Global International Waters Assessment

Yellow Sea

GIWA Regional assessment 34

Teng, S.K., Yu, H., Tang, Y., Tong, L., Choi, C.I., Kang, D., Liu, H., Chun, Y., Juliano, R.O., Rautalahti-Miettinen, E. and D. Daler

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Executive summary

YELLOW SEA & BOHAI SEA

This report presents the results of environmental and socio-economic assessment studies of the Yellow Sea (GIWA region 34a) and the associated water body, the Bohai Sea (GIWA region 34b). The studies, which were facilitated through workshops with the participation of international experts, included impact assessments and causal chain analyses to determine the impacts and root causes of the priority GIWA concerns and issues, respectively. Policy options and associated strategic action programmes were also identified as to address the root causes of the priority environmental problem areas of the region based on the impact assessment and causal chain analysis results.

Yellow Sea region

The Yellow Sea region covers the following sea, river basins, watersheds and their associated coastal and marine habitats:

- Yellow Sea proper and its associated islands, coastal and offshore areas;
- Yalu River (Yalujiang) and its associated coastal and marine habitats at its river mouth located in the northern region of the Yellow Sea;
- Coastal river basins in the Liaodong Peninsula, which drain partially into the northern portion of the Yellow Sea (and partially to the Bohai Sea);
- Coastal river basins in the Shandong Peninsula, which partially drain into the middle and southern portions of the Yellow Sea (and partially into the Bohai Sea);
- Yongsan River (Yongsan-gang), Taedong River (Taedong-gang), Imjin River (Imjin-gang), Han River (Han-gang) and Kum River (Kum-gang) and their basins along the west coast of the Korean Peninsula, which drain into the Yellow Sea.

The region has diverse physical and socio-economic characteristics. The Yellow Sea is a semi-enclosed body of water bordering the Chinese mainland to the west, the Korean Peninsula to the east, and a line running from the north bank of the mouth of the Yangtze River (Changjiang) to the south side of Cheju Island, covering an area of roughly 400 000 km^2. It is an important global resource for coastal and offshore fisheries. Fish species found in the near-shore bays and estuaries include Ocellate spot skate (*Raja kenojei*), Greenling (*Hexagrammos otakii*), Black snapper (*Lutjanus* sp.), Scaled sardine (*Harengula zunasi*), and Spotted sardine (*Clupanodon punctatus*). There are approximately 1 600 species that have been reported from marine and coastal habitats on the Korean side of the region. The region is interesting because of its substantial population and increasing anthropogenic pressure. Approximately 600 million people live in the areas around the Yellow Sea. The region contains the following large cities, with one million or more inhabitants: Qingdao, Tianjin, Dalian, Seoul/Inchon, and Pyongyang/Nampo. People of these large, urban areas depend on the Yellow Sea as a source of marine resources for human nutrition, economic development, recreation, and tourism. The main economic sectors include: fisheries, aquaculture, oil exploitation and tourism.

The detailed assessment indicated that the environmental and socio-economic impacts of the following GIWA concerns and issues in the region were severe:

- Freshwater shortage
  - Modification of stream flow
  - Pollution of existing supplies
- Habitat and community modification
  - Loss of ecosystems
  - Modification of ecosystems
- Unsustainable exploitation of fish and other living resources
  - Overexploitation
  - Destructive fishing practices

Modification of stream flow in the major rivers on both the Chinese and Korean sides of the region has reduced the discharge of river water into the Yellow Sea. This has changed the environment and water quality of the Yellow Sea, affecting the well-being of the marine living resources and coastal habitats in both the Chinese and Korean waters of the region. Pollution of existing supplies in rivers on both the Korean and Chinese sides of the region has brought pollutants across national boundaries with significant transboundary impacts.

Loss and modification of ecosystems has depleted the living resources not only on the Chinese but also the Korean side of the region, particularly for the ecosystems that are the spawning or breeding grounds of fish species.

The major commercial species caught in the Yellow Sea are largely migratory species that are subject to seasonal migrations from one area of the sea to another. The catches in both the Chinese and Korean waters of the Yellow Sea would be seriously affected if overexploitation of these migratory species occurs. Overexploitation of fisheries resources has been found to be the most serious issue in the region. Cooperative efforts on a regional or transnational basis are required to attain sustainable management of the fisheries and other living resources of the region.

Destructive fishing practices are common in the region and can greatly impact on the viability of migratory species. Most of the fish species in the region are migratory species and there is evidence of changes in biological and genetic diversity in some of these species, resulting from overexploitation occurred.

The prioritised issues were analysed in two Causal chain analyses; the first one targeting habitat and community modification as well as freshwater shortage problems in the region, and the second targeting overexploitation and destructive fishing practices in the Yellow Sea. Modification of stream flow and pollution of existing supplies are important issues under the concern freshwater shortage. Habitat and community modification in the region is primarily due to reclamation of coastal land, irrigation, embankments, discharges of nutrients, trace metals and organic material and the introduction of invasive species and diseases.

The sectors involved in these issues are intensified and expanded agriculture; increased discharge of pollutants from a growing industry as well as urbanisation, and infrastructure provisions like the construction of dams and dikes for flood control. Moreover, both increased shipping traffic and modern aquaculture have raised the risk of introducing alien species.

The identified root causes are;

- Demographic: Increased population growth and mass migration to urban area.
- Technology: Poor crop irrigation systems.
- Economic: Changes in economic structure and increased economic growth; Insufficient investments in "green technology".
- Knowledge: Little access to technical and scientific information and low education level of the rural population. Profit-oriented attitudes disregarding environmental impacts.
- Legal: Insufficient enforcement of regulations and laws.
- Natural: Typhoons, causing storms and floods.

The increased fishing effort, higher efficiency and use of destructive fishing practices in the region have led to unsustainable exploitation of fish and other living resources. The environmental and socio-economic impacts are overexploited fisheries resources, destruction of aquatic habitats, decreased employment rates in the fisheries sector and decreased opportunities in the seafood processing industry.

The identified root causes of unsustainable exploitation of fish and other living resources are:

- Demographic: Increased demand for food as a result of increased population.
- Economic: Profit-oriented attitudes disregarding environmental impacts and increased market demand.
- Technology: Easy access to improved fishing technologies.
- Knowledge: Lack of public awareness.

The following policy options were formulated with regards to freshwater shortage:

- Integration of the development and management of agricultural irrigation systems with integrated river basin management programmes.
- Adoption and promotion of water-saving technologies for crop irrigation.
- Adoption of the Natural Forest Protection Program (NFPP) to cope with the uncontrolled deforestation.
- Adoption of integrated forest management practices.
- Adoption of efficient law enforcement mechanisms to prevent illegal logging and other forest destructive practices.
- Adoption of programs for raising public awareness and participation in forest management and restoration.
- Promotion of market incentive systems to encourage the use of green production technology in the industry sector.
- Enhancement of laws and enforcement mechanisms related to pollution prevention and wastewater treatment practices.

- Adoption of laws, regulations and enforcement mechanisms to control the use and disposal of fertilisers and pesticides.
- Adoption of educational and public awareness campaign programs on good practices in agriculture.
- Adoption of sustainable soil management system(s) to improve soil fertility and productivity.
- Adoption of efficient soil fertility improvement technology and crop irrigation systems to improve the soil productivity

The following policy options were formulated with regards to habitat and community modification;

- Adoption of laws, regulations and enforcement mechanisms to restrict population migration.
- Adoption of an approach that encourages the development of small, rural-oriented urban centres in rural areas to cope with population migration.
- Adoption of laws, regulations and enforcement mechanisms to promote good practices in agriculture including minimisation of the discharge of agricultural runoff high in harmful pollutants.
- Adoption of laws, regulations and enforcement mechanisms to restrict the introduction of exotic and invasive species for aquaculture.
- Adoption of programs related to raising public awareness on and participation in good practices in agriculture and recognising the environmental impact of introducing exotic and invasive species for aquaculture.
- Adoption of programs to raise public aware on and participation in good practices in using fertilisers and pesticides.
- Adoption of sustainable agriculture production technologies that would minimise the use of fertilisers and pesticides.

The following policy options were formulated with regards to unsustainable exploitation of fish and other living resources;

- Enhancement of laws, regulations and enforcement mechanisms to restrict the entry of excessive fishing fleets and fishermen into the fishing industry.
- Adoption of alternative livelihood programs for fishermen and other fisheries operators.
- Adoption of public awareness and education programs on the environmental and social consequences of over-harvesting of fisheries resources.
- Adoption of the sustainable production practices to enhance fisheries and aquaculture production.
- Enhancement of law enforcement mechanisms to restrict the destructive fishing practices.
- Adoption of public awareness campaign and education programs on the environmental and social consequences of the destructive fishing practices.

For each of the policy options, a Strategic Action Programme is defined, in order to give suggestions about how the policy options could be implemented.

Bohai Sea

The Bohai Sea is a national sea under the jurisdiction of China. It is located in the northwest corner of the Yellow Sea. From an ecological perspective, the Bohai Sea is a large, shallow embayment of the Yellow Sea. The Yellow Sea, in turn, is a shallow continental sea of the northwest Pacific Ocean. These relationships are important because of the physical and biological links between these systems; in particular, the fish and shellfish stocks in the Yellow Sea are dependent on the Bohai Sea as a reproduction and nursery area.

Given that the Bohai Sea is not a transboundary water body, the assessment report of the Bohai Sea is included in this report as an appendix to be used as a reference for further understanding of the Yellow Sea's environmental problems.

The Bohai Sea region covers the following sea, river basins, watersheds and their associated coastal and marine habitats:

- Bohai Sea, which consists of three bays: the Liaodong Bay to the north, the Bohai Bay to the west and the Laizhou Bay to the south;
- Liao River (Liaohe) Basin, coastal river basins in the Liaodong Peninsula, the Shuangtaizihe River Basin and their associated coastal and marine habitats in Liaodong Bay, north of the Bohai Sea;
- Hai River (Haihe) and Luan River (Luanhe) and their associated marine habitats in Bohai Bay west of the Bohai Sea;
- Yellow River (Huanghe) Basin, coastal river basins in the Shandong Peninsula and their associated coastal and marine habitats in Laizhou Bay, to the south of Bohai Sea.

The region has diverse physical and socio-economic characteristics. It is the historical heartland of China, and one of the most important agricultural and industrial regions in the country. The Bohai Sea has always been known as a "natural fishing ground" and harbours more than 1 540 species. Apart from such sea treasures as Prawn, Sea cucumber and Abalone, the Bohai Sea has over 100 species of major fish species among which the Small yellow croaker and the Hairtail are the fish species with the largest production in the Bohai Sea and also among the four major fish products from China's seas. The Bohai Sea region covers an area of 1.6 million km^2, 19.4% of the nation's total area and with a population of 343.5 million, over 22% of the nation's population. The main economic sectors of the region include: fisheries and marine aquaculture, salt making, port development and marine transport, oil exploitation and tourism.

Based on the results of the assessment for the Bohai Sea region the GIWA issues that have been assessed as having severe environmental impacts were selected for further analysis. They include:

- Freshwater shortage:
  - Modification of stream flow
  - Pollution of existing supplies
  - Changes in water table
- Habitat and community modification
  - Loss of ecosystems
  - Modification of ecosystems
- Unsustainable exploitation of fish and other living resources
  - Overexploitation
  - Impact on biological and genetic diversity

These issues are analysed in two causal chain analyses; the first one targeting habitat and community modification as well as freshwater shortage problems in the region, and the second targeting overexploitation and destructive fishing practices in the Bohai Sea.

The root causes for each of the problem areas have been assessed and prioritised. Key root causes for each of the problem areas were selected and are as follows.

Freshwater shortage and habitat and community modification

- Demographic: Increased population growth and mass migration to urban areas.
- Technology: Inadequate access to technology leading to inefficient use of freshwater. The easy access to modern technology has a propelled industrial growth that requires more use of water.
- Legal: Inadequate enforcement of laws and regulations to control the use of freshwater.
- Economic: Increase in economic growth. Increased energy demand by industries and domestic uses. Low investment in waste treatment facilities.
- Knowledge: Lack of public awareness on environmental impacts. Profit-oriented attitudes that disregard environmental impacts resulting in uncontrolled conversion of coastal wetlands for petrochemical plants.
- Natural causes. Decrease in rainfall has causing excessive extraction of groundwater to meet the needs for crop and industrial production.

Identified root causes regarding unsustainable exploitation of fish and other living resources are:

- Demographic: Increase in population growth leading to increased demand for food, including seafood. Shift in livelihood of fishermen from capture fisheries to aquaculture.
- Knowledge: Profit-driven attitudes of fisheries operators resulting in overexploitation of living resources. Insufficient awareness of the consequences of uncontrolled releases of hatchery-produced juveniles and overexploitation of spawning fish.
- Technology: Easy access to improved or new aquaculture technologies has propelled the increased development of aquaculture, leading to unsustainable use of living resources.

Suggested priority policy options and their associated strategic action programs to address the priority root causes for each of the problem areas have been formulated. Details of the policy options and their associated strategic action programmes are presented in this report.

Abbreviations and acronyms

YELLOW SEA & BOHAI SEA

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BOD	Biological Oxygen Demand
CIDA	Canadian International Development Agency
CITES	Convention on International Trade in Endangered Species
CMC	Coastal Management Center
DANIDA	Danish International Development Agency
DPR Korea	Democratic People's Republic of Korea (North Korea)
DMZ	Demilitarised Zone
DWT	Dead Weight Tonnage
EA	Environmental Assessment (including IEE and EIA)
EABRN	East Asian Biosphere Reserve Network
EIA	Environmental Impact Assessment
ENSO	El Niño Southern Oscillation
ESCAP	Economic and Social Commission for Asia and Pacific
FAO	Food and Agriculture Organisation of the United Nations
GEF	Global Environment Facility
GDP	Gross Domestic Product
GIS	Geographic Information System
GIWA	Global International Waters Assessment
GNP	Gross National Product
HAB	Harmful Algal Bloom
HP	Horse Power
IUCN	International Union for Conservation of Nature
JICA	Japanese International Cooperation Agency
MDB	Multilateral Development Bank
NGO	Non-governmental Organisation
NOWPAP	UNEP Regional Seas Programme's Northwest Pacific Action Plan
NYSAP	National Yellow Sea Action Plan
PEMSEA	Partnership in Environmental Management for the Seas of East Asia
PICES	North Pacific Marine Science Organisation
ROAP	UNEP Regional Office for Asia and the Pacific
ROK	Republic of Korea (South Korea)
Sida	Swedish International Development Cooperation Agency
SAP	Strategic Action Programme
SST	Sea Surface Temperature
TDA	Transboundary Diagnostic Analysis
TRADP	Tumen River Area Development Project
UNESCO	United Nations Educational Scientific and Cultural Organization
UNEP	United Nations Environmental Programme
USAID	US Agency for International Development

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Regional definition

YELLOW SEA

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

Boundaries of the region

The GIWA region Yellow Sea covers the following sea, river basins, watersheds and their associated coastal and marine habitats (Figure 1):

- Yellow Sea proper and its associated islands, coastal and offshore areas;
- Yalu River (Yalujiang) and its associated coastal and marine habitats around its river mouth located in the northern part of the region;
- Coastal river basins in the Liaodong Peninsula, which drain partially into the northern portion of the Yellow Sea (and partially to the Bohai Sea);
- Coastal river basins in the Shandong Peninsula, which partially drain into the middle and southern portions of the Yellow Sea (and partially into the Bohai Sea);
- The Huai River Basin, which includes Hongze Lake (Honzehu) and Chao Lake (Chaohu);
- Yongsan River (Yongsan-gang), Taedong River (Taedong-gang), Imjin River (Imjin-gang), Han River (Han-gang) and Kum River (Kum-gang) and their basins along the west coast of the Korean Peninsula, which drain into the Yellow Sea.

