use of barite for oil and gas drilling due to its toxicity. Some investigations suggest that it is practically non-toxic or only slightly toxic (Georg 1975, Derby & Atema 1981), whereas other studies have found barite to be significantly harmful. Barite increases water turbidity but is quickly deposited on the seafloor where it poses the greatest threat to benthic fauna. It has been found to reduce the number of polychaetes and, to a lesser extent, molluscs in affected areas (Tagatz & Tobia 1978). Further, significant quantities of wastewater are discharged as by-products of drilling operations. So far, the GIWA regional experts estimate that over 100 000 tonnes of wastewater have been discharged by such activities.

Suspended solids

Although the extraction of hydrocarbons from the shelf of the Okhotsk Sea sub-system has caused some impacts associated with suspended solids, the issue was only considered slight.

Oil drilling resuspends bottom sediments, thus increasing water turbidity surrounding the drilling platforms. According to studies in the Gulf of Mexico, these can reach 6 km in diameter and drift with currents for 5-7 km (Steinhauer & Grecelius 1994). Studies conducted within the area of the planned platforms of the Chaivo field (Russia) estimate that suspended material (depending on particle size) can be dispersed up to 40 km. The environmental changes caused by the increased turbidity can force fish to change their migration routes to more favourable spawning grounds (Gorbunova 1988). In North Sakhalin, 40% of salmon spawning grounds and 130 rivers which are important for spawning have been disturbed (Moiseychenko & Abramov 1994). The suspended solids reduce light penetration to the photosynthetic layer which reduces the productivity of the area's ecosystems (Sapozhnikov 1995). The filtration system of bivalves, molluscs and crustaceans are also severely impacted by higher concentrations of sediments (Gorbunova 1988). According to Moiseychenko (1994), a small amount of bentonite and atapulgite results in abortive spawning among the bivalves. Additionally, the changes in seabed character caused by the drilling have a direct impact on the surrounding benthic fauna (Puntas & Abolinsh 1989).

The increased deforestation around the Amur River system has exacerbated erosion. According to the GEF Concept paper (2005), soil erosion is one of the major transboundary threats to the aquatic environment of the Basin.

Oil Spills

There is a significant risk of oil spills in the Sea of Okhotsk region due to the increased occurrence of oil extraction and transportation activities. The expansion of the hydrocarbon industry and its associated infrastructure has the potential to cause major impacts on the ecology of the region if environmental safeguards and precautionary measures are not implemented effectively. So far, three major oil spills have occurred in the Okhotsk Sea sub-system.

The development of the Russian Sakhalin shelf has increased the intensity of oil-related marine traffic on the Okhotsk Sea. Although there have been relatively few incidents to date, there is always a risk of a spill through deliberate or accidental discharges. In 1999, an oil spill occurred following an accident on the Vityaz Marine Terminal which is part of the newly operational Sakhalin-2 project. As a consequence, 3.5 tonnes of oil were emitted (Lapko & Radchenko 2000). Oil-tolerant bacteria are becoming more abundant in the coastal areas of the Okhotsk Sea (Zhuravel' et al. 2004), which may indicate possible increases in hydrocarbon concentrations.

Because the present level of oil development has not caused any significant problems, the environmental impacts of oil spills were assessed as slight. In the future, this issue may increase in severity due to the continued development of the oil industry in the region. The future significance of this threat justified its selection for the Causal chain analysis.

Socio-economic impacts

Pollution was considered to have a moderate economic impact. The deterioration in the water quality of the Amur River and its tributaries has affected fisheries resources and, consequently, commercial and recreational fishing. There has also been an increase in water treatment costs, particularly in the parts of the Priamurye (Russia).

The GIWA regional experts assessed the health impact of pollution as moderate. A considerable proportion of the region's population consume freshwater of poor quality which is often contaminated with bacteria. This has resulted in the spread of diseases and epidemics of dysentery and viral hepatitis, as well as an increase in non-infectious diseases (GEF Concept paper 2005). Freshwater contamination has affected the physiological status of fish and their nutritional value. Fish caught in the Amur River during ice formation failed to meet the basic health standards for fish products. Their gills had evidence of bacterial contamination and their muscle tissue had been damaged as a result of water contamination. The fish species posing the greatest risk to humans were identified as benthic fish (cowfish, burbot, sheatfish), fish with a long life cycle (sturgeon, Great Siberian sturgeon) and migratory species from the Amur estuary (smelt) (Kondratyeva et al. 1999, Kondratyeva & Chukhlebova 1999). The significant quantities of heavy metals, DDT and HCCH found in fish caught in the lower Amur may have adverse affects on the health of consumers. In addition, large-scale pollution could affect the tradability of fish products on the export market (Jen 2003).

Social and community impacts associated with pollution were considered slight. The impacts include a loss of recreational and aesthetic value due to a reduction in biodiversity (Baklanov et al. 2003).

Conclusions and outlook

Overall, the GIWA regional experts considered pollution to have slight impacts. The most significant issues were identified as eutrophication, chemical pollution and oil spills. Eutrophication in the Amur River has been attributed to nutrient enrichment caused by the discharge of domestic wastewater and surface run-off from the catchment area. It is expected to increase in severity over the next 20 years, with the communities of the lower Amur River Basin and Songhua River Basin experiencing the greatest socio-economic impacts. A significant proportion of chemical pollution originates from pesticides used in the agricultural sector, as well as heavy metals released by other human activities. Heavy metals recorded in fish caught in the Amur River have exceeded the maximum permissible concentrations for consumption. Oil and gas exploitation in the Okhotsk Sea provides economic benefits for the region but discharges significant quantities of wastewater as by-products of drilling operations. Drilling is also increasing the quantity of suspended solids which adversely affects the surrounding ecosystems. Although only three major oil spills have occurred in the region since the 1990s, the future expansion of the oil industry in the region will increase the risk of oil spills.

IMPACT Habitat and community modification

There is no record of any major loss of habitat in the region but there is evidence of ecosystem modification (Figure ??), which is resulting in slight environmental impacts.

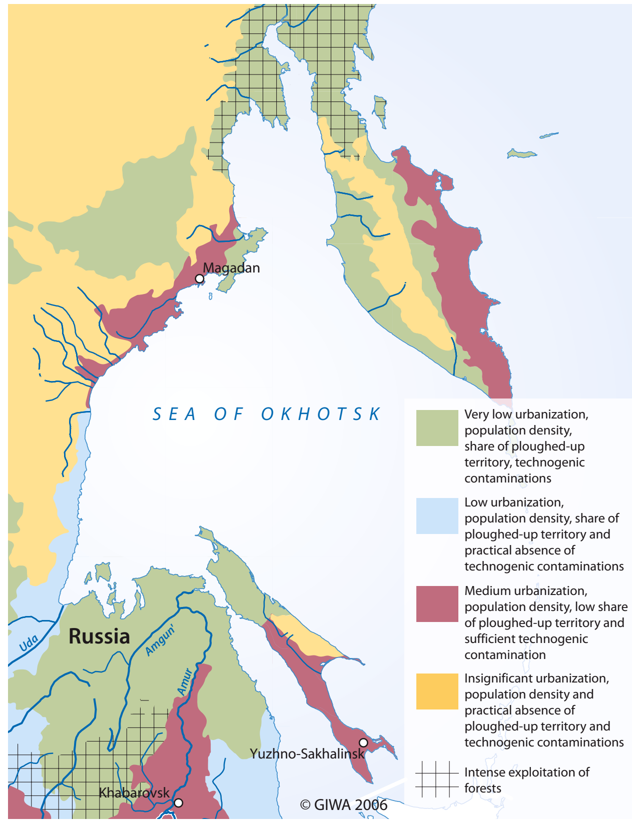

Figure 11 Distribution of anthropogenic pressures in the Sea of Okhotsk Basin.

Environmental impacts

Loss of ecosystems

The encroachment of humans into wetlands is concerning (GEF Concept paper 2005). As much as 2.4 million ha in Russia and 60% of the wetlands in the Heilongjiang province of China have been converted for agricultural use in recent decades (Shcheka 2005). The loss of wetlands, combined with relatively high rates of deforestation, has increased the frequency of flooding.

Modification of ecosystems in the Okhotsk Sea sub-system

Great whales, Gray whales, Southern Baleen whales, Bowhead whales, Northern Fin whales and Humpback whales were listed as endangered species in the Red Book of the Russian Federation (2001). In 2000, The World Conservation Union (IUCN) identified the western Gray whale as critically threatened due to a extremely high risk that the species may become extinct in the near future (Red Book of the Russian Federation 2001).

The western population of Gray whale is geographically and genetically isolated from the eastern population in the north Pacific. In the 1970s, the entire population of Gray whales was almost extinct; only about

100 individuals from the western region remained. Since then, their population has not increased significantly. In contrast, the number of Gray whales in the eastern side of the North Pacific has since been restored.

The western population of Gray whales is concentrated in the waters of the northeast Sakhalin shelf, near Piltun Bay. They feed here on benthic organisms in the summer and autumn and during the crucial fattening period of their life cycle. The Odoptu oilfield covers the central part of this feeding zone while the Chaivo field, located to the south of this, is positioned on the migratory corridor of the whales. Since the mid 1990s, the Gray whale has been threatened by the development of these oil and gas fields due to disturbances from seismic prospecting, temporary drilling rigs, the increasing number of helicopter flights, and the installation of a drilling and extractive platform located only 5 to 20 km from their feeding and fattening zone. These activities can force the whales to change their migration routes, as well as their feeding and reproduction grounds. The physiological stress on the whales may also reduce their immunity to disease.