Figure 1 Boundaries of the Yellow Sea region

The Yellow Sea is neighboured by the GIWA regions Bohai Sea to the north and East China Sea to the south. China's two large rivers, the Yellow River in the Bohai Sea region and the Yangtze River in the East China Sea region are interconnected by the Yellow Sea region's Huai River and its tributaries, and thus, the Huai River Basin.

Three riparian states, the People's Republic of China (China), the Democratic People's Republic of Korea (North Korea) and the Republic of Korea (South Korea), border the Yellow Sea. The Huai River Basin on the Chinese side of the region occupies a total area of 174 000 km^2, about 5% of the land area of China and accommodates 230 million people, about 18% of the nation's total (SEPA 2003a,b). The major lakes in the region include the Hongze Lake and Chao Lake in China while there are no significantly large natural lakes on the Korean side of the border.

Physical characteristics

The Yellow Sea

The Yellow Sea is a semi-enclosed body of water bordering the Chinese mainland to the west, the Korean Peninsula to the east, and a line running from the north bank of the mouth of the Yangtze River (Changjiang) to the south side of Cheju Island, covering an area of about 400 000 km^2. It has an average depth of 44 m, with most of its sea area shallower than 80 m (GEF/UNDP 2000, Tang 2003). It is connected to the Bohai Sea to the north and to the East China Sea in the south, thus forming a continuous circulation system among these three seas.

The Yellow Sea receives a huge volume of sediments (around 1.6 billion tonnes annually) mainly from the Yellow River on its north border and Yangtze River on its south border; both rivers forming large deltas at their mouths. The biotic communities of the southeastern Yellow Sea are complex in terms of their species composition, spatial distribution, and community structure, possibly due to the Sea's complicated oceanographic conditions. The faunal communities are composed of various taxonomical groups of warm and cold-water as well as cosmopolitan and amphi-pacific species. Yet the diversity and abundance of the fauna are comparatively low. All components of the biotic communities show marked seasonal variations. Turbidity and sediment types appear to be the major parameters that affect the distribution of planktonic and benthic organisms in the coastal waters of the Yellow Sea (Tang 1989, Zhang & Kim 1999).

The central part of the Yellow Sea is called the Yellow Sea Basin and is the major over-wintering ground for most fish and invertebrates. The water mass in the Yellow Sea is in continuous circulation with those of the Bohai Sea and the East China Sea. Water circulation in the Yellow Sea is a basin-wide cyclonic gyre, which is comprised mainly of the Yellow Sea Warm Current and the Yellow Sea Coastal Current. The Yellow Sea Warm Current is a branch of the Tsushima Warm Current from the Kuroshio Current, which comes from the East China Sea carrying relatively high salinity (>33‰) and high-temperature (>12°C) water flowing northward along the 124° E meridian and then eastward into the Bohai Sea in the winter (Figure 2). This current, together with the southward flowing Yellow Sea Coastal Current, plays an important role in the water exchange in this semi-enclosed Yellow Sea (Tang 2003).

Figure 2 Currents in the Yellow and Bohai Sea.
(Source: Redrawn from Tang 2003)

The waters of the Yellow and Yangtze rivers flow across the continental shelf, discharging large quantities of sediments into the Okinawa Trough; the rivers also form large deltas along their entrance to the Bohai Sea and Yellow Sea, respectively. These river discharges peak in the summer and have important effects on the salinity and hydrography of the Yellow Sea. A monsoon regime prevails over this region and is the second force in driving biomass changes in the Sea, after fishing.

During winter, the surface water temperatures in the Yellow Sea may decrease to the freezing point in the northern part, but with temperatures gradually warming to the south (Figure 3) while during summer, the water temperatures may rise to as high as 27-28°C (Figure 4).

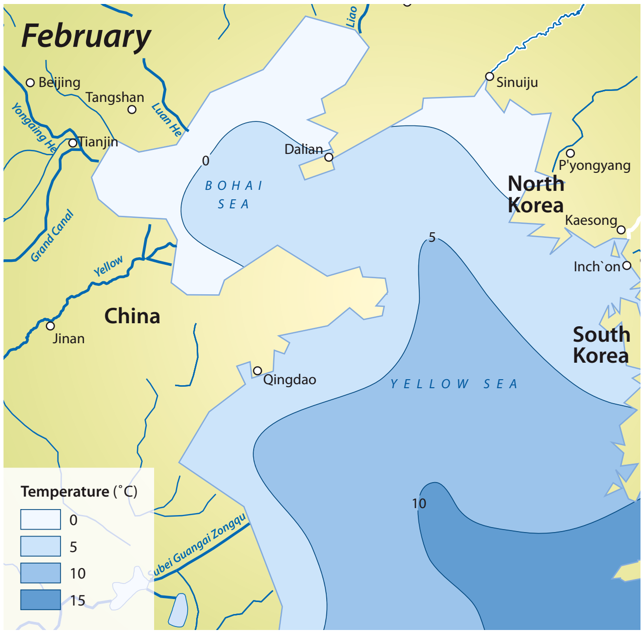

Figure 3 Surface temperature in Yellow Sea during February.
(Source: Lee et al. 1998 in Tang 2003)

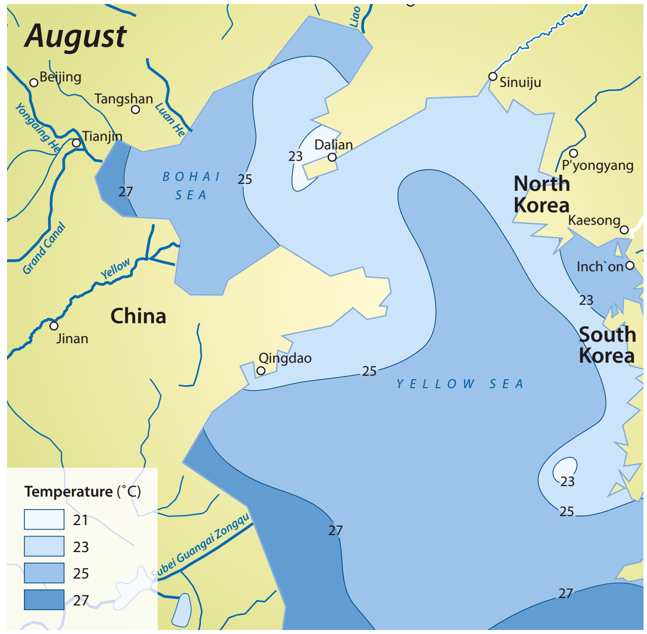

Figure 4 Surface temperature in Yellow Sea during August.
(Source: Lee et al. 1998 in Tang 2003)

The primary productivity of the Yellow Sea varies from 68-320 gC/m^2/year (GEF/UNDP 2002), and seems to vary widely depending on the location and seasons. The phytoplankton populations consist of mainly neritic diatoms, dominated by species such as the *Skeletonema costatum*, *Coscinodiscus* sp., *Melosira sulcata* and *Chaetoceros* sp. The diatom blooms occur during late winter to early spring, and summer to early autumn, concentrating along coasts of Liaoning, Shandong and Jiangsu provinces. The average phytoplankton biomass in the northern region and the southern region of the Yellow Sea is 2.4 million cells/m^3 and 950 000 cells/m^3, respectively (GEF/UNDP 2000, Tang 2003).

Fishery resources

There are about 280 species of fish, which make up the main living resource of the Yellow Sea. About 46% of these fish species are temperate with 45% and 9% belonging to the warm-water and cold-temperate species, respectively. The overall diversity and abundance of fish resources in the Yellow Sea are generally lower than those found in the East China Sea and South China Sea (Tang 2003).

The region is an important global resource for coastal and offshore fisheries and has well-developed multi-species and multinational fisheries (Tang 2003). Fish species found in the near-shore bays and estuaries include Ocellate spot skate (*Raja kenojei*), Greenling (*Hexagrammos otakii*), Black snapper (*Lutjanus* sp.), Scaled sardine (*Harengula zunasi*) and Spotted sardine (*Clupanodon punctatus*). These fish move to deeper waters in winter. Other species such as Chub mackerel (*Pneumatophorus japonicus*), Spanish mackerel (*Scomberomorus niphonius*) and Filefish (*Stephanolepis cirrhifer*) migrate out of the Yellow Sea to the East China Sea in winter. The Yellow Sea is one of the most intensively exploited areas in the world. About 100 species of fish and crustaceans are commercially harvested. Among the commercially important species are Fleshy prawn (*Penaeus* sp.), Southern rough shrimp (*Parapaeneopsis* sp.) and Japanese squid (*Loligo japonicus*). Due to overexploitation and natural fluctuations in recruitment, some of the larger-sized and commercially important species have been replaced by smaller, less valuable, forage fish (Tang & Jin 1999). Pacific herring (*Clupea harengus pallasi*) and Chub mackerel (*Pneumatophorus japonicus*) became dominant in the 1970s. Anchovy (*Thrissa mystax*) and Scaled sardine (*Harengula zunasi*), smaller-bodied and economically less profitable, increased in the 1980s and took a prominent position in the ecosystem. The Japanese anchovy (*Engraulis japonicus*) is presently believed to be the most abundant species in the Yellow Sea, with a potential catch of 0.5 million tonnes a year (Tang & Jin 1999). It appears that uncontrolled fishing or overexploitation has affected the self-regulatory mechanism of the Yellow Sea ecosystem.

River basins

The major rivers discharging directly into the Yellow Sea include Huai River and Yalu River in China; and Yongsan River, Taedong River, Imjin River, Han River and Kum River along the west coast of the Korean Peninsula.

Chinese side of the region

Huai River

The Huai River flows south of the Yellow River through the Henan, Anhui and Jiangsu provinces, draining the North China Plain between the Yellow River and the Yangtze River. It is 1 100 km long and drains an area of 174 000 km^2. The Huai River flows eastward through a very flat plain into Hongze Lake in Jiangsu Province, and from there it drains through many small channels into the Yangtze River (Zhang & Wen 2003).

The Huai River Basin, a major river basin in the region, is one of the major flood-prone areas in China (Figure 5). The river basin has a mean annual run-off of 61.1 km^3. The main reason for flood disasters is that the river system was destroyed by the Yellow River levees, as far back as 1194, when large amounts of sediments from these levees were deposited in the lower reach of the Huai River. This is decreasing the discharge capacity of the lower reaches of Huai River so that the River is no longer able to release upstream flood flows. The lakes and depressions along the River were thus used for floodwater storage and flood retardation. Consequently, the Huai River has changed its lower course and now flows into the Yangtze River (Zhang & Wen 2003).

There are about 195 man-made large- and medium-sized reservoirs located along the Huai River Basin, which could store a total of 23 km^3 of floodwater. Apart from these reservoirs, more than 50 000 km of levees were built or heightened as well as more than 20 large river channels excavated along the lower reaches of Huai River and its network of tributaries (e.g. Yi, Shu and Si rivers) to increase the carrying capacity of the River Basin to 23 000 m^3/s, which is three times as much as that of the original. Also, 13 flood storage and retardation basins with a storage capacity of 28 billion m^3 were completed in the 1960s, which had helped to relieve the problems of flooding in the Huai River Basin (Zhang & Wen 2003).

Figure 5 Flood prone areas along the main rivers in the Yellow and Bohai seas regions.
(Source: Zhang & Wen 2003)

Nowadays, the main stream of the middle reaches of Huai River can withstand floods as high as the 1954 flood (the highest since 1949, corresponding to a 40-year return period) if it is jointly operated with the flood storage and retardation basins. The lower Huai River can resist a 50-year flood but to its main tributaries, the Yi, Shu and Si rivers, can only withstand 10 to 20-year floods (Zhang & Wen 2003).

Yalu River

The Yalu River (Yalujiang), with a catchment of 62 630 km^2, extends along the western boundary between China and North Korea and is a transboundary river. The River flows from a temperate deciduous forest source (1 500-2 500 m above sea level) through extensive areas of agricultural land. It discharges into the Yalu River estuary on the northeast Yellow Sea coast. The Yalu River estuary comprises a main channel and a secondary channel, the latter being silted and with little water flow. The estuary is generally well-mixed as a result of a semi-diurnal tide (range up to 5 m), with strong tidal currents (1.5-2.0 m/s), which may affect the river waters up to 40 km inland. High turbidity may extend up to 10 km in the upper estuary, and the total suspended load in the estuary can be as high as 1 000 mg/l. The estuary is shallow (<5-10 m depth range). The long-term discharge rates of Yalu River averaged to 1 200 m^3/s or 40 km^3/year. The River's sediment load is relatively low (about 5 million tonnes/year) and concentrations of suspended matter are also often low (down to 5-10 mg/l). In the dry season, the River's nutrient profile is relatively stable, reflecting groundwater and tributary inputs in the upper reaches of the River and urban/industrial waste loading from the lower reaches. Heavy summer rainfall and the resultant flood flow probably results in strong leaching of nutrients from agricultural lands (Crossland & Crossland 2000, Wikipedia 2004a).

Korean side of the region

Most of the major rivers in the Korean Peninsula flow into the Yellow Sea, draining the western and southern slopes of the Peninsula. The basin areas and total lengths of these rivers are shown in Table 1. The discharge of these rivers fluctuates greatly due to the summer monsoon. In the summer, rivers swell with heavy rainfalls, often flood valley plains. In other seasons when the weather is relatively dry, the water level drops

Table 1 Major rivers in the Korean Peninsula draining into the Yellow Sea.

River	Basin area (km^2)	Length (km)
Han *	34 473	481.7
Keum	9 810	395.9
Yongsan	3 371	136.0
Ansung	1 700	66.4
Mankyung	1 571	74.1
Sapkyo	1 612	58.6
Dongjin	1 000	40.9

*Note: * Including the portion in North Korea.*
(Source: MOE 1996)

to very low levels and much of the riverbed is exposed. Typhoons hit the southern part of the Peninsula once every two or three years and they bring heavy rainfalls in late summer and early autumn. The largest river in South Korea from the perspective of basin area size and river discharge volume is the Han River (Han-gang). It has a basin area of 34 473 km^2 (including the portion in North Korea) and an annual run-off volume of 27.7 km^3, which constitutes 26% and 28%, respectively, of the nation's total run-off (MOE 1996).