In addition to Gray whales, all other species of marine mammal will be potentially disturbed as a result of the First Stage of the Oil Development Project, but the degree of impact will vary depending on the species. Gray whales are thought to be at greatest risk.

Modification of ecosystems in the Amur River Basin sub-system
The aquatic ecosystems of the Amur River Basin face varying degrees of pressure due to differing levels of urbanisation, population density, agricultural and forestry activity, and pollution discharged in the catchment areas of the rivers.

Approximately 2.4 million ha of wetlands (out of the original wetland area of 15 million ha) on the Russian side of the basin have been significantly drained to become pastureland. In Russia, human-induced fires frequently destroy wetland habitats. In the Heilongjiang province of China, approximately 60% of wetlands have been lost or degraded in recent decades. This has transboundary consequences for biological diversity, and the endangered, threatened and rare species in the basin. Included in these species are several migratory bird species, such as Oriental white storks (95% of the global population breed in the basin), Red-crowned crane (*Grus japanensis*; 65%), White-naped crane (*Grus vipio*; 50%), and Hooded crane (*Grus monacha*; 30%). The basin includes key stop-over sites for shorebirds, ducks, geese and swans along the Northeast Asian Flyway. In response, China and Russia have given various levels of protection to approximately 1 million ha of wetlands in the Amur River Basin, and a total of eleven natural protected areas were designated as Ramsar sites (GEF Concept paper 2005).

Eutrophication and the presence of suspended solids in the water bodies of the Amur River Basin are impeding light penetration. This has reduced the productivity of riverbed photosynthetic plant life and impacted other aquatic species which feed on these plants. Additionally, 130 rivers which are important for spawning have been disturbed by anthropogenic pressures in North Sakhalin (Moiseychenko & Abramov 1994).

Human activities are threatening the biodiversity of Lake Khanka and its surrounding wetlands. Seven species of bird that previously bred in the Russian side of the basin have disappeared, including three species listed in the Russian Red Book. Four other species may also disappear from the basin. One-third of the original wetlands have been destroyed and there are ten times fewer waterfowl. The degradation of the lake basin's ecosystem is attributed to agricultural development which has encroached upon wetlands; the lowering of the water table; and agricultural run-off and other pollution. Forest clearance and the destruction of biological corridors have also decreased biodiversity. Further, untreated sewage from the city of Mishan is predominantly discharged into the Muling River, and flood water is introduced periodically to the lake through sluice gates (GEF Concept paper 2005).

Approximately 20 alien fish species have been introduced to the Amur River (Novomodny et al. 2004). Among these are alien sturgeon species in China (Wei et al. 2004) and several species of carp (Novomodny et al. 2004) which were introduced to the Amur River through aquaculture. They are seriously threatening the genetic pool of the Kaluga sturgeon which is on the brink of extinction, yet artificial propagation remains uncontrolled (Wei et al. 2004).

Socio-economic and health impacts
The GIWA regional experts considered the socio-economic impacts of Habitat modification to be moderate. The reduction in fisheries productivity due to the degradation of ecosystems reduces the income of fishing households. Catches of sturgeon have decreased in China possibly due to the introduction of alien sturgeon species (Wei et al. 2004). There are some costs associated with managing the decreasing stocks of the Kaluga sturgeon, such as fry release, surveillance and, possibly, a future restocking programme (Wei et al. 2004).

Conclusions and future outlook
The GIWA regional experts assessed Habitat and community modification as having a slight impact. Human activities in the Okhotsk Sea sub-system have altered the habitats of pollock, Humpback whale and the endangered Gray whale, among other species. Whales are threatened by the increasing exploration and extraction of marine oil

and gas reserves. Habitat and community modification is expected to increase in severity in the future due to further oil and gas development, which will also necessitate the development of bulk-oil complexes and harbours for large tankers (Shcheka 2005). In the Amur River Basin sub-system, the extent of wetlands has declined in both Russia and China, which is threatening biological diversity and endangered species in the Basin, notably several migratory bird species.

IMPACT Unsustainable exploitation of fish and other living resources

This concern was evaluated for both the Amur River Basin and the Okhotsk Sea sub-systems. The GIWA regional experts considered that overexploitation has a severe impact in the Amur River Basin sub-system, and a moderate impact in the Okhotsk Sea sub-system.

Environmental impacts – Okhotsk Sea sub-system

Overexploitation

Overfishing affects most of the major fish stocks in the Okhotsk Sea. The volume of fish and sea products caught in the Sea between 1992 and 2003 is given in Table 8. Since 1990, the volume of catches has reduced by one-third due to the depletion of fish stocks.

The maximum annual catch of Pacific halibut (*Hippoglossus stenolepis*) was 16 200 tonnes in 1977. Overfishing has adversely affected the stocks. In 1980, the annual catch was only 2 600 tonnes and, since then, catches have continued to decline. Spawning stock biomass of Walleye pollock declined in the late 1990s due to natural environmental variability and overexploitation (Shuntov et al. 1997, Chereshnev et al. 2001). During the most prolific years prior to this, annual catches were as much as 2 million tonnes, but catches have decreased by 3-4 times. Since 2000, when the stock biomass reached its lowest level in 20 years, there have been indications that stocks are beginning and will continue to grow in the Okhotsk Sea in the next five years (PICES 2004). The total biomass of groundfish, including flatfish, cod and sculpins, in the Okhotsk Sea shelf decreased from about 3.5 million tonnes in the 1980s to about 1.6 million tonnes by 2000. During the 1980s, biomass estimates for Japanese sardine (*Sardinops sagax melanostictus*), which make seasonal use of the Sea, exceeded 1 million tonnes. Catches of this species, however, declined considerably in the Okhotsk Sea. After 1993, sardines have not been caught by the fisheries of the region (PICES 2004).

In the area outside of the Russian Exclusive Economic Zone (EEZ), and therefore out of Russian control, many foreign fishing fleets from countries such as Japan, Taiwan, North Korea, South Korea and China overexploit the fisheries. Such illegal fishing and poaching is reducing the stocks of aquatic living resources and causing Russian TACs to be exceeded by 2-10 times (Kotenev & Zaytseva 2003). Fishing products such as sea urchin and King crab are in high demand in Japanese markets. Illegal fishing to supply these markets is considered to be responsible for the gradual disappearance of these species (Nazarov 2004, Ozolinsh & Spiridonov 2001).

Prior to 1968, the commercial harvesting of true seals was uncontrolled with annual catches of 66 000-102 000 animals, which resulted in a dramatic reduction in their population. Their population was restored, however, due to a reduction in sealing based upon scientific recommendations. Since the mid-1980s the harvest has increased again to between 72 000 and 89 000 animals per year, reaching 95% of the catch limits in the Okhotsk Sea (PICES 2004).

Excessive by-catch and discards

There are believed to be significant quantities of by-catch in the Okhotsk Sea sub-system but there is a lack of information to substantiate this claim (Shuntov 2001). During the 1990s, approximately one-third of catches of young pollock were disposed of overboard, contributing to the severe reduction of its stock.

Environmental impacts – Amur River Basin sub-system

Overexploitation

The fish resources of the Amur River Basin sub-system have decreased over the past 100 years as a result of overfishing, pollution, habitat degradation and hydropower development. Populations of autumn Chum salmon have decreased in the Amur due to overfishing. In 1910,

Table 8 Catches of commercial fish from the Sea of Okhotsk between 1992 and 2003

	1992 (thousand tonnes)	1994 (thousand tonnes)	1996 (thousand tonnes)	1998 (thousand tonnes)	1999 (thousand tonnes)	2000 (thousand tonnes)	2001 (thousand tonnes)	2002 (thousand tonnes)	2003 (thousand tonnes)
Catches's by Russia's fleet in the Sea of Okhotsk (according to DalRyba)	1 510.8	1 495.9	2 132.6	1 878.4	1 454.1	1 418.5	1 257.8	865.3	1 060.0
Catches by Russia's and foreign fleets in the Sea of Okhotsk (according to Radchenko)	2 353.2	1 775.2	2 417.6	2 030.0	1 584.2	1 509.1	1 308.7	ND	ND

45 000 tonnes of autumn Chum salmon were fished annually, compared with only 2 000 to 5 000 tonnes between 1991 and 2001.

The Humpback salmon is a relatively important fishery. Variations in the productivity of the fishery results in abundant catches one year followed by limited catches the next year. In the 1920s and 1930s, 20 million fish with a total weight of 10 000-14 000 tonnes were caught every other year, while catches in the other years weighed a total of only 1 200 tonnes. Catches have continued to decrease since then; today, total annual catches of Humpback salmon weigh between 200 and 500 tonnes (Shuntov 2001).

In the early 20th century the summer Chum salmon was extensively fished in the Amur River. In 1910, average annual catches weighed a maximum of 53 400 tonnes. As a result of relentless overfishing and unfavourable spawning conditions during the winter months, stocks of summer Chum salmon rapidly declined between 1914 and 1932, leading to the near collapse of the fishery.

At the beginning of the 20th century, catches of sturgeon in the Lower Amur River totalled 250-350 tonnes, 4-5 times less than catches between 1890 and 1895. Between 1923 and 1930, sturgeon fishing was prohibited. In the late 1930s, catches totalled 150-190 tonnes, which decreased to 75 tonnes a decade later. Today, catches continue to decrease (Wei et al. 2004). Poaching and illegal catches of Amur and Kaluga sturgeons are believed to occur throughout the Basin (Wei et al. 2004).

Owing to unfavourable natural conditions and anthropogenic factors, catches of fish since 1996 have been relatively small. Total fishing catches in the Lower Amur basin for 1999 have been estimated by the TINRO-Centre at 5 000 tonnes (Kondratyeva et al. 1999). Further, catches contain a higher proportion of juvenile fish, indicating that the average fish size has declined. Illegal fishing in the Amur Basin is exacerbating the situation, but has not been fully researched.

In Heilongjiang province of China, fishing and fish farming are important industries. The province's population has grown rapidly in the past 50 years, and especially in the last 20 years. Fishing and habitat modification have led to the disappearance of sturgeons, salmon, and other fish species in the Songhua River. In the Upper and Middle Amur, sturgeon populations have significantly decreased. Fishing farming was developed as an alternative to fishing in the mid-1960s. In 2002, fish farming produced almost 90% of the entire regional fish harvest (over 400 000 tonnes) (Novomodny et al. 2004).

Socio-economic impacts

The fishing industry is a major determinant of the region's social and economic characteristics. It provides an important source of employment, with one fisherman creating 6-7 work places onshore. In the Russian part of the Sea of Okhotsk region the fishing industry accounts for 21% of GRP and in Kamchatskaya Oblast' as much as 53%.

The fishing industry has experienced a downturn as a result of reduced fish stocks. About 3 500 fishermen became unemployed in the region, meaning that 10 000 dependents also lost their incomes (Okey 2003). Indirect unemployment data confirms that the pressure on the fishing labour market (number of persons applying for one job vacancy) in the region is over twice that of any other region in Russia. In 1999, around 200 000 people were estimated to be unemployed in the fishing sector of the region. Since then, unemployment has continued to grow (Voitolovsky et al. 2003).

The capacity of the fishing fleet and refrigerating vessels has decreased by over two-thirds and the production of tinned food five-fold since 1990 (Barushko 2005). By 2010, only 10% of fishing vessels (again with respect to 1990) will be operational, the number of refrigerator vessels will decrease four-fold, and the production of tinned food eight-fold. This could lead to the collapse of the fishing industry, changes to the type of food consumed in the region, a downturn in the regional economy, a rise in unemployment and emigration from coastal settlements (Zhuk et al. 2003).

The fishing industry is important for the social structure of coastal communities. Unemployment and reduced incomes due to the downturn in the fisheries, combined with a lack of alternative job opportunities, have led to the migration of the population to other regions of the country. In addition, the local population receives less protein as fish consumption per person decreased by 50% between 1990 and 2002 (The Development Concept 2003).

Conclusions and future outlook

Over the past 15 years, total catches in the Okhotsk Sea sub-system have reduced by 2-2.5 times. Catches of pollock – the major commercial species – have decreased significantly in recent years due to a reduction in fish stocks caused mainly by overfishing. Because the central area of the Sea is outside of any country's EEZ, access to the biological resources is open to international fishing fleets, not only from Asia but from countries as far away as the Baltic. The quantity of pollock caught by these fleets makes estimating total catches extremely difficult, if not impossible. However, the reduction in pollock available at local markets is a good indication of the poor state of fish stocks.

In the Amur River Basin, stocks of salmon and sturgeon have declined as a result of overfishing and the degradation of spawning habitats. The problem is exacerbated by inappropriate fishing practices as well as adverse natural conditions. There has been a decrease in the size and age of the population due to intense fishing during the spawning season. The GIWA regional experts expect that salmon will continue to be overfished for the foreseeable future.

Global change

There are insufficient data available to accurately assess the environmental and socio-economic impacts of global changes.

Priority concerns for further analysis

The priority issues selected for further analysis by the GIWA regional experts were: eutrophication in the Amur River Basin sub-system; oil spills in the Okhotsk Sea sub-system; and overexploitation in the entire Sea of Okhotsk region. The GIWA concerns were prioritised as follows:

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

According to the GIWA regional experts, the impact of the concerns is likely to remain the same or slightly increase in severity in the future.

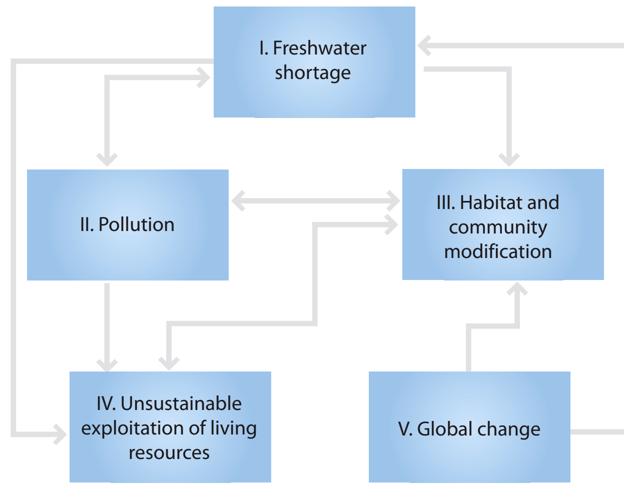

Figure 12 Synergies and inter-linkages between the GIWA concerns.

The synergies and linkages between the concerns are illustrated in Figure 12. The severest issue facing the Okhotsk Sea sub-system was identified as overexploitation. The fisheries of the Sea of Okhotsk region continue to be overfished despite the implementation of regulatory and control measures. The fisheries industry has declined due to catches declining by one-third in the last ten years.

The water quality of the Okhotsk Sea sub-system appears to be better than other Pacific seas and does not pose any threat to human health. However, oil spills were chosen for further analysis because the risk of them occurring will increase in future due to oil and gas development in the region. Eutrophication is threatening the ecological integrity of the Amur River Basin sub-system and the well-being of its population.

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 involved a step-by-step process that identified the most important causal links between the environmental and socio-economic impacts, their immediate causes, the responsible human activities and economic sectors and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis (CCA) recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. The CCA uses a relatively simple and practical analytical model. For further details on the methodology, please refer to the GIWA methodology section in the end of this report.

The prioritised transboundary issues of oil spills in the Okhotsk Sea sub-system, eutrophication in the Amur River sub-system and overexploitation in the whole region are studied further in the CCA in order to identify their root causes so that policy options and priority actions can be developed by decision-makers in the region to address these driving forces of adverse environmental pressures. For further details of the environmental and socio-economic impacts, and immediate causes of the prioritised concerns, please refer to the Assessment chapter.

Eutrophication

Environmental and socio-economic impacts

Environmental impacts

- Poor water quality and pronounced eutrophication during minimal flow periods in the winter and summer;
- The water quality of the Lower Amur is classified as V-VI (i.e. contaminated, polluted, or heavily polluted);
- The growth of phytoplankton and zooplankton has reduced light penetration in the water column and, therefore, the productivity of photosynthetic plants;
- Increased ecological risks, including poisoning of fish;
- Decreased oxygen levels due to an increase in microscopic organisms which feed on decaying plant matter;
- Algal blooms in coastal and freshwater systems;
- Reduced biodiversity;
- Changes to the hydrological, chemical and temperature regimes;
- Deterioration of reproduction and spawning conditions; and
- Migration of species away from affected areas.

Socio-economic impacts

- Reduced fisheries productivity;
- Loss of recreation amenities and unpleasant odours during the winter;
- Decreased availability of potable water for the population in Priamurye;
- The consumption of contaminated fish is affecting the health of indigenous populations, particularly those living on the banks of the Amur, Nanaian, Ulchi and Niwchs rivers.

Immediate causes

Considerable quantities of organic matter and biogenic material enter the Amur River within domestic and industrial wastewaters and surface run-off from the basin (particularly during periods of heavy rainfall). The run-off of fertilisers from agricultural areas also stimulates eutrophication.

The sectors responsible for eutrophication were identified by the GIWA regional experts as:

- Industry
- Urbanisation
- Agriculture
- Aquaculture

Root causes

There are a number of institutional weaknesses which are either promoting or failing to prevent transboundary pollution in the Amur River Basin. These include, among others: (i) lack of economic planning harmonised with the need for conservation and sustainable use of living resources and ecosystem functions in the basin; (ii) inadequate basin-wide legal and institutional arrangements among the riparian countries in addressing transboundary environmental issues; (iii) inadequate capacities of institutions involved in water and other resource management and environmental protection, and lack of wider stakeholder participation; (iv) significant gap in information and monitoring activities in identifying transboundary environmental issues in the basin; (v) lack of harmonised designation of protected areas among the riparian countries and gap in the degree of enforcement of regulations for protected areas; and (vi) lack of public awareness, and creation and mobilisation of civil communities in monitoring and management of land and water in the basin (GEF Concept paper 2005).

Each riparian country explores its own economic development and/or conservation of ecosystems. However, in the absence of a basin-wide institutional mechanism, transboundary issues were not given attention in national policy and each riparian country's conservation efforts were not conducted in an efficient manner. To date, there have been limited basin-wide cooperative actions, although local governments have demonstrated a willingness to work together in addressing transboundary issues. Further, stakeholders do not have platforms to discuss and provide suggestions for decision-making institutions with their country or regionally. Differences in regulations and weak enforcement capacities have led to uncoordinated approaches to the management of protected areas (GEF Concept paper 2005).