The major characteristics of Korean rivers, most of which drain into the Yellow Sea, are:

- River reaches are relatively short and channel slopes are relatively steep. The river reaches are short and drainage areas are small in Korea compared with other major continental rivers. The channel slopes are relatively steep upstream because of steep mountains and deep valleys in the uplands.
- Floods occur quickly and peak flood discharges are enormous. Due to the topographical conditions and torrential rainfalls, the hydrographs of rivers in Korea are very sharp and peak flood discharges are enormous compared with other comparable rivers on the continent.
- Flow variations are high. The coefficients of Korean river regimes, expressed by maximum discharge over minimum discharge, usually range from 100 up to 700. This large variation in the flow discharge causes serious problems in river management of flood control and water use.

Climate

The climate on the Chinese side of the region, like other areas in northeastern China, is under the influence of the Eastern Asia monsoon; monsoon winds, which are caused by differences in the heat-absorbing capacity of the continent and the ocean (Zhang & Wen 2003, Wikipedia 2004b). The monsoon starts in September-October and ends in March-April the following year. During winter the monsoon wind from Siberia and the Mongolian Plateau blows into China and decreases in force as it travels southward, resulting in dry and cold winter in the region. During summer, the monsoon wind blows into China from the ocean, bringing in warm and wet air currents and rain. The annual precipitation in the Huai River Basin is around 800-900 mm, which is lower than areas in southwest China (over 2 000 mm) but higher than areas in the northeast China and along the North China Plain, where rainfall averages around 400-800 mm (Zhang & Wen 2003, Wikipedia 2004b).

The climate of Korea is characterised by four distinct seasons: spring, summer, autumn and winter. Winter is bitterly cold and is influenced primarily by the Siberian air mass. Summer is hot and humid due to the maritime influence from the Pacific High. The transitional seasons, spring and autumn, are sunny and generally dry. The variation in annual mean temperature ranges from 10°C to 16°C, except for the mountainous areas. August is the hottest month with the mean temperature ranging from 20°C to 26°C. January is the coldest month with the mean temperature ranging from -5°C to 5°C. The annual precipitation averages about 1 500 mm in the central region. More than a half of the total rainfall amount is concentrated in the summer, while precipitation in winter is less than 10% of the total precipitation (Asianinfo 2004).

The prevailing winds are southeasterly in summer, and northwesterly in winter. The winds are stronger in winter, from December to February, than those of any other season. The land-sea breeze becomes dominant with a weakened monsoon wind in the transitional months, September and October. The relative humidity is the highest in July, at about 80-90% and is the lowest in January and April, averaging between 30-50%. The monsoon front approaches the Korean Peninsula from the south in late June, and moves gradually to the north. Significant rainfall occurs when a stationary front lies over the Korean Peninsula. There are about 28 typhoons in the western Pacific each year, of which two or three approach the Korean Peninsula from June through September (Asianinfo 2004).

The distribution of precipitation on the Korean Peninsula is mainly affected by orography. The southern coastal and adjacent mountain regions have the largest amount of annual precipitation, over 1 500 mm. The sheltered upper Yalu River Basin in the northern region, on the other hand, experiences less than 600 mm of rainfall. Since most of the precipitation is concentrated in the crop-growing areas in the south, the water supply for agriculture is normally adequate. Even though the annual mean precipitation is more than 1 200 mm, however, Korea often experiences droughts due to the large fluctuation and variation of precipitation, making the management of water resources difficult (Asianinfo 2004).

General land forms

The Korean Peninsula extends for about 1 000 km southward from the northeast part of the Asian continental landmass. The west coast of the Peninsula is bordered by the Korea Bay to the north and the Yellow Sea to the south; the east coast is bordered by the Sea of Japan. The 8 640 km coastline of the Peninsula is highly indented. Some 3 580 islands lie adjacent to the Peninsula and most of them are found along the south and west coasts (Asianinfo 2004).

The northern land border of the Korean Peninsula is formed by the Yalu and Tumen rivers, which separate Korea from the provinces of Jilin and Liaoning in China. The original border between the two Korean states was the 38th latitude. After the Korean War, the Demilitarised Zone (DMZ) formed the boundary between the two Koreas. The DMZ is a heavily guarded, 4 000 m wide strip of land that runs along the line of cease-fire, from the east to the west coasts for a distance of 241 km (238 km of that line form the land boundary with North Korea) (FAO-AQUASTAT 2004).

The total land area of the Korean Peninsula, including the islands, is 220 847 km^2. Some 44.6% (98 477 km^2) of this total, excluding the area within the DMZ, constitutes the territory of the South Korea. The largest island, Cheju, lies off the southwest corner of the peninsula and has a land area of 1 825 km^2. Other important islands include Ullung in the East Sea and Kanghwa Island at the mouth of the Han River. Although the eastern coastline of South Korea is generally unindented, the southern and western coasts are jagged and irregular. The difference is caused by the fact that the eastern coast is gradually rising, while the southern and western coasts are subsiding (Asianinfo 2004).

The Chinese side of the region falls within the North China Plain, formed from deposits from the Yellow River. It is the largest alluvial plain of the eastern Asia. The plain is bordered on the north by the Yen mountain range and on the west by the Taihang mountain range. To the south it merges into the Yangtze River plain and from northeast to southeast it fronts the Bohai Sea, the highlands of the Shandong Peninsula and the Yellow Sea. The plain covers an area of about 409 500 km^2, most of which is less than 50 m above sea level. This flat yellow-soil plain is the main area of kaoliang, millet, maize and cotton production in China. Wheat, sesame seed, peanuts and tobacco are also grown there. The plain is also one of the most densely populated region in the world (World Bank 2003, Wikipedia 2004b).

In addition, the fertile soil of the North China Plain gradually merges with the steppes and deserts of Central Asia, and there are no natural barriers between these two regions. Although the soil of the North China Plain is fertile, the weather is unpredictable, because it is at the intersection of humid winds from the Pacific Ocean and dry winds from the interior. This makes the North China Plain prone to both floods and droughts. Finally, the flatness of the North China Plain creates massive flooding when the river's various flood control structures are damaged. In the opinion of many historians these factors have encouraged the development of a centralised Chinese state to manage granaries, manage hydraulic works, and man fortifications against the steppe peoples (Wikipedia 2004b).

Biodiversity

Approximately 1 600 species have been reported from marine and coastal habitats on the Korean side of the region. These include 70 species of phytoplankton, 300 benthic diatoms, 300 marine algae, 50 halophytes, 500 marine invertebrates, 150 fishes, 230 water birds and 10 marine mammals (GEF/UNDP 2000). Several species of endangered marine mammals such as the Spotted seal (*Phoca largha*), Black right whale (*Eubalaena glacialis*), Whitefin dolphin (*Lipotes vexillifer*), Kurile harbour seal (*Phoca kurilensis*), and Japanese sea lion (*Zalophus clifornianus japonicus*) live in the region; the Striped dolphin (*Stenella coeruleoalba*, northwest Pacific stock) is believed to be exploited beyond sustainable yield (GEF/UNDP 2000).

The Yellow Sea has specific oceanographic conditions unique for a semi-enclosed sea, which include the warm-temperate marine ecosystem with coastal ice covers formed in the winter, along with clear seasonal changes in biotopes. It is, therefore, anticipated that endemism of benthic invertebrates might be high; however, the diversity of endemic species has not been well studied, nor has the rate of loss of species diversity (NEPA 1994). There are no data on introduced species in the Yellow Sea. Little study has been made of genetic diversity (Choi pers. comm.).

Many marine animals such as Spotted seal (*P. largha*), Herring (*Clupes harengus*), Pacific cod (*Gadus macrocephalus*), Blue mussel (*Mytilus edulis*), Abalone (*Haliotis discushannai*), Sea snake (*Ophiura sarsii*) and other species of the temperate zone feed and breed in the Sea. The main threat to these coastal habitats is land reclamation, especially in estuaries and shallow bays. During the past few decades, many sites have been reclaimed, resulting in the loss of approximately 25% of the total tidal flats in the region. The waste materials and pollutants from industrial complexes and cities located in along the coast, along with tourist visits to the coast also contribute to degrading habitats (GEF/UNDP 2000).

Although the region is endowed with high species biodiversity, it has suffered high levels of loss. For instance, around 80 species of birds are classified as threatened on both the Chinese and South Korean sides of the region (Baker 2002). The main threats are: (i) the introduction of alien species that out-compete endemic species; (ii) habitat destruction; (iii) hunting; (iv) overexploitation; and (v) sometimes, deliberate extermination. Habitat destruction in the region is particularly significant, arising from conversion to other uses, removal of vegetation or erosion, and/or fragmentation, in which habitat is reduced into areas too small to support endemic species. In addition, future changes in global climate may further stress habitats in the region (Zarsky 2003).

To conserve biodiversity, the riparian countries of the region have adopted two approaches to conserving and restoring biodiversity. First, they have attempted to protect flagship threatened species such as the East Asian tiger (*Panthera tigris amoyensis*), the Panda bear or Giant panda (*Ailuropoda melanoleuca*), and the common crane (*Grus grus*). Second, they have created networks of protected areas to maintain habitats. The region has an extensive network of nature reserves of many different types and status, including biosphere reserves, world heritage sites, national parks, forest reserves and watershed reserves.

The total protected area varies greatly between countries. Despite current efforts, many critical habitats for endangered plants and animals remain unprotected; and in some cases, protected areas are inadequate. Moreover, some critical habitats cross national boundaries, yet protected areas either stop at the border or are managed differently by bordering countries (Zarsky 2003). The habitat of the Siberian tiger (*Panthera tigris altaica*), for example, extends across the borders of the Russian Far East, China and North Korea. There are only some cross border management capacity and limited exchange of information through the efforts exerted by EABRN of UNESCO (Zarsky 2003).

One of the most significant transboundary biodiversity issues is the threat to migratory species, especially birds. Birds migrate over a variety of routes in and across Northeast Asia, respecting no national or political boundaries, not even the tense DMZ between North and South Korea. White-naped cranes, for example, have been tracked by satellite flying from Izumi, Japan, to stopover points in South Korea, the DMZ, and North Korea, before flying on to Russia and China (Simard 1995).

Socio-economic characteristics

Population

The region is remarkably dense populated resulting in substantial anthropogenic pressure. Approximately 110 million people live in the region. Large cities in the region with 1 million or more of inhabitants include Qingdao, Tianjin, Dalian, Seoul/Inchon, and Pyongyang/Nampo. People living in these large, urban areas are dependent on the Yellow Sea as a source of marine resources for human nutrition, economic development, recreation, and tourism (Zhiang & Wang 2000). Figure 6 shows the population density in the Yellow Sea region. For more information on major socio-economic activitiy centres in the region see Box 1.

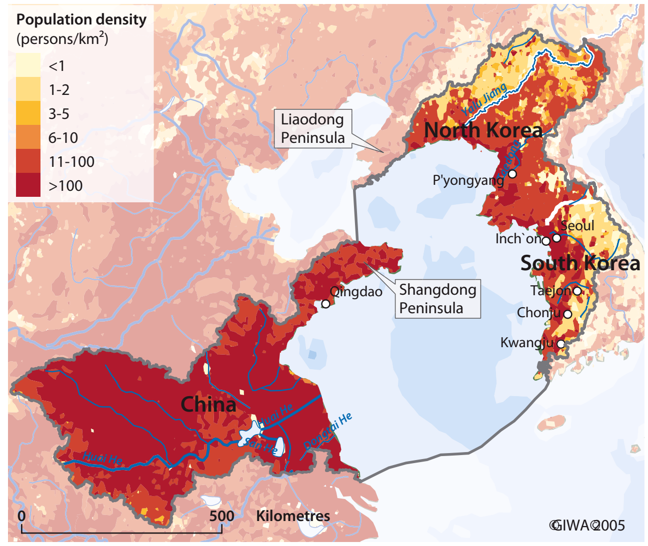

Figure 6 Population density in the Yellow Sea region.
(Source: ORNL 2003)

Economic sectors

Fisheries

In the region, particularly in the Yellow Sea, fish stocks remained fairly stable during World War II. However, due to a great increase in fishing effort throughout the entire Yellow Sea, nearly all the major stocks were being heavily fished by the mid-1960s. Since then, the composition of the fish catch has changed greatly and the catch-per-unit-square kilometre has decreased to 2.3 tonnes in recent years (GEF/UNDP 2000).

The Yellow Sea is one of the most intensively exploited areas in the world. The number of species commercially harvested amounts about 100 including cephalopods and crustaceans. The abundance of most species is relatively small, and only 23 species exceed 10 000 tonnes in annual catch. These are the commercially important species and account for 40 to 60% of the annual catch. Demersal species used to be the major component of the resources and accounted for 65 to 90% of annual total catch. The resource populations of demersal species such as Small yellow croaker (*Pseudosciaena polyctis*) , Hairtail (*Trichiurus haumela*), Large yellow croaker (*Pseudosciarna crocea*), flatfish (*Pleuronectis* sp.), and cod (*Gadus* sp.) declined in biomass by more than 40% when fishing effort increased threefold from the early 1960s to the early 1980s (CAFB 2003).

Box 1 Major socio-economic and human activity centres in the Yellow Sea region.

Population centres (population >1 million)

- South Korea: Seoul, Inchon, Daejeon and Kwangju;
- North Korea: Pyongyang;
- China: Dandong, Dalian, Yantai, Weihai, Qingdao, Lianyungang and Rizhao.

Ports and shipping routes

The ports located along the coastal areas bordering the Yellow Sea:

- South Korea: Inchon, Kun San and Mok Po;
- North Korea: Nampo;
- China: Dalian, Qingdao, Rizhao and Lianyungang.

The shipping routes found in the Yellow Sea are as follows:

- Inchon - Qingdao;
- Weihai - Dalian;
- Inchon - Japan;
- Dalian - Inchon;
- Pusan - Kunsan;
- Dalian and Qingdao to Middle East through Malacca Straits for crude oil shipping.

Aquaculture areas

In South Korea, aquaculture is practiced in the shallow coastal waters along its west coast; species cultured include shrimps, shellfish and seaweeds (*Porphyra* spp.) in marine waters. In China, large scale aquaculture farms for scallops and kelps (*Laminaria* spp.) are found in the Sanggou Bay of the Shandong Peninsula; for scallops around the Changshan Island of Liaodong Peninsula; and for nouri (*Porphyra* spp.), prawns and crabs in Haizhou Bay of the Jiangsu Province.

Industrial complexes (include power plants)

Major industrial complexes in China are situated in Qingdao (beer brewery, ship building and repair, electronics, pharmaceuticals and power plants), Dalian (ship building, sea food processing and textiles), Rizhao (mainly manufacturing of cement) and Lianyungang (nuclear power plant under construction, which may be in operation between 2003-2004). In South Korea, the industrial complexes are mainly located in Inchon (steels and automobiles), Kunsan (mainly automobiles), Seosan (mainly petrochemicals), Ansan (mechanicals and electronics) and Yaoung Kwan (nuclear plant).