Each country has developed its own monitoring programmes to provide baseline environmental information. However, there is a serious gap in the amount of available data and their quality for the purpose of technically sound, policy-relevant decisions. Many of the data produced by the riparian countries are not comparable in their quality, and much of the information is not accessible by the public or decision-makers, particularly beyond the national boundaries (GEF Concept paper 2005). A major hindrance for policy-makers when setting priorities for remediation is the lack of knowledge of the ecological characteristics and their reaction to human activities. The

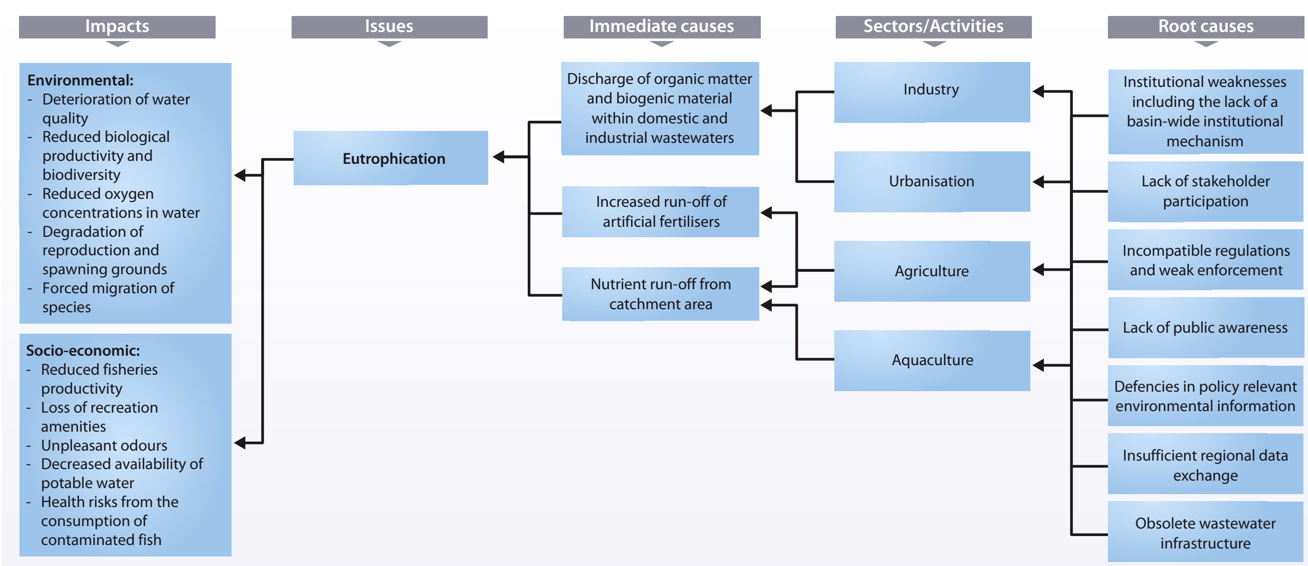

Figure 13 Causal chain diagram illustrating the causal links for eutrophication in the Amur River Basin.

Khabarovsk and Amur Scientific Centres of the Far East Branch of the Russian Academy of Sciences have collated data on different natural parameters, complexes and ecosystems. There has, however, been no comprehensive assessment of this data (Voronov 2003). The true impact of pollution on freshwater ecosystems in the Basin is unclear. The public lacks awareness of the environmental issues, including eutrophication, affecting freshwater ecosystems and their well-being. Information exchange between the countries sharing the Amur River Basin is limited and policy-makers, the public and other stakeholders have insufficient access to ecological databases and information. There is also the absence of a basin-wide monitoring system.

Wastewater treatment infrastructure is often obsolete due to insufficient funds for maintenance and a lack of investment in new facilities. Economic root causes of environmental degradation, including the demand for short-term economic gains, an inappropriate taxation system and financial-credit policies, inequitable development within the region, and the unattractive investment climate, stem from the Russian Far East's long economic recession and the major reforms in the economic and social structures of Russia.

The linkages between the root and immediate causes of eutrophication and their environmental and socio-economic consequences in the Amur River Basin sub-system are presented in Figure 13.

Oil spills

Environmental and socio-economic impacts and immediate causes

Despite four spills occurring in the region, the overall impact of oil spills has not been too severe. The rapid development of the Russian Sakhalin shelf for oil and gas exploration, exploitation and transportation will, however, increase the probability of oil spills. Despite providing many economic benefits, oil and gas production in Sakhalin may cause ecological problems. For example, oil spills would degrade spawning habitats of commercially important fish in the region. The northeastern coastal waters of Sakhalin Island will be particularly vulnerable to future oil spills (PICES 2004). Further, when drilling oil wells and during oil production, poisonous waste products are produced.

Oil and gas exploitation is likely to also commence on the northwest shelf of Kamchatka and in the lower reaches of the Amur River Basin. Oil refining and gas processing will be developed in Sakhalin Island and in Khabarovskiy Kray, but limited amounts will be processed in Kamchatka. There are plans to establish an oil and gas distribution network to supply the markets of the Asian-Pacific Region. Pipelines from Siberia and Sakhalin to Vladivostok are planned, some of which would be laid along the Amur River. Two alternative oil pipeline routes and several transnational gas pipelines are proposed (Alekseev et al. 2001).

The future socio-economic impacts of potential spills in the Okhotsk Sea sub-system will include the cost of oil spill response and clean-up operations, the rehabilitation of habitats, and ecological protection and monitoring, as well as the rehabilitation and treatment of rare and commercially important species (Baklanov et al. 2002a).

Root causes

In the Russian Far East, oil and gas exploitation is seen as a means of generating immediate revenues. Government authorities, international companies, and public financial institutions have focused their attention on developing the Sakhalin's oil and gas fields as rapidly as possible. Limited effort has been made to strengthen Sakhalin's capacity to prevent and respond to oil spills (Lawn et. al 2001).

There is a lack of preparedness for an environmental emergency and insufficient measures have been adopted to mitigate any possible impact on coastal marine and freshwater ecosystems. There is an absence of a regional mechanism that evaluates the transboundary consequences of the proposed oil and gas infrastructure and associated economic development. Public discussion among the riparian countries about these issues has not been initiated (GEF Concept paper 2005).

Currently, there is a lack of funding for environmental protection and social welfare programmes in order to avoid the negative consequences of oil and gas development in the region. The region lacks the necessary equipment for cleaning up oil spills during periods of fast-ice consolidation. The Sakhalin Basin Agency for Emergency Situations has insufficient technical resources to decontaminate large and/or remote oil spills. Many oil tankers operating in the region do not have double hulls.

According to the GIWA regional experts, these root causes are determined by the poor economic development in the Russian Far East and the dramatic social and economic changes Russia has experienced over the past 20 years.

The linkages between the root and immediate causes of oil spills in the Okhotsk Sea sub-system and their environmental and socio-economic consequences are presented in Figure 14.

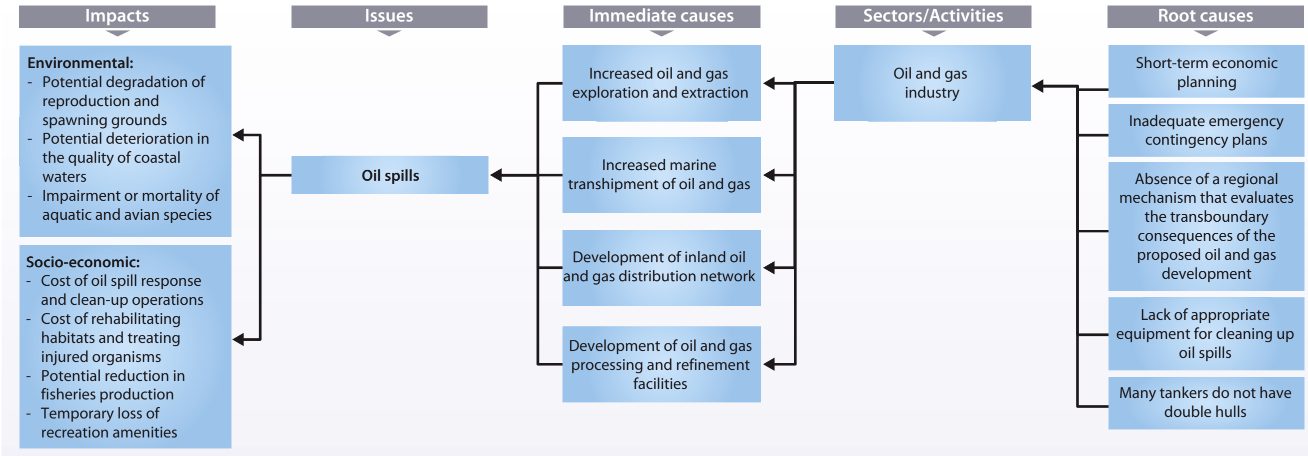

Figure 14 Causal chain diagram illustrating the causal links for oil spills in the Sea of Okhotsk.

Overexploitation of fish and other living resources

Environmental and socio-economic impacts

Environmental impacts

- The main commercial fish stocks have been severely depleted;
- Regional populations of whales have declined dramatically, with many species endangered or critically endangered;
- Stocks and catches of the main commercial fish species – walleye pollock – reduced more than two-fold within two decades;
- Species which are valuable on the international fish markets, such as sea urchin and king crab, are at particular risk;
- Overfishing of the main commercial species has destabilised the aquatic ecosystems of the Sea of Okhotsk region.
- Populations of Chum and Humpback salmon, and sturgeon, among others species, have decreased in the Amur River due to overfishing.
- The average fish size in the Amur River Basin has decreased with catches containing a higher proportion of juvenile fish.

Socio-economic impacts

- Reduced catches has caused a downturn in the fisheries industry;
- High unemployment in the fisheries sector;
- Reduction in economic returns and investment activity;
- Consumption of fish products per capita has decreased;
- Social problems and reduced quality of life for inhabitants of fishing communities due to a loss of household income; and
- Increased competition for the limited fisheries resources has led to the growth of a black market in fish products, conflicts between groups of fishermen, and greater corruption.

Immediate causes

Excessive fishing effort and fleet capacity

Over the past several decades, fishing effort has increased dramatically. The capacity of the fishing fleet operating in the seas of the Russian Far East exceeds catch limits by approximately seven-fold. Over 100 crab fishing boats have the capacity to far exceed the average annual allowable catch for King crab (Spiridonov 2001).

Excessive by-catch and discards

Although there is a lack of data to verify its impact, the volume of by-catch and discards of non-target species is also believed to be a significant cause of overexploitation (Spiridonov 2001, Ozolinsh & Spiridonov 2001, Kotenev & Zaytseva 2003).

Illegal fishing

The uncontrolled extraction of fisheries resources by the illegal fishing sector is contributing to overfishing. Account auditors of the Chamber of the Russian Federation believe that greater volumes of King crab and sea-urchin are often supplied illegally to the Japanese market than the entire catch limit for the Okhotsk Sea (Nazarov 2004). Poaching of Walleye pollock, which has a growing demand in markets of the Pacific region, exceeds established TACs by 2-3 times (Kotenev & Zaytseva 2003, Ozolinsh & Spiridonov 2001, Spiridonov 2001). Illegal fishing is believed to occur in the Amur River Basin sub-system but it has not been fully investigated.

Loss of spawning habitat

The spawning habitat of salmon and other fish species has been degraded due to eutrophication and other forms of pollution in the Amur River Basin and in the rivers of Sakhalin. Fishing and habitat modification have led to the disappearance of sturgeons, salmon and other fish species in the Songhua River (China).

Root Causes

Economic

Economic policy and market trends have aggravated the problems faced by the fishing sector. The reform of Russian economic policy, market failures, and inappropriate taxation and financial credit systems are causing economic hardship for fishing communities and forcing fishermen to increase fishing effort in order to receive sufficient income. As a result of these economic conditions, the social and environmental problems of the fishery have been aggravated (Voitolovsky et al. 2003, Titova 2004).

The large number of intermediaries between fishermen and consumers has led to a significant rise in the prices on the domestic market which has decreased consumer demand. The decline in domestic fish sales has negatively affected the prosperity of fishing communities. While increased demand for specific species on the international fish market has resulted in their overexploitation, other species remain underexploited.

The excessive by-catch and discard of non-target species and small fish, as well as the growth of the illegal fishery, are associated with fishermen needing to increase their income in the short-term. Moreover, fishermen land their catches at the ports of other coastal states in order to avoid registering their catches in Russia.

The introduction of auctions of fish quota-rights, in addition to a burdensome tax system, has reduced the profitability of the fisheries, resulting in fishermen undertaking poaching and illegal fishing in order to supplement their income. For the purchase of a King crab quota to be economically viable, it is necessary to catch 3-4 times more crabs than the quota allows (Korelsky et al. 2003). The requirement of purchasing quotas has led to inflated fish prices, increased debt and a reduced income for fishing households (Zilanov 2004). Fishermen are forced to catch more fish in order to maintain their profit levels. The existing fishing auction system is perceived negatively by the majority of fishermen. The reduction in economic returns and investment activity in the fisheries sector has prevented the modernisation of the fleet and fishing gear.

Legal

Russian and international fisheries laws and regulations are undermined by deep-rooted corruption and ineffective enforcement (despite vessel confiscations by the Russian coast guard). The weak legislative framework in Russia leads to the illegal export of fish products to Japan and the Republic of Korea. The illegal export market to Japan is around 20 times more valuable than the legal market (5-7 billion USD compared to 300 million USD) (Okey 2003).

Governance

Fisheries management is opaque to the public and fishermen, and highly corrupt. Coastguards detain no more than 2% of the fishermen who violate the law and some even participate in poaching themselves (Ozolinsh & Spiridonov 2001). In 2000-2001, annual illegal catches in the Far East seas of Russia caused by the inefficient monitoring and enforcement system have been estimated at 1.5 million tonnes of Walleye pollock and 27 000 tonnes of King crab (Kotenev & Zaytseva 2003). Russian fishermen are dissuaded from landing their catches in Russian ports due to complicated, bureaucratic procedures and having to pay fees. Bribing of officials is known to occur in the region (Voitolovsky et al. 2003). Small-scale fisheries and coastal fishing associations have not been supported during the periods of political and economic reform (Belyaev et al. 2004). Alternative employment opportunities are neither available nor created by the government.

Technology

Drift nets are used in the salmon fishery of the Okhotsk Sea sub-system. Although the number of vessels using these nets has reduced considerably since the 1970s, one of these vessels can kill about 1 000 sea birds, ten dolphins and several seals in one year. Some sea birds are attracted to the searchlights of vessels fishing at night for crabs and become caught in the nets. When crab traps are disposed of overboard they pose a great danger to sea vertebrates and fishes. The number of such traps left on the sea bottom continues to increase every year (Ozolinsh & Spiridonov 2001).

Stocks of invaluable fish species, such as Green cod, flounder, squid and various shrimp species are underexploited. The fishing fleet and coastal processing plants are not equipped to process these less valuable fish species (Spiridonov 2001).

Today, the average ages of large-capacity vessels (with an operational age of 20 years), medium capacity vessels (with an 18 year operational age) and small capacity vessels (with a 12 year operational age) are 21.6 years, 15.6 years and 18.9 years respectively. Due to the ageing of fishing and tinned food mother-ship vessels, many are out of service and have not been replaced.

Education and knowledge

According to the GIWA regional experts, there are a lack of fisheries statistics and monitoring programmes. An ecosystem approach is not

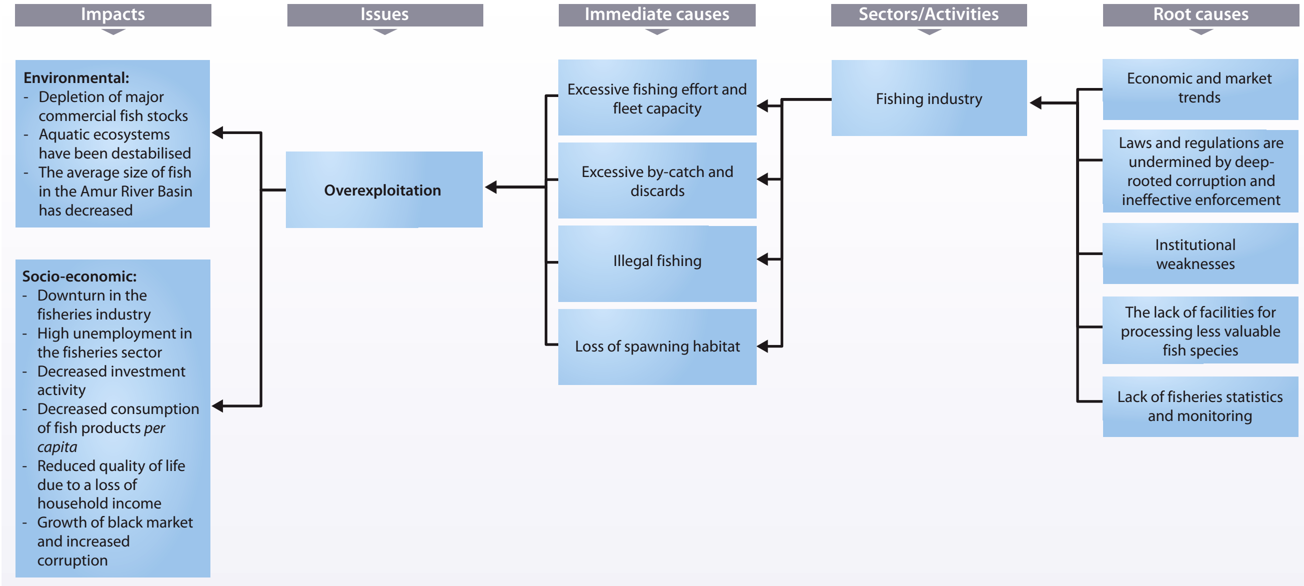

Figure 15 Causal chain diagram illustrating the causal links for overexploitation in the Sea of Okhotsk region.

used to calculate TAC quotas. There is inadequate knowledge of the size of fish stocks and their maximum sustainable yield (Kotenev & Zaytseva 2003). Until recently, by-catch had not been considered in fisheries statistics or in establishing catch quotas (PICES 2004), and fisheries managers have insufficient access to ecological databases. Fishermen lack awareness of the long-term impacts of overfishing on the viability of regional fish stocks and, consequently, their future livelihood. There is insufficient exchange of fisheries information between the countries fishing in the Sea of Okhotsk region (Ozolinsh & Spiridonov 2001, Novomodny et al. 2004). Additionally, environmental education and ethics are weak and there are few research agreements between Russia, China and Mongolia (Novomodny et al. 2004).