Major mining sites

Limestone mining along the Han River Basin as well as sand and gravel mining in Inchon and Taean Peninsula are common on the Korean side of the Yellow Sea. In the Chinese side, the mining activities include gold mining in Yantai; diamond mining (second largest in China) in Yishu River basin; sand and gravel mining in Rizhao and Qingdao.

Major tourist sites

Major tourist sites on the Korean side of the Yellow Sea are Inchon, Seoul, Taeam Peninsula and Pyeong Yang. On the Chinese side, the Dalian and Qingdao areas are famous among local and foreign tourists for their sandy/swimming beaches, Weihai and Penglai for historical sites and beaches.

Major lakes and reservoirs

On the Korean side of the region, there are no natural lakes and reservoirs of significant size but there are several large man-made reservoirs such as the Soyang, Paldang, Daechung and Yongsan. On the Chinese side, there are two relatively large natural lakes, the Hongzehu in Jiangsu Province and Chaohu in Anhui Province; natural water reservoirs include the Andi and Bashan in Shandong Province.

Major fishing grounds

Major fishing grounds on the Korean side of the region are located in the coastal waters around Taean (for crabs and shrimps) and Icheon (for blue crabs and shrimps). On the Chinese side, the main fishing grounds are found in the coastal waters around Yanwei (for Spanish mackerels, hairtails and jellyfish), and Lusi and Lianqingshi, mainly for anchovies.

(Source: Zhiang & Wang 2000)

Overfishing has also caused a decline in stock abundance for Red seabream (*Pagrosomus major*), Jew-fish (*Otolithoides mijuy*), Yellow croaker (*Nibea albiflora*) and White croaker (*Argyrosomus argenteus*). However, under the same fishing pressure, the abundance of some species such as cephalopods, skates, Dagger-tooth (*Anotopterus pharaoh*) and Pike-conger (*Muraenesox lucioperca*) appears to be fairly stable. This may be due to their scattered distribution or their tolerant nature. Shifts in species dominance due to overfishing in the Yellow Sea are striking. For instance, the dominant species in the 1950s and early 1960s were Small yellow croaker (*P. polyctis*) and Hairtail (*T. haumela*), while Pacific herring (*Clupea harengus pallasi*) and Chub mackerel became dominant during the 1970s. Some smaller-bodied, fast-growing, short-lived, and low-valued fish (e.g. Half-fin anchovy (*Setipinna taty*), anchovy and scaled-sardine) increased markedly about 1980 and have taken a prominent position in the ecosystem resources since. As a result of overfishing, some larger-sized and higher trophic level species were replaced by smaller-bodied and lower trophic level species, and the resources in the Yellow Sea declined in quality.

Aquaculture

On the Chinese side of the region, aquaculture, particularly the marine aquaculture, is commonly practiced in all the coastal provinces bordering the Yellow Sea, with the most advanced practices in Shandong and Liaoning provinces. In both the Qingdao and Dalian regions the same fishery communes that culture invertebrates also cultivate seaweeds. The major species of invertebrates cultured are oysters (*Ostrea* spp.), mussels (*Mytilus*, *Septifer*, *Brachydontes*), razor clams (*Solenus* spp.), cockles (*Cardium* spp.), Short-necked clams (*Venerupis philippinarum*), pearl oysters (*Pinctada* spp.), scallops (*Pecten* spp.) and Hard clams (*Meretrix meretrix*). The mariculture area in 1978 was 148 000 ha but increased to 540 000 ha in 1997. The yield of fresh meat from bivalves was 200 000 tonnes, 44% of the total mariculture yield in 1978; in 1997 it was 300 000 tonnes. Others aquaculture species that grow successfully in the coastal areas of the region include: scallops (*Chlamys farreri, Pecten* spp.), sea cucumbers (*Stichopus japonicus, Stichopus* spp.) and Large chinese shrimp (*Penaeus orientalis*). The most important cultivated seaweed in China is the brown variety (*Laminaria japonica*), also known as kelp, which was introduced from Hokkaido, Japan. This cold-water kelp is now grown in more than 3 000 ha of China's coastal waters, with a production of 10 000 tonnes per year in dry weight. Half of this is consumed directly and half is used for extraction of alginates. There are 15 hatcheries on the north China coast, and the young plants are transferred to growing frames in the Sea when the seawater temperature drops below 20°C. Brown kelp (*L. japonica*) grows 3 m fronds at Qingdao and 5 m fronds at Dalian where the water cools down more quickly in the autumn and the growing season is longer. The respective yields are 30 and 50 dry tonnes/ha/year (CAFB 2003).

On the Korean side of the region, the total yield of invertebrate mariculture in 1997 was 301 873 tonnes representing 29.7% of the South Korea's total mariculture production (more than 1 million tonnes) which includes 200 973 tonnes of oysters (20%) and 63 572 tonnes of mussels (6.3%) (MOMAF 1998). Major species of mariculture include oysters

(*Ostrea* spp.), mussels (*Mytilus* spp.), abalones (*Haliotis discus hannai*, *H. discus*, *H. sieboldi*, *H. gigantean* and *H. japonica*), Hard clam (*Meretrix meretrix*), Short-necked clam, Ark shell (*Anadara broughtonii*), Pen shell (*Atrina pectinata*), and Hen clam (*Mactra sulcataria*). Seaweed is another important crop cultured commercially in the coastal areas of the Yellow Sea. Species of brown and red seaweeds cultured include *Sargassum pallidum*, *Plocamium telfairiae*, *Pelvetia siliquosa* and *Bryopsis plumose*. The *Pelvetia siliquosa* is found on the Shandong Peninsula, the Liaodong Peninsula, and the Korean Peninsula. This species of seaweed grows more luxuriantly in the Korean waters, and for hundreds of years the Koreans have exported large quantities of this seaweed to China. It was sold in North China markets under the name of deer-horn vegetable (CAFB 2003).

Oil exploitation

Oil exploration has been successful in the Chinese and North Korean portions of the Yellow Sea. In addition, the Sea has become more important with the growth in trade among its bordering nations. The main Chinese ports are Shanghai, Lu-ta, Tienjin, Qingdao, and Ch'in-huang-tao. The main port in South Korea is Inch'on, the outport of Seoul; and that for North Korea is Namp'o, the outport for P'yongyang (Zhiang & Wang 2000).

Tourism

Tourism is an industry in its infancy in the region. Several sites of picturesque beauty around the coastlines of these countries have been promoted as tourist attractions. As access to China and Korea has become easier for foreign visitors, the tourist industry has expanded in recent years. The Karst coast near Dalian, the granite mountains of the western Liaoning coast in China, and the islands and swimming beaches of South Korea, in particular Cheju Island, have become the most frequented tourist spots in the region (Zhiang & Wang 2000, Asianinfo 2004).

Economic characteristics

The Chinese side of the region forms part of the Bohai Bay Area, which includes provinces around the Bohai Sea and Yellow Sea. In 1995, the GDP of the region accounted for about 139 billion USD which constituted around 19.9% of the national GDP during the same period. Fisheries products in the same year contributed to around 33% of the total national production value, or around 9 billion USD (Zhiang & Wang 2000).

In 1994, the Chinese government formulated the key points of the Programme for Economic Development of the Bohai Bay Area up to the year 2000, and extended the economic development area to Shanxi Province and the Inner Mongolia Autonomous Region. Thus, the Bohai Bay Area covers an area of 1.86 million km^2, 19.4% of the nation's total area and with a population of 270 million, over 22% of the nation's total. The Bohai Bay Area sits in the centre of the Northeast Asian economic sphere. It has communication links with the Yangtze and Pearl river deltas, Hong Kong, Macao, Taiwan and the Southeast Asian countries to the south, with South Korea and Japan to the east, and Mongolia, and the Russian Far East to the north. The Bohai Bay Area is rich in mineral resources, which are relatively evenly distributed and with favourable mining conditions. Statistics show that this area's reserves of iron, coal, petroleum, salt, natural gas and limestone account for 44, 40, 37, 50, 23 and 16% of China's totals, respectively. The Liaohe Oilfield in Liaoning, the Dagang Oilfield in Tianjin and the Shengli Oilfield in Shandong are important petroleum production bases for China. In recent years progress has been made in offshore oil surveys in Bohai Bay, showing that the exploitation of offshore oil has great potential. Shanxi is abundant in raw coal, with its annual output accounting for 27% of the nation's total (Zhiang & Wang 2000, MF 2003, CIA 2003).

The Bohai Bay Area has well-developed agriculture, with 26.57 million ha of cultivated area, over one-fourth of China's total. Its grain yield accounts for more than 23% of the nation's total. In addition, the output of oil-bearing crops, aquatic products, pork, beef and mutton also constitute substantial percentages of the nation's total. Shandong, Hebei and Liaoning provinces are China's important production and supply bases for agricultural and sideline products. The Inner Mongolia Autonomous Region is the largest animal husbandry production base in China. In addition, the Bohai Bay Area has a solid industrial foundation, where heavy and chemical industries are especially prominent. Some large-sized enterprises, such as the Anshan Iron and Steel Company in Liaoning, Capital Iron and Steel Company in Beijing, Taiyuan Iron and Steel Company in Shanxi, and Baotou Iron and Steel Company in Inner Mongolia, are located in this area. The Beijing Yanshan Petrochemical Group and Tianjin Bohai Chemical Group are China's two leading petrochemical enterprises. In addition, Shenyang's heavy machinery and precision machine tool building industry, Beijing and Tianjin's electronic products and automobile industries, Shijiazhuang's cotton spinning, Hohhot's wool spinning and Taiyuan's mining machinery industries are all well known in China (Zhiang & Wang 2000).

After the reform and opening to the outside world China is being expanded in depth and breadth and the pace of economic development in the Bohai Bay Area has been quickened. Currently it is the engine of economic development in North China, and the area that has registered the third greatest economic growth, following the Pearl and Yangtze deltas. In the future, the Bohai Bay Area will take full advantage of advanced communications, the large number of large and medium-sized cities, its strong contingents of scientific and technical personnel and wealth of natural resources (MF 2003).

North Korea is a socialist country that has a centralised, planned, and primarily industrialised command economy. The principal means of production are owned by the state through state-run enterprises or cooperative farms. Prices, wages, trade, budget, and banking are placed under strict government control. The growth rate in 1984-1990 averaged about 3% annually. The GNP in 1991 was 22.9 billion USD, or 1.04 USD per capita. Withdrawal of Soviet aid in 1991 negatively affected the economy (CIA 2003). The country's principal crops include rice, corn, potatoes, soybeans, and pulses, the production of which is largely self-sufficient, although food shortages have been reported. The growth in agriculture, forestry, and the fisheries sector accounted to 2.8% in 1991; an increase in rice and other crops offset the decrease in fish products. The machine industry, military products, electric power, chemicals, mining, metallurgy, textiles, and food processing constitute the main industrial sectors of the country. Manufacturing concentrates on heavy industry; the ratio of heavy to light industry in 1990 was 8:2. In 1991 oil imports fell 25%, coal production 6.5%, and electricity generation 5.2%. Shortages in oil, coal, and electricity in 1991 led to idled plants and a 13.4% decrease in manufacturing output. The labour force was estimated at about 11.2 million people in mid-1990 (CIA 2003).

South Korea has achieved an incredible record of growth and integration into the high-tech modern world economy. Three decades ago, the GDP per capita was comparable with levels in the poorer countries of Africa and Asia. Today the country's GDP per capita is 18 times of the North Korea's and equal to the lesser economies of the European Union. This success through the late 1980s was achieved by a system of close government/business ties, including directed credit, import restrictions, sponsorship of specific industries, and a strong labour effort. The government promoted the import of raw materials and technology at the expense of consumer goods and encouraged savings and investment over consumption. The Asian financial crisis of 1997-1999 exposed longstanding weaknesses in South Korea's development model, including high debt/equity ratios, massive foreign borrowing, and an undisciplined financial sector. Growth plunged to a negative 6.6% in 1998, and then strongly recovered to 10.8% in 1999 and 9.2% in 2000. Growth fell back to 3.3% in 2001 because of the slowing global economy, falling exports, and the perception that much-needed corporate and financial reforms had stalled. Led by consumer spending and exports, growth in 2002 was an impressive 6.2%, despite anaemic global growth, followed by moderate 2.8% growth in 2003. In 2003 the six-day work week was reduced to five days (CIA 2003).

Legal and institutional framework

The Yellow Sea is an international water body and many of its problems can be solved only through international cooperation. It is therefore imperative that the coastal nations should realise the importance of regional cooperation. There are currently several agreements for bilateral regulation or development of the Yellow and East China Seas, but none of them are binding on all the coastal nations; nor is any nation a party to all the agreements. This means that there is insufficient consultation among the coastal nations. In addition, many of the existing national management policies or bilateral management programmes for the region have been designed and carried out with insufficient attention to the transnational nature prevailing in the region, particularly its major water body, the Yellow Sea (Kim 1998, Haas 1998).

Cooperation among the countries in the region is possible only when each nation is convinced that it will gain more from cooperation than it would without it. However, China, South Korea and North Korea already cooperate in many regional initiatives such as the Northwest Pacific Action Plan (NOWPAP), the Tumen River Area Development Programme (TRADP), the Asia-Pacific Economic Cooperation Forum (APEC), Fisheries Marine Resources Conservation Working Groups, and the GEF/UNDP/IMO East Asian Seas project (Kim 1998). These already existing institutional structures will play a crucial role by providing umbrella agreements between the countries. The international programmes and initiatives as well as the specific laws related to the environmental management in the region are provided in Annex III and IV. These initiatives address the management of water-related environmental issues and problems. They form a strong institutional framework; they themselves as well as in cooperation with the international and regional agencies/organisations play vital roles in ensuring the environmental well-being of the region.

The management of the Yellow Sea is especially complicated in that it is surrounded by nations that share some historical and cultural aspects but differ in political systems, political and economic alignment, and levels of economic development. There are several agreements for bilateral regulation or development of the Yellow Sea Large Marine Ecosystem, however none of them are binding on all the nations and nor is any nation a party to all the agreements. In addition, many of the existing national management policies or bilateral management programme for the region have been designed and carried out with insufficient attention to transnational issues (Haas 1998, Kim 1998).

Assessment

YELLOW SEA

Table 2 Scoring table for the Yellow Sea region.

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

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

The arrow indicates the likely direction of future changes.