The linkages between the root and immediate causes, and the environmental and socio-economic impacts of overexploitation in the Sea of Okhotsk are presented in Figure 15.

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.

Eutrophication in the Amur River Basin sub-system

Problem definition

Eutrophication in the Amur River Basin sub-system has been caused by the increasing quantities of nutrients discharged in domestic and industrial wastewater, and by the run-off of chemical fertilisers from cultivated land in the catchment area. Population growth, economic development and the intensification of agriculture will exacerbate eutrophication in the future.

A range of institutional weaknesses are either promoting or failing to prevent transboundary pollution in the Amur River Basin sub-system. Economic planning does not incorporate environmental considerations or involve stakeholders. There is an absence of basin-wide institutional arrangements, and transboundary issues are not given attention in national actions. Much of the data produced by the riparian countries is not presented in a format suitable for policy- makers, and information is often not accessible by the public or decision-makers, particularly beyond the national boundaries (GEF Concept paper 2005). Wastewater treatment infrastructure is frequently dilapidated due to insufficient funds for maintenance and a lack of investment in new facilities.

Policy framework

The policy options for addressing eutrophication in the Amur River Basin should be based upon the principles established at the World Summit on Sustainable Development (WSSD 2002). There are also several other international conventions, as well as Chinese and Russian legislation, regarding environmental protection and sustainable development that should be considered. Asset 42 of the Constitution of the Russian Federation gives a human right to a propitious environment and calls for reliable information about its state to be collated.

In this respect, the policy options should aim at not only halting the increasing trends of eutrophication but also at gradually curtailing nutrient enrichment processes and rehabilitating ecosystems.

The main objectives of the policy options should include the following:

- Accurately calculate the water budget of the Amur River Basin, including the assessment of the freshwater dynamics;
- Assessment, protection and control of water quality in the Basin;
- Coordination of water management in the basin;
- Assessment of status and changes in relation to:
  - Forests and forest management and the connections with water and water management;
  - Land and land use and the connections with water and water management;
- Land use zoning in the basin;

- Coordination of natural resources management in the basin; and
- Development of a basin-wide management system for water resources.

Policy options

There is a need to improve the social well-being of the population, restore the environment, promote the sustainable use of natural resources, and to develop an integrated regional policy regarding river basin management in Priamurye (Russia), and between Russia, China and Mongolia.

The establishment of an international monitoring programme to regularly assess the current ecological status of the freshwater environment within the Amur River Basin involving institutions of China, Mongolia and Russia**.** The components of such a monitoring programme should include:

- Environmental monitoring;
- Assess the resource potential of the Amur River Basin;
- Develop criteria/indicators for evaluating environmental change in the Basin;
- Create maps showing zones which represent the various degrees of anthropogenic-induced environmental change in the Amur River Basin; and
- Predict future environmental changes.

Conduct transboundary environmental impact assessments before undertaking infrastructure development, such as hydroelectric plants, nuclear power plants, flood-control systems, and land reclamation schemes. The results of such assessments should be incorporated into development strategies so that not only the environmental changes within a country are considered but also those in the other countries sharing the Amur River Basin. The following should be considered:

- Problems of water consumption, wastewater treatment, surface run-off and changes to the hydrological regime;
- Impact of agriculture, forestry and mining development;
- Impact of fishing and aquaculture on ecosystems, migrating species and rare species of flora and fauna;
- Develop a basin-wide network of protected areas;
- Multi-national and coordinated monitoring of environmental quality; and
- Prepare and adopt an agreement between China, Mongolia and Russia which establishes the principles of river basin management in the Amur River Basin.

Oil spills in the Okhotsk Sea sub-system

Problem definition

The exploitation of oil and gas fields in southern Sakhalin is resulting in the release of oil products in concentrations above maximum permissible limits into shallow bays. Oil contamination has been recorded along the northeastern coast of Sakhalin Island. Further oil and gas development on the Sakhalin shelf will increase the risk of oil spills in the future. While government authorities, international companies, and public financial institutions have focused their attention on developing Sakhalin's oil and gas fields as rapidly as possible, they have given little attention to preparing the region to prevent and respond to oil spills (Lawn et al. 2001).

Policy framework

Russia has ratified the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78). The Regulations for the Prevention of Pollution by Oil (1983) provides a legislative framework for oil spill prevention. In Russia, legal provisions for the prevention of oil spills are found in the Law No. 2060-1 of 1991 of the RSFSR on Environmental Protection which guarantees citizens Constitutional rights to a healthy environment.

The government of the Russian Federation has converted these legislative provisions into concrete actions and programmes through a number of resolutions:

- Resolution of the Russian Government No 613 on Immediate actions on oil spill prevention and response, 2000;
- Russian Government Resolution No 240 on the Order of oil spill prevention and response activities organisation on the territory of the Russian Federation, 2002; and
- Russian Government Resolution No 794 on the Unified state system of emergencies prevention and response, 2003.

The first of these resolutions includes technical and organisational measures for preventing oil spills, including:

- Monitoring of potential oil spill accidents;
- Number of emergency services and facilities needed for clean-up operations following an oil spill;
- Organisational arrangements for cooperation between emergency services;
- System of control and early warning;
- Securing constant readiness of all emergency services;
- System of information exchange;
- Procedures for immediate action after an emergency alert;

- Surveillance of geographic, navigational, hydrographic, hydro-meteorological and other environmental conditions of the area surrounding the oil spill in order to plan clean-up operations; and
- Safety of the population and provision of medical aid.

The following unresolved problems have been taken into consideration during the formulation of the policy options:

- Lack of appropriate equipment for the decontamination of oil spills during fast-ice consolidation;
- Sakhalin Basin Agency lacks the technical equipment and facilities to clean-up large and/or remote oil spills;
- Lack of double-hull tankers; and
- While the increasing volumes of oil being transported across the Okhotsk Sea will heighten the risk of oil spill incidents, emergency services remain under-developed.

Policy options

Economy

- Improve economic and financial mechanisms for environmental protection;
- Provide funds for the rehabilitation of ecosystems in the event of an oil spill;
- Evaluate the long-term environmental and socio-economic costs of oil and gas infrastructure development;
- Compensate the local population and other economic sectors for the negative effects of oil and gas extraction, and in the event of an oil spill;
- Accurately assess the economic value of the natural resources of the Okhotsk Sea, particularly those along the coast of Sakhalin.
- Provide economic incentives (and disincentives), such as discounted (or increased) ports fees, to oil companies which use (or do not use) environmentally sound practices, like double hulled tankers.

Legal

- Legislation should be comprehensive and consistent;
- The use of regulations, restrictions and prohibitions needs to be balanced with the promotion of operational safety and environmental protection using appropriate technologies; and
- Industry self-regulation, independent monitoring and regular auditing of internal control systems should be encouraged, in addition to State control and monitoring provisions.

Governance

- Minimise the adverse effect of oil and gas production on other economic sectors;
- Establish regular forums for stakeholders, such as the indigenous population and local industries, to discuss with government authorities and oil companies their concerns over problems related to the oil and gas development;
- Create mechanisms to compensate businesses or individuals for damages caused by the oil and gas development;
- Review operational procedures and create an operational safety system to reduce the risk of spills; and
- Ensure presence of independent technical and environmental inspectors at the offshore oil and gas fields to ensure compliance with Russian law.

Technology

- Use surveillance technologies, such as radar, to monitor tanker traffic;
- Modernise transport and oil distribution infrastructure to comply with highest environmental standards;
- Use appropriate navigational aids to minimise the risks of spills; and
- Phase in double hulls for all vessels using the tanker ports and offshore terminals.

Education and knowledge

- Support regional scientific research into the ecological consequences of oil and gas operations in the region;
- Build capacity in the institutions responsible for environmental monitoring;
- Ensure high standards of training for employees of oil companies and the crews of tankers;
- Conduct regular and independent (subject to peer review) Environmental Impact Assessments (EIAs) for the entire Sakhalin coastline;
- Monitor shipping activity:
- Estimate the carrying capacity of the region's ecosystems prior to developing oil and gas fields;
- Carry out constant environmental monitoring during the entire period that the oil and gas fields are exploited; and
- Develop environmental awareness campaigns to encourage public engagement in the development of the region for oil and gas.

The proposed options can be implemented on different scales: (i) internationally, e.g. multi-lateral investigations into the risks of oil spills and the adoption of internationally recognised best technologies; (ii) nationally e.g. strengthen the enforcement of Federal laws related to pollution; and (iii) locally e.g. develop operational safety and environmental protection measures based on accurate scientific and technical information.

Overexploitation of fish and other living resource in the Sea of Okhotsk region

Problem definition

Overfishing is threatening the sustainability of the most commercially valuable fish stocks in the Sea of Okhotsk region. The bioresources in most demand on the global fisheries market, such as sea urchin and King crab, are at risk of disappearing completely from the region. Further, the spawning grounds and habitat of salmon and other fish have deteriorated due to eutrophication and other pollutants in the Amur River Basin and the rivers of Sakhalin. Overfishing of the main commercial species has destabilised the ecosystems of the Sea of Okhotsk region.

The introduction of auctions of fish quota-rights, in addition to a burdensome tax system, has reduced the profitability of the fisheries, resulting in fishermen undertaking poaching and illegal fishing in order to supplement their income. The reduction in economic returns has also prevented the modernisation of the fleet and fishing gear. Russian and international fisheries laws and regulations are undermined by deep-rooted corruption and ineffective enforcement. The illegal export market to Japan is more valuable than the legal market (Okey 2003). There is a lack of fisheries statistics and monitoring programmes, and fishermen lack awareness of the long-term impacts of overfishing. Further, the countries fishing in the Sea of Okhotsk region insufficiently exchange fisheries information and rarely conduct joint research activities (Ozolinsh & Spiridonov 2001, Novomodny et al. 2004). There is, however, a growing recognition that the current trends in the fisheries sector of the region need to be halted.

Policy framework

The marine jurisdictional boundaries and hence the fisheries boundaries of Russia were determined by the United Nations Convention on the Law of the Sea (UNCLOS 1982), which Russia ratified in 1997. The Federal Law on the Continental Shelf of the Russian Federation (1995) defines the status of the continental shelf of Russia in accordance with UNCLOS. The Law on Internal Seas, The Territorial Seas and Adjacent Zone of the Russian Federation (1998) revised Soviet-era legislation to take into account the new area occupied by Russia.

In 2004, the Federal law on Fishery and Preservation of Biological Resources was passed. Although this may improve the status of the Russian fishery, the new law does not resolve many of the problems faced by the fisheries. It is believed that the law will be fully effective only if it is further developed (Zilanov 2005).

In addition, other international agreements and recommendations aim to improve and better coordinate international efforts aimed at addressing overfishing, e.g. the FAO Code of Conduct for Responsible Fisheries (1995). The United Nations Conference on Environment and Development (UNCED 1992) and the World Summit on Sustainable Development (WSSD 2002) also established principles regarding the preservation of biodiversity, the protection of the marine and the coastal environment, and the protection and rational use of marine living resources.

Despite the adoption of a number of global and regional initiatives aimed at addressing the problem of overfishing, the fisheries of the Sea of Okhotsk region remain highly vulnerable. The following outlines the main achievements and obstacles facing the fisheries sector.

Achievements:

- The United Nations Fish Stocks Agreement of 1995, applying to straddling fish, dictates that nations shall apply the precautionary approach (Article 6). The principles, parameters and models used in stock assessments of the Sea of Okhotsk need to be revised in order to execute this agreement, (Kotenev & Zaytseva 2003, Korelsky 2004);
- In 2002, to reduce the negative effects of overfishing, time limits for vessels at sea and satellite monitoring of bioresources were introduced in Russia (Bliznezov 2002);
- In 2003, the future development of the Russian fisheries sector was defined until the year 2020 (Governmental Resolution 2003). The resolution presented an analysis of the current status of the Russian fisheries sector. The policy aims to increase the sustainability of fish stocks in the Sea of Okhotsk through:
- The development of a legislative and organisational framework to enable the sustainable exploitation of fish based on the precautionary approach;
- The reduction of the capacity of the fishing fleet to a sustainable level;
- Practical actions to implement the FAO Code of Conduct for Responsible Fisheries (FAO 1995);
- The reduction of by-catch and discards;
- The mitigation of socio-economic problems caused by the reduction of fish stocks in the Sea of Okhotsk;
- The control of poaching, illegal markets and corruption; and
- The elimination of gaps in knowledge concerning aquatic ecosystems and the fisheries.

Unresolved problems:

a) International (general) issues:

- Increased demand for fish products;
- The impact of anthropogenic factors and natural variability on the fisheries, which increases the financial risks for the fisheries industry;
- Overcapacity of the fishing fleet resulting in the overfishing of commercial stocks;
- Lack of efficient international mechanisms and coordination between the concerned countries to combat illegal fishing;
- Gaps in fisheries statistics and low quality of collected data on which scientific conclusions are based; and
- Gaps in knowledge needed in order to establish TACs based on an ecosystem approach.

b) Russian issues:

- Economic crisis caused by market reforms following the collapse of the Soviet Union.
- Lack of governmental support for unemployed fishermen and the coastal fishery which is resulting in the stagnation of social standards in coastal settlements where the fishery is the dominant economic activity;
- The fisheries industry of the region is characterised by deteriorating fishing gear and processing facilities, an obsolete fishing fleet, and the widespread use of non-selective fishing gear;
- Increased export-oriented fishery;
- Lack of efficient policy to control by-catch and discards and insufficient financial support for the processing of fish with a low market value; and
- The lack of transparency in the fishing quota allocation system allows corruption, illegal transactions and provokes conflict among fishermen.

Policy options

Economy

- Reduce the capacity of the fishing fleet by compensating fishermen if they voluntarily decommission their fishing vessels;
- Invest in facilities to process less commercially valuable fish caught as by-catch, which are currently discarded; and
- Review and reform the credit and taxation systems to reflect the specific characteristics of the fisheries sector.

Legal

- Enforce legislation more stringently;
- Strengthen legislation and enforcement capacity in order to eliminate corruption in the quota allocation system;
- Improve international legislation in order to reduce poaching and illegal landings of fish in other countries.

Governance

- Formulate policies that promote the adoption of more sustainable fishing practices;
- Implement the FAO Code of Conduct for Responsible Fisheries;
- Ensure economic and social sustainability in the fisheries sector;
- Develop a national social strategy for the fisheries sector aimed at securing optimal employment and stable incomes for those employed in the fisheries sector;
- Strengthen the capacity of national fisheries control and enforcement agencies;
- Incorporate accurate fisheries statistics into the decision-making process;
- Adjust quotas according to the capacity of fishing vessels;
- Increase the transparency and equality of the Russian quota allocation system, taking into account the financial constraints of the small-scale coastal fishery; and
- Develop international sturgeon restocking programmes.

Technology

- Provide incentives and disincentives to encourage the use of selective fishing gear; and
- Develop alternative fishing gear.

Education/knowledge

- Improve the knowledge of fisheries dynamics and initiate fish stock assessments based on an ecosystem approach;
- Set TACs based on more accurate fisheries statistics; and
- Disseminate information to fishermen and the local population to build awareness of the environmental and socio-economic benefits of sustainable fishing.

Conclusions and recommendations

The Sea of Okhotsk region contains a wide range of natural resources, including one of the richest fisheries of the world and vast hydrocarbon resources. The fisheries industry of both the Okhotsk Sea and Amur River Basin is well developed. In the Okhotsk Sea sub-system, fishing fleets from not only the riparian countries of Russia and Japan but also other parts of the world are unsustainably exploiting the Sea's bioresources. Stocks of the most commercially valuable species on the international market are considerably depleted. Despite a number of international conventions and the adoption of national laws, the fisheries remain vulnerable. The GIWA regional experts, therefore, found the overexploitation of the fisheries to be a priority issue for the Okhotsk Sea. They also found oil spills to be a considerable future threat to the Sea because, although there has been rather limited oil contamination to date, the extensive oil and gas development, particularly on the continental shelf of Sakhalin (Russia), and increased shipment of oil across the Sea will significantly increase the risk of spills. There has been considerable effort made to rapidly develop the oil and gas industry in the region but, unfortunately, progress in establishing emergency contingency plans was considered unsatisfactory. Other than spills, some of the oilfields encroach upon the feeding areas and migratory corridor of the critically threatened western Gray whale. Disturbances caused by hydrocarbon exploitation activities may force the whales to change migration route and their feeding and reproductive behaviour.

The Amur River Basin sub-system is characterised by great geographical and cultural diversity. The Basin has experienced rapid economic development, especially in the Chinese section, which has placed increasing pressure on its ecosystems and living resources. The GIWA regional experts considered the overexploitation of the fisheries and eutrophication to be the priority issues of the Amur River Basin sub-system. Overfishing has caused the populations and physical size of Chum and Humpback salmon, and sturgeon, among other species, to decrease in the Amur River and its tributaries. At the same time, the habitats of many fish species, including important migratory fish, have been destroyed or altered. Large areas of wetland have been drained to form pastureland affecting biodiversity and threatened species in the Basin, notably several migratory bird species. The nutrient enrichment of the Amur and its tributaries by agricultural run-off containing artificial fertilisers and by the discharge of untreated wastewater is causing severe eutrophication. The River's ecosystems are now being affected by eutrophication not only during periods of low water in the summer and autumn but also during the period of ice formation. The Songhua River, which has experienced rapid agricultural, urban and industrial development, is the major source of pollutants in the Amur River. The benzene spill in the Jilin province of northeast China in 2005 which polluted the Songhua River and later the Amur illustrated the transboundary nature of the region's pollution problems.

There are a number of institutional weaknesses which are either promoting or failing to prevent transboundary pollution in the Amur River Basin sub-system. Each riparian country explores its own economic development and/or conservation of ecosystems, with limited basin-wide cooperation. There is, however, recognition of the need to work together to address transboundary issues. There is limited stakeholder involvement in the decision-making process and public awareness of pollution issues is rather rudimentary. A major hindrance for policy-makers when setting priorities for remediation is the lack of knowledge of the ecological characteristics and their reaction to human activities. A technical problem is the poor condition of wastewater treatment infrastructure.