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

Yellow Sea	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	2.6* ↘	1 ↗	1 ↘	2 ↘	1.3	5
Modification of stream flow	3					
Pollution of existing supplies	3					
Changes in the water table	2					
Pollution	1.9* →	3 ↘	1 →	2 →	1.9	3
Microbiological pollution	2					
Eutrophication	3					
Chemical	1					
Suspended solids	1					
Solid waste	2					
Thermal	1					
Radionuclide	0					
Spills	1					
Habitat and community modification	3.0* →	1 →	2 ↘	3 →	2.1	2
Loss of ecosystems	3					
Modification of ecosystems	3					
Unsustainable exploitation of fish	2.6* ↘	1 ↗	3 ↘	2 ↗	2.2	1
Overexploitation of fish	3					
Excessive by-catch and discards	1					
Destructive fishing practices	3					
Decreased viability of stock	1					
Impact on biological and genetic diversity	2					
Global change	1.4* ↗	1 ↗	2 →	2 →	1.6	4
Changes in hydrological cycle	2					
Sea level change	1					
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. For further details see Detailed scoring tables (Annex II).

** This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).

*** 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 2.

Freshwater shortage

In China, although the Yangtze River and Yellow River together possess a huge water reserve totalling to 2 800 km^3, the uneven distribution of water reserves has created severe shortages in areas within the country (SEPA 2003a,b). In the densely populated southern China, a relatively abundant water supply has been provided by the Yangtze River and Pearl river basins. The Yellow Sea and Bohai Sea regions, that account for 60% of China's land mass and half of the country's population, receive only 20% of the nation's water resources. This results in a severe shortage of freshwater in this part of China. The situation of freshwater shortage in northern China is further aggravated by serious soil erosion, deforestation, land conversion, excessive water usage for agricultural production and conversion of wetlands along lake shores into rice fields (SEPA 2003a,b). Compared to the Chinese side, the situation of freshwater shortage on the Korean side of the region is in general less serious (Asianinfo 2004).

Environmental impacts

Modification of stream flow

Modification of stream flow in the major rivers on both the Chinese and Korean sides of the region has reduced the discharge of water into the Yellow Sea. This has changed the environment and water quality of the Yellow Sea, affecting marine resources and coastal habitats in the region. The transboundary implications are significant. Main river basins or systems that contribute to the sources of freshwater supplies in the region include those associated with the Huai River (Huaihe), Yalu River (Yalujiang), Han River, Kum River and Yongsan River. Among them, the Yalu River Basin is the largest, and separates China from North Korea with an area of 48 330 km^2 (WRI 1998a). On the Chinese side of the region, over the past 5 years, the average flow in the Huai River has been reduced by 50% due to the intensive use of the river water for agricultural and industrial activities (Lu 1998, World Bank 2003) but the flow reduction over the same period in the Yalu River was less compared to that of Huai River (Crossland & Crossland 2000). Measurable reductions in water flow, mainly due to damming upstream in the Han River and downstream in the Kum and Yongsan rivers have been observed (US-AEP 2003).

Pollution of existing supplies

Pollution of river water on both the Korean and Chinese sides of the region has brought pollutants across national boundaries resulting in transboundary impacts. More than 10% of the Huai River Basin area has been polluted causing deterioration in nearby habitats, which has greatly depleted the dissolved oxygen (to as low as 1-2 mg/l), making some water bodies unable to support fish (Wang et al. 2003). The pollution was caused by discharges from the various chemical and paper pulp factories located along the Huai River. According to a report from the State Environment Protection Agency (SEPA), the number of polluting factories in the Huai River Basin has increased from 365 in 1996 to 1 320 in 2002 (Wang et al. 2003). Along the west coast of the Korean Peninsula, mass fish kills involving the death of thousands of fish each time, have occurred in river basins more than twice each summer due to oxygen depletion, mainly as a result of industrial discharges and agricultural run-off (US-AEP 2003, MOE 2003). In accordance with national standards for surface water quality in China (Table 3), the quality of water in the Huai River tributaries was that only 10.7% of the water monitored met the water quality standard for Grade I and 44.1% were worse than Grade V (see also Figure 7). In the mainstream Huai River, recorded values were: 38.5% met the water quality standard for Grade I to III, 46.2% met Grade IV or V, and 15.3% were worse than Grade V. Thus, the overall water quality in Huai River was poor and the water quality in the River's tributaries was more polluted than its mainstream.

Changes in the water table

Salinisation of normally freshwater coastal wetland habitats in Liaodong Peninsula and Shangdong Peninsula on the Chinese side of the region has occurred at the scale of tens to hundred of square kilometres over

Table 3 National quality standards for surface water in China.

Parameter	Water Quality Classification [1]				
	I	II	III	IV	V
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6-9
Sulphate (mg/l)	< 250	250	250	250	250
Chloride (mg/l)	< 250	250	250	250	250
Soluble iron (mg/l)	< 0.3	0.3	0.5	0.5	1.0
Total manganese (mg/l)	< 0.1	0.1	0.1	0.5	1.0
Total copper (mg/l)	< 0.01	1.0 [2]	1.0 [2]	1.0	1.0
Total zinc (mg/l)	0.05	1.0 [3]	1.0 [3]	2.0	2.0
Nitrate (mg N/l)	< 10	10	20	20	25
Nitrite (mg N/l)	0.06	0.1	0.15	1.0	1.0
Non-ionic nitrogen (mg/l)	0.02	0.02	0.02	0.2	0.2
Kjeldahl nitrogen (mg/l)	0.5	0.5	1	2	2
Total phosphorus (mg P/l)	0.02	0.1 [4]	0.1 [5]	0.2	0.2
Permanganate index	2	4	6	8	10
Dissolved oxygen (mg/l)	> 6	6	5	3	2
Chemical oxygen cemand (COD) (mg/l)	< 15	< 15	15	20	25
Biochemical oxygen demand (BOD_5) (mg/l)	< 3	3	4	6	10
Fluoride (mg/l)	< 1.0	1.0	1.0	1.5	1.5
Selenium (four valence) (mg/l)	< 0.01	0.01	0.01	0.02	0.02
Total arsenic (mg/l)	0.05	0.05	0.05	0.1	0.1
Total mercury (mg/l)	0.00005	0.00005	0.0001	0.001	0.001
Total cadmium (mg/l)	0.001	0.005	0.005	0.005	0.01
Total chromium (six valence) (mg/l)	0.01	0.05	0.05	0.05	0.1
Total lead (mg/l)	0.01	0.05	0.05	0.05	0.1
Total cyanide (mg/l)	0.005	0.05 [6]	0.2 [6]	0.2	0.2
Volatile phenol (mg/l)	0.002	0.002	0.005	0.01	0.1
Oil category (mg/l)	0.05	0.05	0.05	0.5	1.0
Anionic surface-active agent	< 0.2	0.2	0.2	0.3	0.3
Total coliform bacteria (cells/l)	ND	ND	1000	ND	ND
Benzo(a)pyrene (µg/l)	0.0025	0.0025	0.0025	ND	ND

Notes: [1] Water Quality Classifications: Class I: Water from sources, and the national nature reserves. Class II: First class of protected areas for centralised sources of drinking water, protected areas for rare fishes, and spawning grounds for fish and shrimp. Class III: Second class of protected areas for centralised sources of drinking water, protected areas for common fishes and swimming areas. Class IV: Water for industrial use and entertainment which is not in direct contact with people. Class V: Water bodies for agricultural use and landscape requirement. [2] Fishery 0.01 mg/l [3] Fishery 0.1 mg/l [4] Lakes and reservoirs 0.025 mgP/l [5] Lakes and reservoirs 0.05 mgP/l [6] Fishery 0.005 mg/l
ND = No Data.

(Source: UNEP 2003)

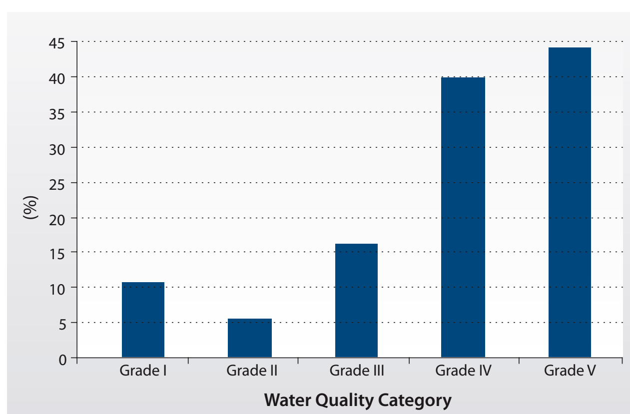

Figure 7 Water quality in the tributaries of Huai River, classified according the Chinese National Water Quality Standards

(Source: SEPA 2004)

the past two to three decades e.g. in Qingdao area (SEPA 2003a,b). Thus, in several urban centres of the region, overextraction of groundwater for industrial and domestic uses has been found to lower groundwater tables in these areas. Lower water levels will not only aggravate water shortages, but will also decrease water quality and increase the risk of earthquakes and landslides. On the Korean side of the region, extensive uses of underground water (extracting through wells) has led to seawater intrusion but the problems were largely localised and have not appear to be too serious (US-AEP 2003).

Socio-economic impacts

Some potential socio-economic and health impacts were identified in the region. These were evidenced by frequent interruptions of freshwater supply for several hours in several cities, e.g. Yantai and Weihai, on the Chinese side of the region, which greatly affected the urban population (Wang et al. 2003). The impacts could be further worsened by the inefficient use of the region's limited water supply, particularly in the Chinese river basins, as indicated by studies that showed in China: (i) only 20-30% of its industrial water is recycled; (ii) water consumption per unit of industrial production is 5-10 times higher than that of industrialised countries; and (iii) only 25-30% of irrigation water is effectively used due to poor irrigation facilities, resulting in about 2.5 million tonnes of grain yield lost each year (SEPA 2003a,b).

Box 2 The South-North Water Diversion Programme in China.

China has a very disproportionate distribution of water resources. In the southern region of China, just the Yangtze River (Changjiang) Basin alone contributes to more than 80% of the nation's total water resources, while the contribution from the northwest and north regions accounts to only 12%. This issue of depleted water resources has impeded the exploration and utilisation of the rich mineral resources and oil as well as the agriculture development in northern China regions, rendering the population in these northern areas being much poorer in living standard compared to those in the southern and coastal areas of China.

To address these problems, a South-North Water Diversion Programme has been initiated by the Chinese Government in recent years. Three projects, namely the Western Route Project (WRP), the Middle Route Project (MRP) and the Eastern Route Project (ERP) were formulated under the South-North Water Diversion Programme. The WRP, MRP and ERP will divert water from the upper, middle, and lower reaches of Yangtze River respectively, to meet the water requirements for the development of northwest and north regions of China. The WRP also aims to divert water from the upper reach of Yangtze River to the upper and middle reaches of Yellow River (Huanghe) to meet the requirements for water in the northwest region of China. The MRP will divert water from the middle reach of Yangtze River and its tributary as well as Han River (Hanjiang) by gravity flow to the most parts of the northern region of China, particularly the great Huang-Huai-Hai plain while the ERP will divert the water from the lower reaches of Yangtze River to the northern region of China by pumping.

Upon successful implementation of the WRP, about 20 billion m^3 of water from the three rivers will be diverted to increase an irrigated area of about 2 million ha and to supply 9 billion m^3 of water for human consumption and industrial uses in the provinces of the northern region of China such as Qinghai, Gansu, Shanxi and Ningxia as well as the Hui and Nei Mongol Autonomous regions. This will consequently enhance promotion of the economic development of these poorer northwest and inland areas of China as well as improve the biological environment of Northwest Loess Plateau. The MRP will divert water from Danjiangkou Reservoir on the Hanjiang, a tributary of Changjiang, to Beijing City through canals to be built along Funiu and Taihang mountains. In future, additional amounts of water will be drawn from Three Gorges Dam or downstream of the dam on the Yangtze River. The MRP will greatly mitigate the existing crisis of water resources in northern region of China and supply water for Tang-bai-he Plain, middle and western parts of Huang-Huai-Hai Plain, covering a total area of about 155 000 km^2.

(Source: MOWR 2003)

Conclusion and future outlook

On the Chinese side of the region, although the overall flow volume of the rivers is decreasing, the flow is likely to be improved in the coming 10 years when the government project that aims to channel the abundant water resources from the southern to the water-depleted northern China region is realised (see Box 2). The flow volume for the Huai River is expected to improve while that for the Yalu River could be decreased further (World Bank 2003, Crossland & Crossland 2000). Flow volumes of the Korean rivers are unlikely to be improved but they will be kept on the current level (FAO-AQUASTAT 2004, Asianinfo 2004).

The Huai River Basin is at risk of further pollution with the increased economic activities and urbanisation in the northeast region of China (SEPA 2004). Similarly, the water quality of river basins in the Korean Peninsula could also deteriorate with the increase in economic activities in both South and North Korea (MOE 2003, UNEP-RRC.AP 2003). However, in view of the great efforts on the part of both the Chinese and Korean governments in taking measures to control pollution, the quality of the freshwater resources in the region is likely to improve in the future (SEPA 2003a,b, MOE 2003, UNEP-RRC.AP 2003).

The water table situation is likely to improve on the Chinese side of the region as a result of outreach programmes to introduce measures for effective use of irrigation water as defined in the Chinese Agriculture Department's "15th Five Year Plan" (SEPA 2004), coupled with the government's ambitious project to channel abundant water resources from the southern to the northern part of China (Box 2). Similar measures have been or are being taken by the Korean governments (US-AEP 2003, UNEP-RRC.AP 2003). Further deterioration of the groundwater table in the region is unlikely.

In recognising the vital need to address water shortage issues in China in order to maintain the nation's development, China promulgated its Law of Water Resources, which provided a legal basis for water resource management in 1988. In 1993, further legal support to ensure efficient water use emerged as China adopted water resource licenses. By the end of 1995, nearly 90% of the nation's water utilities were registered and licensed. Since then, China's water supply is estimated to have increased 1% per year. The Chinese government is also promoting wastewater recycling by increasing investments in water pollution prevention and treatment facilities. Finally, efforts to tap new water resources, such as desalination of seawater, are being initiated. Measures were also taken by the Chinese government to cope with the problem of severe shortage of freshwater resources through restructuring the pattern of development in agriculture and industries, controlling the effective use of water and alternative use of seawater by industries along the coast. Implementation of the measures over the past 10 years have reduced the water use on the Chinese side of the region by 30-50%, yielding some economic benefits. Additionally, there are fewer cases of infectious diseases caused by the quality and quantity of the freshwater resources (World Bank 2003). Compared to the Chinese side, the Korean side of the region has experienced fewer socio-economic impacts due to freshwater shortage problems (US-AEP 2003, UNEP-RRC.AP 2003).

Efforts taken by both the Chinese and Korean governments in restructuring the pattern of development may improve the economy in the region, but continued growth in economic development is likely to aggravate the problem of water supply shortages in the future (SEPA 2004). However, public awareness of human health issues can be expected to improve, coupled with the measures taken by the governments to improve the welfare of human health, which together lower the chance for outbreaks of diseases due to freshwater shortages (World Bank 2003, US-AEP 2003).

IMPACT Pollution

Pollution in the Yellow Sea originates mainly from several land- and sea-based sources as well as atmospheric deposition, and includes organic material, petroleum, metals (e.g. zinc, arsenic, chromium, mercury), and inorganic nitrogen (Zhou et al. 1995, She 1999). Major pollutants come from industrial wastewater, domestic sewage, coastal cities, and agriculture and aquaculture areas (Zhou et al. 1995, She 1999). The most serious source of pollution comes from the rivers that discharge into coastal areas and harbours (She 1999). Each year about 1 500 million tonnes of industrial wastewater and 200 million tonnes of domestic sewage flow into the Yellow Sea (She 1999).

Environmental impacts

Microbiological

On the Chinese side of the region, incidents of gastrointestinal disorders caused by the consumption of seafood and freshwater products have shown a slight increase over the past several years (She 1999, SEPA 2003b). Although the *Escheria coli* counts in Jiaozhou Bay exceeded the national standard for Class III water quality (see Table 3 for the water quality standards), depuration centres were established by the Fisheries Bureau of the Agricultural Department to control the contamination of aquatic products, both from sea and freshwater habitats. In 1988, a serious outbreak of hepatitis A in Shanghai City, and Jiangsu and Shandong provinces was caused due to the consumption of blood clams (*Arca* sp.) contaminated with viruses during transportation in a boat containing manure (SEPA 2004). This has created a great amount of concern regarding health problems in the coastal population, which caused great economic losses; the whole clam fishery collapsed for several years in localised areas. However, such incidences were brought under control and have not occurred since then (SEPA 2004). On the Korean side of the region, seasonal incidences of diarrhoea due to consumption of raw seafood (sashimi) have occurred only during the summer (US-AEP 2003).

Eutrophication

The frequency, extent, and duration of harmful algal blooms (HAB) have increased since the early 1970s. This has mainly been as a result of eutrophication due to organic pollution caused by increased discharges of industrial, agricultural and aquaculture wastes. Natural disasters such as typhoons or tsunamis that bring up excessive amounts of bottom nutrients are also a contributor (She 1999). In addition, HAB organisms may be transported by shipping traffic, as well as from the huge discharge from the Yangtze River (Changjiang) during the summer monsoon season, which sometimes reaches the southern end of the Korean peninsula (MOE 2003). In 2002, a total of 79 HAB incidents were recorded over China's entire marine area. The total area affected exceeded 10 000 km^2; among these incidences, 51 HAB cases were found in the East China Sea, with the affected area exceeding 9 000 km^2, 17 HAB cases were found in the Yellow Sea and Bohai Sea, with affected area nearly 600 km^2 (SEPA 2004). Eutrophication in freshwater rivers and lakes in the region also occurs frequently, causing depletion of dissolved oxygen content (less than 2.0 mg/l) in the water leading to fish kills and changes in plankton species composition in coastal waters (US-AEP 2003, SEPA 2004).

Chemical

Acid rain, caused by the atmospheric transport and deposition of sulphur and/or nitrogen compounds emitted particularly by coal-burning power plants, is a transboundary source of chemical pollution in the region. In terrestrial and aquatic ecosystems, acid rain may decrease biomass productivity and thereby degrading existing forests. The main sources of acid rain are high levels of sulphur dioxide emissions from coal-burning power plants and factories in the region (Gregory & Richard 2003). In the areas adjacent to the Yellow Sea, it has been estimated that the industry may emit about 700 000 tonnes of sulphur dioxide per year, some of which may be transported across the Yellow Sea to the Korean Peninsula by the predominantly northwesterly winds (Shim 2003). Fortunately, the problem is amenable to technological controls at the source: a modern power plant with flue-gas desulphurisation equipment can remove more than 90% of the emissions. Countries in northeastern Asia are promoting the use of such equipment for their industries as well as establishing facilities to monitor acid rain deposition. However, much remains to be done in terms of establishing common monitoring methodologies, comprehensive baseline monitoring, and ecosystem impact studies (Sinton 2003).

Apart from acid rain, agricultural run-off and industrial discharges have also been observed to contribute to minor chemical pollution in localised areas in both the Korean and Chinese sides of the region (MOE 2003, SEPA 2004). Furthermore, the concentration of metals, pesticides, and oil in marine organisms is gradually increasing, sometimes to levels exceeding those allowable for consumption (She 1999).

Suspended solids

On the Chinese side of the region, some erosion along the coastal areas has occurred during the last two decades, which might contribute to an increase in the suspended solids content in adjacent coastal waters (World Bank 2003). The suspended solids concentration in rivers and coastal waters has increased due to other human activities such as dredging of navigation channels, dam construction and conversion of wetlands for agriculture (SEPA 2004). Many commercial species of shrimp, crab, and shellfish, especially in nursery and spawning areas, as well as benthic communities, have been seriously affected or have disappeared due to the effects of high sediment concentrations (She 1999). Suspended sediment problems in the coastal areas and rivers on the Korean side of the region are localised and have not been serious (MOE 2003).

Solid wastes

Indiscriminate dumping of garbage and other solid wastes by the aquaculture sector, residents in urban centres, and tourists has greatly increased the amount of floating solid wastes in rivers and coastal waters in the region (US-AEP 2003, UNEP-RRC.AP 2003, SEPA 2004). These have caused public concern regarding their impacts on recreational activities and tourism. Currently, there are an insufficient number of sanitary landfills to handle solid waste, particularly on the Chinese side of the region (SEPA 2004). Also, wide spread of litter and fishing gear on beaches and sea bottoms as well as in some recreational places were observed in the region. However the impact of solid wastes on the environment in the region was largely local although some of the waste such as fishing gears might have transboundary implications (US-AEP 2003, SEPA 2004). The impact of this GIWA issue to the region is moderate.

Thermal

There are power plants in Jiangsu and Anhui provinces, and the Huai River Basin as well as along the upper reaches of Yalu River on the Chinese side of the region; these power plants are discharging high-temperature cooling waters. However, the discharges have not appear to cause effects on the biotic structure and composition outside the mixing zones (SEPA 2003a, Crossland & Crossland 2000). On the Korean side of the region, some thermal difference around power plant discharge points has been observed, but the difference was not significant enough to cause any severe environmental impacts (US-AEP 2003, MOE 2003).

Radionuclides

The environmental impact of this GIWA issue is unknown as, at the moment, there are no nuclear power plants in operation in the region (US-AEP 2003, SEPA 2004).

Spills

On the Chinese side of the region, there were three to four incidences of oil spills in 1984, with amount of spilled oil as much as 3 300 tonnes in Jiaozhou Bay. The incidents of oil spills on the Chinese side of the region have increased substantially over the years (SEPA 2004). On the Korean side, minor spills have occurred in restricted areas and their biological impacts were insignificant (UNEP-RRC.AP 2003, US-AEP 2003). Additionally, incidences of oil spills from maritime activities have come under control as a result of effective enforcement by both the Chinese and Korean governments in recent years (MOE 2003, SEPA 2004). Oil and chemical spills are likely to have transboundary importance as spilled oils or chemicals may be carried by currents across the state, national and international boundaries (US-AEP 2003, SEPA 2004).

Socio-economic impacts

Over the past few decades, increased water pollution has resulted in adverse impacts on communities, particularly on the Chinese side of the region. Between 30-50% of the coastal areas were potentially open for recreational development, while at the same time, the water in several rivers such as the Huai and Han Rivers has become unfit for swimming (MOE 2003, SEPA 2003a & 2004). Over the past decade, increased pollution resulting in the destruction of aquatic habitats in the region has also caused: (i) drastic decreases in the production of penaeid shrimps (*Penaeus* spp.) and scallop (*Pecten* spp.); (ii) a 50% decrease in fisheries activities due to decreased catches; and (iii) a slight increase in the incidences of diseases from the consumption of contaminated seafood and aquatic organisms (Liu & He 2001, Jin 2003, US-AEP 2003).

Conclusion and future outlook

Microbiological pollution is expected to decrease with the implementation of integrated waste management programmes such as the "Greening Program" in Korea (MOE 2003) and other environment awareness campaigns initiated by the Chinese government (SEPA 2004) to reduce the discharge of untreated industrial and domestic sewage proposed. The culture of fish in floating cages in coastal areas of the region, that has been widely encouraged by both the Chinese and Korean governments, coupled with the increase in industrial development, are likely to aggravate eutrophication in coastal areas (MOE 2003, SEPA 2004). Unless measures are taken to control mariculture practices and industrial development, the eutrophication situation may deteriorate further.

Some improvements may be expected for the chemical pollution issue as a result of the efforts on the part of both the Chinese and Korean governments to improve industrial waste treatment. National programmes to combat water pollution problems have been implemented or will be implemented by both the Chinese and Korean governments; the successful implementation of these programmes will substantially improve the environment of the region in the future (UNEP-RRC.AP 2003, MOE 2003, SEPA 2004).

Concerning suspended solids in the region, measures currently taken by both the Chinese and Korean governments to increase reforestation along coastal areas and riverbanks may yield some improvements in controlling erosion in the future (SEPA 2004, US-AEP 2003). Enforcement of ecosystem protection measures in the region is relatively weak and improvement is needed.

The solid waste situation may worsen as a result of increased standards of living and urbanisation, both of which can increase the generation of solid wastes. However, with the increase in public awareness of environmental protection, and efforts taken by both the Chinese and Korean governments to gradually develop more sanitary landfills, as well as to recycle wastes and develop waste incineration plants, the situation is expected to improve somewhat in the future (UNEP-RRC.AP 2003, SEPA 2004). Also the demand for energy in the region is expected to increase with the growth of economic development. Consequently, more power plants will be built to cope with the increased energy demand, resulting in an increased volume of cooling water and subsequent thermal pollution.

Incidences of oil spills are expected to increase in the region with the on-going increase in petroleum and natural gas exploration/exploitation activities in the Bohai Sea and Yellow Sea (SEPA 2004). The accompanying growth in tanker and shipping traffic and other maritime activities could further add to the oil spill problem. International trade is anticipated to triple in the next 20 years and between 80-90% of this is expected to move by shipping (GEF/UNDP 2000). The marine areas of the region are important shipping routes for oil, and with the increased economic development in China, petroleum-related traffic can be expected to increase. There have already been around 300 oil spills resulting in more than 760 000 m^3 of oil spilled in the East Asian Seas region since the mid-1960s. Although oil spill prevention and combating measures could be adopted by using modern equipment and technology, the majority of GIWA experts believed that threats from oil spills would remain high in the future.

Increased economic growth over recent decades in the region has generated increasing amounts of industrial and solid wastes, which are major sources of marine pollution in the region. The current level of sewage treatment in the region is generally low. Unless this is drastically improved, the sewage from increasingly densely settled areas will accelerate eutrophication, which may threaten public health at transboundary levels. There are increased non-point sources of pollution, or run-off from diverse activities such as agriculture, mining, timbering and land-clearing, and residential and commercial development. Evidence indicates that land-based sources are polluting localised near-shore areas and bays as well as the coastal habitats affecting the livelihood of the local population in the region (Zarsky 2003).

Water pollution may continue to seriously affect ecological functions of the coastal areas in the region. The decrease in the production of fish and shellfish due to the effects of water pollution would likely be alleviated with the improvement in aquaculture technologies and other measures taken by both the Chinese and Korean governments (US-AEP 2003, Wang and Zhiang 2003). The increase in the incidences of disease outbreaks due to water pollution is likely to be low in the future and the impact of water pollution in the region is likely to remain unchanged if not improved in the future (US-AEP 2003, SEPA 2004).

Habitat and community modification

Environmental impacts

Loss of ecosystems or ecotones

Several types of habitats or ecosystems in the region have been lost to various extents. These include the following (Simard 1995, SEPA 2001):

- Marshlands: More than 30% of the total area of marshlands was lost over the past 30 years in both the Chinese and Korean sides of the region.
- Standing waters (lakes): A decrease of 30% of the total surface area of lakes has occurred over the past 30 years on the Chinese side of the region, while on the Korean side, there are no natural lakes.
- Periodic waters (e.g. rice paddy fields): About 10% of the total area of rice paddy fields has been lost over the past 30 years on the Chinese side, but on the Korean side of the region, more than 30% has been lost due to embankment, damming and diking. However, efforts have been made by both the Chinese and Korean governments to protect the rice paddy fields.
- Running waters (rivers): Over the past 30 years, the total surface area of the rivers in the region (on both the Chinese and Korean sides) has decreased by 30%. Many river tributaries have even dried up.
- Sandy foreshores: On the Chinese side of the region, roughly 30% of the area's sandy foreshores have seen heavy erosion, mainly due to sand mining of the beaches, road construction and recreational activities along the coastal plains. There was also evidence of loss of sandy foreshores due to road construction on the Korean side of the region, but the extent of loss was not known.
- Lagoons: The loss of lagoons in Shandong Province was obvious, decreasing over the past 30 years from the original 29 to only 3-4 nowadays. For the whole region, over the same period, more than 30% of the total area of lagoons has been lost.
- Muddy foreshores: More than 30% of the mud bottoms in the region have been lost over the past 30 years due to increased mariculture activities, opening up of salt-pans and increased agricultural activities as well as reclamation (e.g. reclamation in northern Jiangsu Province).
- Wetlands in saline habitats: Salt marshes are the habitats for a number of endangered species such as the red-crown crane and reindeer. Measures (e.g. development of protected areas for wetlands, legislation to control the use of wetlands and saline habitats) to protect salt marshes were taken by the Chinese government. As a result of this protection, not more than 30% of their area has been lost over the past 30 years.
- Estuaries: Some damage to habitats due to human activities has occurred in the estuaries at the mouth of Huai River, but the damaged area accounted to less than 30% of the total. The functional services of estuaries in the region have transboundary importance in that they provide spawning and breeding grounds for fish and shrimp as well as the recruitment grounds for migratory fish species.

Heavy erosion has occurred in about 30% of the sandy foreshore area on the Chinese side of the region. The erosion was mainly due to sand mining of the beaches, road construction, and recreational activities along the coastal plains (SEPA 2001). There is also evidence of loss of sandy foreshores due to road construction on the Korean side of the Yellow Sea, but the extent of loss is not known (GEF 2001). More than 30% of the mud bottom habitat in the region was lost over the past 30 years due to increased mariculture activities, opening up of salt-pans, and increased agricultural activities, as well as land reclamation. Some damage also occurred to the estuaries at the mouth of Huai River although the damaged area was less than 30% of the total (Li 2003). The Yellow Sea estuaries have transboundary importance since they are the spawning and breeding grounds for fish and shrimps as well as the recruitment grounds for migratory fish species.

Modification of ecosystems or ecotones

Several ecosystems or habitats in the region have been modified, resulting in various degrees of change in biodiversity, species composition and community structures. These included the following (Simard 1995, SEPA 2001, Zarsky 2003):

- Marshlands: There were obvious indications of the alteration of marshland ecosystems and of the goods and services that they can offer. This significant alteration was the effect of increased urbanisation, economic activities and accompanying pollution.
- Running waters (rivers): Increased economic development activities have caused pollution and decreased river flows and volumes. Changes in river functions (e.g. providing irrigation water and drinking water, fisheries production) has occurred.
- Standing waters (lakes): Persistent eutrophication of lakes has substantially altered species structure and composition, and contaminated water intended for human consumption.
- Sandy foreshores: The species community structure and abundance of aquatic life in the sandy shore areas have been greatly altered. Species such as Nereidae and Lancelets, which were previously found in these habitats, have now become rare. Biodiversity has been substantially reduced.
- Lagoons: Production of Sea cucumbers around the Yuehu Lake area in Shandong Province used to be in thousands of kilos per year, but now production has been greatly reduced to only tens of kilos per year. Such a tremendous decrease in the production of sea

cucumbers was due to uncontrolled overexploitation. Overgrowth and subsequent deterioration of macro algae have further modified the ecosystems, altering the goods and services that these systems can provide.