The overcapacity of the fishing fleet is resulting in the overexploitation of the region's commercial stocks. Globally, there has been increased demand for fish products which has intensified the pressure on the region's fisheries resources. The introduction of auctions of fish quota-rights, in addition to a burdensome tax system, has reduced the profitability of the fisheries, resulting in fishermen undertaking poaching and illegal fishing to supply the large international black market for fish products. Regional cooperation in combating illegal fishing is limited and national laws and regulations are undermined by deep-rooted corruption and weak enforcement. There is a lack of fisheries statistics and monitoring programmes, and fishermen lack awareness of the long-term impacts of overfishing. According to the GIWA regional experts, many of the problems affecting the fisheries of the Sea of Okhotsk region stem from economic hardship in the Russian Far East and economic and social reform in Russia during the 1990s.

Recommendations

International level

- Prepare and implement an intergovernmental agreement between the countries sharing the Amur River Basin's transboundary water resources;
- Establish an international system of environmental monitoring in the Amur River Basin;
- Prepare and implement an intergovernmental agreement between Russia and Japan regarding the protection of the marine ecosystems of the Okhotsk Sea sub-system;
- Prepare and enact Russian federal laws on nature conservation and water resources management in the Amur River Basin and the Okhotsk Sea sub-system;
- Establish a commission responsible for the management of ecosystems within the Amur River Basin sub-system;
- Create inventories of the natural resources of the Amur River Basin sub-system, the coastal zone and the Okhotsk Sea sub-system; and
- Implement research programmes.

Regional level

- Establish a coordination committee for nature management within the Amur River Basin sub-system;
- Coordinate environmental monitoring systems within the Amur River Basin sub-system and the Okhotsk Sea sub-system; and
- Carry out environmental monitoring of oil and gas production on the Sakhalin shelf.

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Annexes

Annex I
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Annex II
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	1	N/a	Freshwater shortage	1
2. Pollution of existing supplies	2	N/a		
3. Changes in the water table	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	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	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	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	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	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		**1**	

N/a=Not applied

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	1	N/a	Pollution	1
5. Eutrophication	1	N/a		
6. Chemical	1	N/a		
7. Suspended solids	1	N/a		
8. Solid wastes	1	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	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	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 – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		**1**	

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	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	N/a	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	N/a	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	N/a	N/a
Degree of severity	Minimum 0 1 2 3 Severe	N/a	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	N/a	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	N/a	N/a
Degree of severity	Minimum 0 1 2 3 Severe	N/a	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	N/a	N/a
Weight average score for Other social and community impacts		**1**	

N/a=Not applied

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3/2*	N/a	Unsustainable exploitation of fish	2/3*
15. Excessive by-catch and discards	2/0*	N/a		
16. Destructive fishing practices	2/1*	N/a		
17. Decreased viability of stock through pollution and disease	2/0*	N/a		
18. Impact on biological and genetic diversity	1/1*	N/a		

**Amur River Basin sub-system/Okhotsk Sea sub-system*

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	N/a	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	N/a	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	N/a	N/a
Degree of severity	Minimum 0 1 2 3 Severe	N/a	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	N/a	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	N/a	N/a
Degree of severity	Minimum 0 1 2 3 Severe	N/a	N/a
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	N/a	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	0	N/a		
22. Changes in ocean CO_2 source/sink function	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	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		**2**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	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 – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	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	1	1	1	1	1	1	1	1	1	3
Pollution	1	1	2	2	2	2	1	1	2	1
Habitat and community modification	1	1	2	2	1	1	1	1	2	4
Unsustainable exploitation of fish and other living resources	2	2	2	2	1	1	1	1	2	2
Global change	1	1	2	2	2	2	1	1	1	5

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Sea of Okhotsk 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.

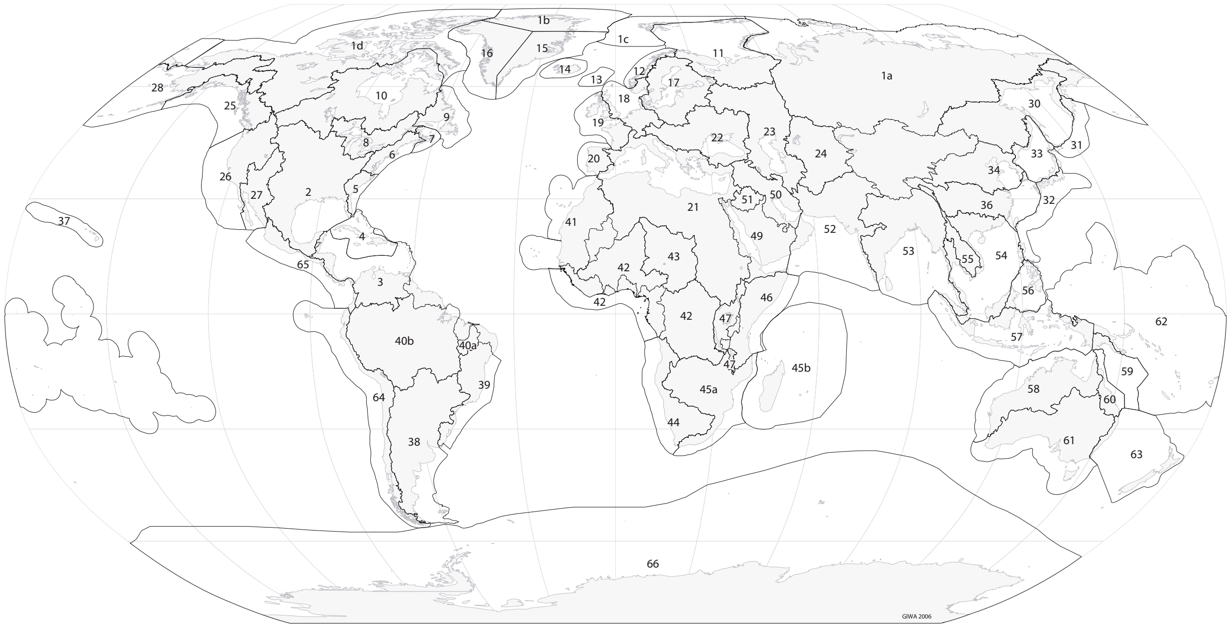
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and 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

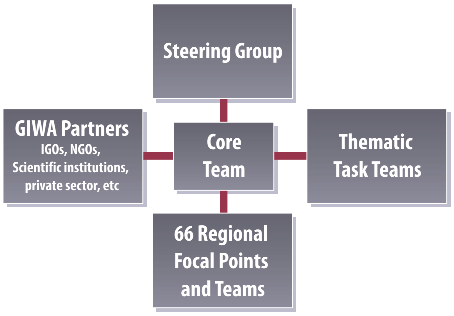


Figure 2 The organisation of the GIWA project.

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 CO2 source/sink function	**V Global change**

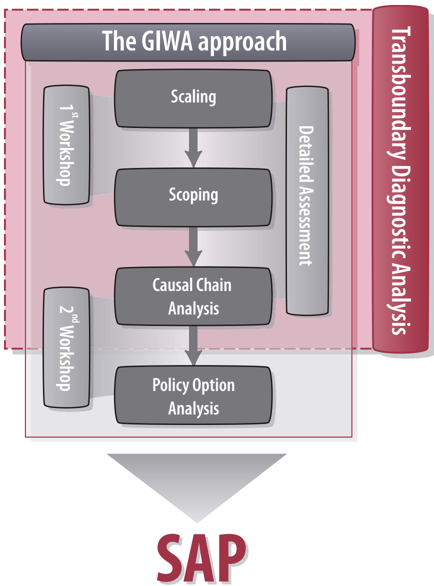

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

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	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community 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**

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 the world's transboundary waters that recognises the inextricable links between the freshwater and the coastal marine environments and integrates environmental and socio-economic information to determine the impacts of a broad range of influences on the world's aquatic environment.

Broad Transboundary Approach

GIWA recognises that many water bodies and resources, and the human impacts on them, are not confined to a single country.

Regional Assessment – Global Perspective

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

Global Comparability

In each region, the assessment focuses on five major concerns comprising 22 specific water-related issues.

Integration of Information and Ecosystems

GIWA recognises the inextricable links between the freshwater and the coastal marine environments and assesses them together as an integrated unit. GIWA recognises that the integration of socio-economic and environmental information and expertise is essential in order to obtain an holistic understanding of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

GIWA identifies the priority concerns of each region, determines their societal root causes and discusses options to mitigate the future impact of those concerns.

This Report

This report presents the results of the GIWA assessment of the Sea of Okhotsk region. Rapid population growth and economic development have led to increasing pollution loads in the Amur River basin – the region's largest drainage basin – placing increasing pressure on its diverse ecosystems. In the Sea of Okhotsk region, fishing fleets are unsustainably exploiting the Sea's fisheries, and the extensive oil and gas development will significantly increase the risk of spills in the future. The report assesses the past and present status and future prospects of the region, and traces the transboundary issues back to their root causes. Policy options are proposed that aim to address these driving issues in order to enhance the environmental quality of the region and secure the future prosperity of its inhabitants.

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