- Muddy foreshores: Substantial changes in species composition and abundance of benthic organisms in the muddy foreshores of the region, such as those in the Changkou area of Shandong Province. The benthic communities used to be comprised of about 170 species in the 1950s, but this was reduced to some 70 species in 1980s, and to only a few pollution-resistant species in 1990s. The introduction of salt hay (*Spartina* sp.) has greatly altered these ecological systems, causing reductions in biodiversity and habitat area for rare species such as the Acorn worm (*Saccoglossus kowalevskii*), and Tornaria larvae have been significantly reduced.
- Salt marshes: Salt marshes in the Chengshantou area have been well-maintained, and swans have returned. However, signs of some ecological changes have been observed in recent years, due to indiscriminate sewage discharges from the surrounding urban centres.
- Estuaries: In estuaries along the mouths of the Yalu River and the Huai River, small-sized food fish species, which used to be abundant in the 1950s, had disappeared by the 1980s. The number of economic species was reduced in these habitats and the ecological function of the habitats as spawning and breeding grounds for fish and shrimp have also become threatened.
- Sand and gravel bottom: The sand and gravel bottom area used to be an important habitat for an endangered species, the lancelet (*Branchiostoma belcherii*). However, lancelets cannot be found in these habitats nowadays, and the habitats are losing their ecological functions.
- Neritic systems: Ecosystem services have changed, the number of commercial species has been significantly reduced, size of fish caught has decreased, the predator-prey relationship has been altered, the food web changed, and high natural mortality of anchovy eggs has occurred.
- Rocky foreshores: Changes in species composition due to contamination, reclamation and mariculture (e.g. culture of abalone) have occurred.

Habitat modification has resulted in changes in biodiversity, species composition, and community structures in some areas. For example, species from the family Nereidae and lancelets have become rare and biodiversity has been substantially reduced in sandy foreshores. Substantial changes in species composition and abundance of benthic organisms in the muddy foreshores of the region have also occurred. The main threat to the coastal habitats of the region is intensive coastal development and land reclamation, especially in estuaries and shallow bays. During the past decades, many sites have been reclaimed, resulting in the loss of approximately 25% of the total tidal flats in the region (Simard 1995). The waste materials and pollutants from industrial complexes, coastal cities, and tourism and recreational activities also degrade coastal habitats.

Socio-economic impacts

Degradation of ecosystems has affected not only the ecological functions and the scientific value but also the daily livelihood of coastal and riverside communities (Xie & Wang 2003). For instance, the degradation of wetlands in the Huai River Basin has resulted in a decreased catch of fish, destruction of coastal areas and a loss of the revenues for local communities during the past decade; certain cultural heritage sites have also been seriously destroyed (Li 2003). These impacts have greatly affected the local population. The impact on the socio-economic situation of local communities has been severe. The employment rate in industries such as tourism and aquaculture has been affected; for instance, in the Huai River Basin, the employment rate has been found to decrease by 10% over the past decade (Wang et al. 2003). The production of some important Chinese medicinal products from the coastal seas such as the seahorse, sea-dragon, scallop (*Pina* spp.), in for example the Yalu estuaries has decreased by 30-50% over the past decade, due to the destruction or modification of ecosystems in the region (Crossland & Crossland 2000, CAFB 2003). Serious conflicts in the last 10 years have occurred over resource use for activities such as sand-mining and aquaculture. This has resulted in some social problems (Lu 1998).

Conclusion and future outlook

Damaged ecosystems are unlikely to be restored in the next 20 years. It is also possible that these ecosystems may tend to deteriorate further. This, in turn, would have profound impacts on the local population. The economic loss and loss of employment due to the damage to ecosystems are unlikely to show much improvement in the coming 20 years. With the efforts exerted by both the Chinese and Korean governments to protect the resources, some improvements in the production of the Chinese medicinal products from the coastal and marine areas would be expected in the future (Li 2003, MOE 2003).

Future prospects for habitat loss in the region are, as evaluated by the GIWA Experts in the workshops, likely to be as follows:

- Marshlands: Areas will be further reduced.
- Standing waters (lakes): Mitigation measures have been taken by the government, further deterioration may not be expected.
- Periodic waters (rice paddy fields): Further reduction of the areas is expected due to increased economic development.

- Running waters (rivers): Further reduction may be expected.
- Sandy foreshores: Further area reduction is anticipated.
- Lagoons: Further area reduction is anticipated.
- Muddy foreshores: Further area reduction is anticipated.
- Wetlands of saline habitats: Further area reduction is anticipated; irreversible changes are likely to occur.
- Estuaries: Further area reduction is anticipated.

Future prospects for habitat modification in the region, as evaluated by the GIWA Experts, are likely to be as follows:

- Marshlands: Further deterioration in ecosystem services is anticipated.
- Running waters (rivers): Thermal pollution in Yalujiang River might get worse, with further impairment of ecosystems.
- Standing waters (e.g. lakes): Habitat conditions may be further deteriorating, largely due to eutrophication caused by aquaculture wastes.
- Sandy foreshores: No significant changes expected.
- Lagoons: Further deterioration is expected.
- Muddy foreshores: There will likely be further increase in shellfish culture, causing further alteration and deterioration of habitats.
- Salt marshes: They are mostly in protected areas. No significant changes are expected.
- Estuaries: With further reduction in area, habitat conditions would be altered.
- Sand and gravel bottom: The situation might be getting worse as insufficient attention is given to threats.

IMPACT Unsustainable exploitation of fish and other living resources

The Yellow Sea region is an important global resource for coastal and offshore fisheries, has well-developed multi-species and multinational fisheries and is one of the most intensively exploited areas in the world (Tang 2003). About 100 species of fish and crustaceans are commercially harvested, including e.g. Fleshy prawn (*Penaeus* sp.), Southern rough shrimp (*Parapaeneopsis* sp.), and Japanese squid (*Loligo japonicus*). Due to overexploitation and natural fluctuations in recruitment, some of the larger-sized and commercially important species have been replaced by smaller, less valuable, forage fish (Tang & Jin 1999). When bottom trawlers were introduced in the early 20th century, many stocks were intensively exploited by Chinese, Korean, and Japanese fishermen. All the major stocks were heavily fished in the 1960s, which had a significant effect on the ecosystem. Pacific herring (*Clupea harengus pallasi*) and Chub mackerel (*Pneumatophorus japonicus*) became dominant in the 1970s. Anchovy (*Thrissa mystax*) and Scaled sardine (*Harengula zunasi*), smaller-bodied and economically less profitable, increased in the 1980s and took a prominent position in the ecosystem. The Japanese anchovy (*Engraulis japonicus*) is presently believed to be the most abundant species in the Yellow Sea, with a potential catch of 0.5 million tonnes a year. It is still under-exploited (Tang & Jin 1999). The general increase in fishing activities since the 1970s has depressed fish populations and has required a higher fishing effort than before to sustain the same catch. Fish and invertebrates declined in biomass by over 40% from the early 1960s to the early 1980s. Cold-water species such as the Pacific cod (*Gadus macrocephalus*) are almost extinct. It appears that uncontrolled fishing or overexploitation has affected the self-regulatory mechanism of the Yellow Sea ecosystem. The commercially important species are Fleshy prawn (*Penaeus* sp.), Southern rough shrimp (*Parapaeneopsis* sp.), and Japanese squid (*Loligo japonicus*). Total catch was about 2.7 million tonnes in 2000 (Figure 8).

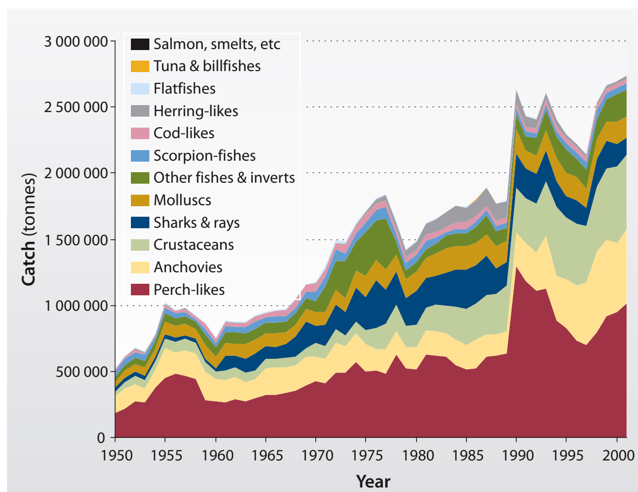

Figure 8 Fish catch in the Yellow Sea.
(Source: LME 2005)

Many of these resources are threatened by both land- and sea-based sources of pollution and loss of biomass, biodiversity, and habitat resulting from extensive economic development in the coastal zone, and by the unsustainable exploitation of natural resources. Non-sustainable fishing practices have also resulted in significant changes in the structure of the fisheries. Overfishing on the Korean side of the region is serious. Similarly, catches of major fish species on the Chinese side of the region also showed a remarkable decline, particularly for the Large yellow croaker (*Pseudosciaena crocea*) and Small yellow croaker (*Pseudosciaena polyactis*) in the last decades (GEF/UNDP 2000). Due to overexploitation and natural fluctuations in recruitment, some of the larger-sized and commercially important species were replaced by smaller, less valuable and forage fish (Tang & Jin 1999).

Overexploitation of the major stocks in the 1960s has had a significant impact on the ecosystem, as reflected by major biomass flips (Sherman 1989). These have been documented by Tang and Jin (1999), Zhang and Kim (1999), and Tang (2003). The decline in biomass of the larger and commercially important demersal species such as Small yellow croaker (*Pseudosciaena polyactis*) and Hairtail (*Trichiurus haumela*) was accompanied by an increase of about 23% in the biomass of smaller, less valuable fish between the 1950s-1980s (Tang 2003). Pacific herring (*Clupea harengus pallasi*) and Chub mackerel (*Pneumatophorus japonicus*) became dominant in the 1970s. Anchovy and Scaled sardine increased in the 1980s and species such as the Japanese anchovy, Spotted sardine, and Scaled sardine have nowadays become the most abundant species in the Yellow Sea, with an estimated maximum sustainable yield (MSY) of 0.6 million tonnes per year (Tang & Jin 1999). While natural environmental perturbations might have contributed to the increase in the abundance of pelagic species in the Yellow Sea (Tang & Jin 1999), overfishing has been found to be the primary driving force of biomass changes in the Yellow Sea (Tang 2003). The changes in species composition were accompanied by changes in the size structure of the fish populations. In 1986 about 70% of the biomass consisted of fish and invertebrates with a mean standard length of 11 cm and a mean weight of 20 g (Tang 2003).

Environmental impacts

Overexploitation

The region is one of the most intensively exploited areas in the world; many stocks were intensively exploited by Chinese, Korean, and Japanese fishermen following the introduction of bottom trawlers in the early 20th century (Tang 2003). The increase in fishing effort and its expansion has resulted in almost all major stocks being fully fished by the mid-1970s and overfished by the 1980s (Zhang & Kim 1999, Tang 2003). From the early 1960s to the early 1980s, the biomass of fish and invertebrates declined by more than 40% (Tang 1993). Dramatic declines in CPUEs of the Korean fleet occurred in the late 1970s (Figure 9), and the average CPUE in the 1990s was less than one-tenth of the highest CPUE in the mid-1970s (GEF/UNDP 2000). Similarly, catches of major fish species (e.g. Yellow croakers, Hairtail, and Chub mackerel) on the Chinese side of the region have also shown a remarkable decline particularly for the Large yellow croaker and Small yellow croaker (GEF/UNDP 2000).

Catches of the major economic species such as prawns (*Metapenaeus joyneri*, *Parapenaeopsis tenellus*), Small yellow croaker (*Pseudosciaena polyactis*), and Hairtails (*Trichiurus brevis*), exceeding their Maximum Sustainable Yield (MSY) levels has occurred in all coastal seas along the Chinese and Korean coasts of the region (GEF/UNDP 2000). Other evidence of overexploitation of the region's natural resources, particularly its fisheries

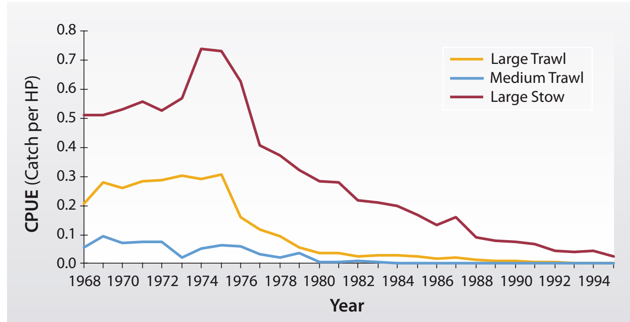

Figure 9 Catch per unit effort (horsepower) of three major fisheries on the Korean side of the region.
(Source: GEF/UNDP 2000)

resources include: (i) all major stocks had been heavily fished in the 1960s; (ii) more fishing effort is required to sustain the same catch because of increased fishing activities since the 1970s, which has depressed fish populations; (iii) the biomass of fish and invertebrates has declined by 40% from the early 1960s to the early 1980s; and (iv) cold-water species such as the Pacific cod are now almost extinct (Tang & Jin 1999).

Overexploitation of the fish resources over the past decades has resulted in decreased quantity or biomass but also decreased catch quality. For instance, Small yellow croaker and Hairtail were the commercially important demersal species in the Yellow Sea, with peak catches reaching 200 000 and 64 000 tonnes in 1957, respectively.

The major commercial species caught in the Yellow Sea are largely migratory species that are subject to seasonal migrations from one area of the Sea to another. The catches in both the Chinese and Korean waters of the Yellow Sea would be seriously affected causing transboundary implications such as encroachment on fishing grounds across national boundaries if overexploitation of these migratory species occurs. Overexploitation of fish resources has been found to be the most serious issue in the region. Cooperative efforts on a regional or transnational basis will be required to attain sustainable management of the fish and other living resources of the region.

Excessive by-catch and discards

About 30% or less of all the fisheries caught from the Chinese and Korean sides of the region have been found to consist of by-catches, occasionally also seals (Jin 2003). The proportion of fisheries by-catch in the region has therefore been considered to be relatively insignificant.

Destructive fishing practices

Common destructive fishing practices in the region include indiscriminate trawling along the coastal waters of Yellow Sea, fishing with explosives in lakes, and use of pesticides for fishing (Jin 2003, MOE 2003). As a result of these destructive fishing practices, aquatic habitats have been destroyed, leading to the collapse of fish populations and loss of biodiversity. The long-term implications for the protection of the environment and resource conservation after such destructive fishing practices are obvious.

Decreased viability of stock through pollution and disease

Pollution and diseases have caused decreases in production and species composition of bivalves, clams and cockles, but not to the extent that they could cause resource depletion (Yuxiang pers. comm.). On the Korean side of the region, deformation of freshwater fish due to disease and water pollution has occurred but without significant impact on the fish stock; the situation is not serious (Shang pers. comm.). There is evidence that diseases originating from cultured fish stocks were being transmitted to wild stocks (Jin 2003). This is likely to decrease the viability of wild stocks, affecting overall production in the future.

Impact on biological and genetic diversity

International shipping transfers approximately 10 billion tonnes of ballast water around the world annually. Although necessary for ship safety, ballast water can contain marine organisms that threaten ecosystems and public health. For example, in some countries harmful algal bloom organisms have been introduced by ballast water and have contaminated shellfish. As ships get larger and faster, and as maritime trade increases, the problem will become more acute (SEPA 2001).

A decrease in genetic diversity and species composition in clams and oysters was observed due to mariculture and release of hatchery-produced larvae; however it has not depleted any resources (NEPA 1994). A measurable decline of native populations due to the introduction of alien species has occurred in Korean reservoirs (Choi pers. comm.). Genetic differences (or changes) in prawns as a result of the mass release of hatchery-produced prawn larvae have been observed in both Korean and Chinese waters (NEPA 1994).

Socio-economic impacts

The employment rate in the region has shown a decrease of 30-50% over the past decade due to overfishing and environmental degradation that affect the abundance of fish resources (CAFB 2003). This has affected the overall livelihood of coastal communities and has increased migration of the coastal and rural population to urban centres in a search for employment. Although some measures have been taken by the governments to protect resources, improvement is unlikely to be significant in the future. As mentioned earlier, decreasing catch per unit effort (CPUE) has been widely experienced by fishing fleets in the region. The poor catches have reduced business activities in the seafood processing industries by around 10% over the past decade (Tong pers. comm.). Fish and other marine living resources form important food items for the local population. Cases of infectious diseases due to the consumption of contaminated seafood have been frequently reported. A massive infection of Hepatitis A caused by the consumption of contaminated cockles in Shanghai and the neighbouring populations in Jiangsu Province during the 1990s is a good example of impacts on human health (Xin 2003, SEPA 2004).

Conclusion and future outlook

Unsustainable exploitation of fish and other living resources is likely to continue in the coming 20 years (Tong pers. comm.). This would further aggravate the unemployment rate, which would affect the local population. In the past 5 years, the contribution from fisheries production to the national domestic product (GDP) in the Shandong Province, one of the Chinese provinces in the region, was decreasing annually, indicating a stagnation in the fisheries sector (Tang 2003). Therefore, in the coming 20 years, capture fisheries production is expected to decrease by 30-50% due to the continued overfishing and environmental degradation (CAFB 2003). With the increase of public awareness of health aspects and measures taken by both the Chinese and Korean governments to combat diseases, the incidents of infectious disease outbreaks due to consumption of contaminated seafood are likely to be kept at a low level in the future.

In view of the open access or common property nature of the fish resources, fishing efforts in both the Chinese and Korean sides of the region are expected to intensify in order to meet market demands in the future (OECD 1997, Jin 2003). Overexploitation of fish resources will worsen if measures are not taken to conserve or to encourage rational use of the resources.

Destructive fishing practices have transboundary implications in that the practices in one country can affect the viability of migratory fish in another country. The destructive fishing practices also destroy fish spawning and breeding grounds, reducing the recruitment potential for marine and ocean fish stocks, which are common resources for China and Korea (Jin 2003). Enforcement of regulatory measures to control destructive fishing practices in the region have been and will be implemented by both the Chinese and Korean governments in the future (MF 2003, MOE 2003). Consequently, the situation may be gradually improved. As evaluated by the GIWA Experts, some impacts are expected from introduced species but the situation is unlikely to change much in the future.

Global change

Environmental impacts

Changes in the hydrological cycle

Due to the increased effects of ENSO and El Niño, the flow volume of the warm Kuroshio Current has been observed to increase over the past decade (Yuxiang pers. comm.) and because of the close proximity of the Yellow Sea to the Kuroshio Current, the temperature and water circulation patterns in the Yellow Sea have been changed (Lu 1998). This may cause localised changes in the hydrological cycle without strong effects on the productivity and biodiversity in the region. Changes in climatic conditions, such as an increase of air temperature and sea level rise, and the observed disappearance of floating ice blocks in Jiaozhou Bay on the Chinese side of the region could also modify the hydrological cycle; the economic loss due to these changes has been estimated to be as high as 60-80 billion USD (Xinhuanet 2004a & 2004b, PDO 2004).

Sea level change

Sea level rise at the rate of around 1.5-2.0 mm/year has been observed in the southern part of the Yellow Sea since 1982, but has not appeared to affect the biodiversity and species composition of the aquatic life in the region (PDO 2004).

Increased UV-B radiation as a result of ozone depletion

Both Korean and Chinese Experts believe that no evidence of increased UV-B radiation has been observed in the region.

Changes in ocean CO_2 source/sink function

Both Chinese and Korean Experts indicated that there was no clear evidence of changes in the ocean CO_2 source/sink functions in the region, although some studies did show some changes, causing a slight increase in primary productivity due to increased nutrient inputs (Lu 1998).

Socio-economic impacts

The retreat of coast line and the intrusion of seawater due to sea level rise both have substantial implications for the overall economic development in the region, but the level of impact is still low (PDO 2004). Incidences of disease outbreaks due to changes in water quality, seawater intrusion and floods resulting from the sea level rise have shown signs of increase (World Bank 2003).

Conclusion and future outlook

As evaluated by the GIWA Experts, in the coming 20 years, conflicts over resource use will be expected to be aggravated and the associated social problems will intensify. The situation may show some limited improvement with measures that have been and/or will be taken by both the Chinese and Korean governments to resolve the problems. Although the three governments have taken and/or will take the necessary measures to control the outbreaks of diseases, the risks of disease outbreaks brought about by the unpredictable impact of global climate change and the associated changes in water resources still remains (World Bank 2003). The current situations are likely to remain in the future. Changes in the hydrological cycle is expected to improve in the future when more effective predictive and preventive mechanisms/measures are developed and strengthened. The impacts of sea level change are unpredictable in the future, although preventive measures to cope with the consequences of sea level rise are being taken by both the Chinese and Korean governments (Lu 1998).

Priority concerns for further analysis

Many environmental issues, particularly those that are water-related, are increasingly of transboundary concern. For instance, land-based pollutants discharged into the Yellow Sea may affect the environment in both Chinese and Korean coastal areas, creating transboundary problems for environmental management. Similarly, the destruction of spawning and breeding habitats along the Korean coasts may affect the catches in waters on the Chinese side of the region or vice versa, creating another critical transboundary issue (JICA 2002). Almost all the priority GIWA concerns and issues for the region have transboundary implications.

Based on the results of the assessment and the diagram showing the linkages between the GIWA concerns (Figure 10) the concerns were prioritiesed in descending order:

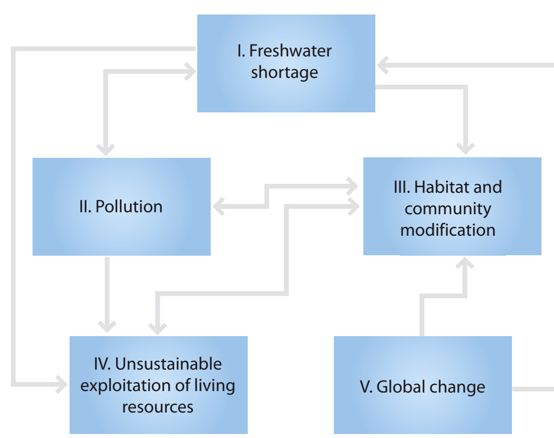

Figure 10 Linkage between the GIWA concerns in the Yellow Sea region.

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

The priority GIWA concerns and issues that have severe environmental impact for the region include:

- Freshwater shortage:
  - Modification of stream flow
  - Pollution of existing supplies.
- Habitat and community modification:
  - Loss of ecosystems
  - Modification of ecosystems.
- Unsustainable exploitation fish and other living resources:
  - Overexploitation
  - Destructive fishing practices.

The environmental and socio-economic impacts of these priority GIWA concerns and issues in the region and the possible causes for these impacts are presented in Table 4.

Table 4 Summary of prioritised environmental and socio-economic issues in the Yellow Sea region.

Concern	Issue/Impact	Score	Impacts	Possible causes
Habitat and community modification	Loss of ecosystems	3	More than 30% of the areas of freshwater marshlands, rice fields and lakes have been lost over the past 30 years.	Losses due to construction of dams, dikes and embankments in areas of the freshwater marshlands, rice fields and rivers; and reclamation sedimentation and lowering of water tables in lakes.
			Severe losses of the areas of muddy shores, salt marshes, sandy beaches, estuaries and lagoons in localised areas.	Muddy shores in northern Jiangsu Province in China as well as salt marshes and sandy beaches lost due to erosion, mining, reclamation and road construction; severe shrinking in the areas of estuaries of Yalujiang River between North Korea and China due to diking; loss of lagoons due to reclamation and port development (e.g. Lianyungang Port, China).
			Significant losses of seagrass beds (e.g., *Zostera marina*) in the South Korea side of the Yellow Sea.	Losses due to pollution and eutrophication.
	Modification of ecosystems	3	The neritic system in terms of its ecosystem services, size and composition of species, food web, species mortality and predator-prey relationships have been seriously modified.	Modifications and changes in the neritic systems include: ecosystem services changed; number of commercial species significantly reduced; size of fish caught decreased; predator-prey relationship altered; food web changed; high natural mortality of anchovy eggs occurred (reasons for intensive studies).
			Volume and biodiversity of lakes and rivers changed significantly.	Changes in species composition due to contamination, eutrophication, aquaculture practice and overexploitation of resource occurred in lakes of China. Disappearance of indigenous species and reduced biodiversity has occurred in rivers of South Korea and China.
			Muddy shores greatly modified with increased opportunistic organisms.	Muddy shore habitats modified due to reclamation, aquaculture practice and overexploitation leading to occurrence of increased opportunistic organisms.
			Species population structure in estuaries significantly modified with increased dominance of HAB organisms.	Modification of estuary habitats (e.g. in South Korea) is evidenced by the dominance of red tide organisms (dinoflagellates) in the plankton biomass, and due to damming or diking, reduced stream flow and upstream activities.
	Socio-economic impacts	3-1-2[1]	Aesthetic and recreational values of the habitats greatly reduced.	Modifications of habitats have changed the goods and services the habitats can provide.
			Cost of controlling alien species and restoring ecosystems substantially increased.	The increase is due to restoring the damaged habitats.
			Employment opportunities particularly for the fisheries sector substantially reduced.	Modifications or loss of habitats indirectly influence the fisheries production, which, in turn, changes the employment opportunities for fishermen.
Unsustainable exploitation of living resources	Overexploitation	3	Fish stocks severely overexploited.	More than one stock of fish is exploited beyond MSY (e.g. Yellow croakers).
	Destructive fishing practices	3	Frequent practices of illegal fishing techniques and bottom trawls seriously destroyed the aquatic habitats.	Practicing of illegal fishing techniques and bottom trawls which can easily destroy the bottom habitats is common.
	Socio-economic impacts	2-1-3[1]	Transboundary implications in competition for common fishing grounds between Korea, China and Japan are evident.	Conflicts in use or encroachments on fishing grounds by fishermen of these countries frequently reported.
			Employment opportunities in fisheries sector substantially decreased.	Overexploitation leads to reduced CPUE, lower catches, which affect employment opportunities in the fisheries sector.
			Livelihood of local communities significantly changed.	The change is due to loss of commercially valuable fish species and destruction of habitats.
Freshwater shortage	Modification of stream flow	3	Water flow in major rivers significantly reduced.	More than 20% reduction of stream flow in the major rivers of China over the past 30 years (e.g. Huai River). There is measurable reduction in water flow mainly due to damming in Korea (e.g. upstream damming in Han River and estuarine river damming in Keum and Yongan rivers).
	Pollution of existing supplies	3	Fish kills due to pollution in rivers are evident.	Fish kills due to pollution in many drainage basins >25 000 km^2 were often reported in China (e.g., Huai River, which is the most serious). Fish kills frequently occurred in Korean rivers during summer.
	Socio-economic impacts	2-1-1[1]	Serious freshwater shortage problem is evident on the Chinese side of the Yellow Sea involving spending 6-7 billion USD annually for mitigation.	In China, high cost (billions of USD) projects needed to divert water supply from the water-rich south to northern semi-arid areas (including the Yellow Sea area) for mitigating freshwater shortage. Hydroelectric power production affected (e.g. Weihai power plant in China stopped production due to insufficient supply of water in summer).
			Conflicts among local governments for use of water, migration of people from water shortage areas and effects on human health are evident.	Conflicts among local governments for water and migration of people as a result of water shortages frequently reported.

Note: [1] Indicates overall scores for Social-Economic-Health, respectively.

Causal chain analysis

YELLOW SEA

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

Based on the results of the assessment for the region, the GIWA issues assessed to have the severe environmental impacts have been selected for the following analysis. They are as follows:

- Modification of stream flow;
- Pollution of existing supplies;
- Loss of ecosystems or ecotones;
- Modification of ecosystems or ecotones;
- Overexploitation;
- Destructive fishing practices.

These issues are analysed in two causal chain analyses; the first one targeting habitat and community modification as well as freshwater shortage problems in the region, and the second targeting overexploitation and destructive fishing practices.

Habitat and community modification and freshwater shortage

The impacts arising from the issue of modification of stream flow are serious as demonstrated by the measurable and significant reduction of water flow in the major river systems on both the Chinese and Korean sides of the region. The impacts resulting from the issue of pollution of existing supplies include the significant deterioration of habitats along rivers in China and incidences of fish kills in the river systems of the region.

There has been significant losses of habitat in the region in the past 30 years, with losses covering a wide range of habitats including freshwater marshlands, lakes, rivers, lagoons, muddy foreshores, rice fields, sandy foreshores and seagrass (*Zostera marina*) beds. Also, many habitats e.g. neritic systems, lakes, rivers, muddy shores and estuaries in the region have been significantly modified as evidenced by their obvious changes in biodiversity, ecological functions, species population structure and complete or partial replacement of endemic with alien species (e.g., the exotic salt hay, *Spartina marina*) observed over the past decades.

Figure 11 illustrates the causal links for habitat and community modification and freshwater shortage in the Yellow Sea region.

Environmental impacts

Major impacts of freshwater shortage and habitat and community modification in the region are for example (for more information and references see Assessment):

- The major Chinese river basins such as Huai and Yalu rivers have shown more than 20% reduction in stream flow over the past

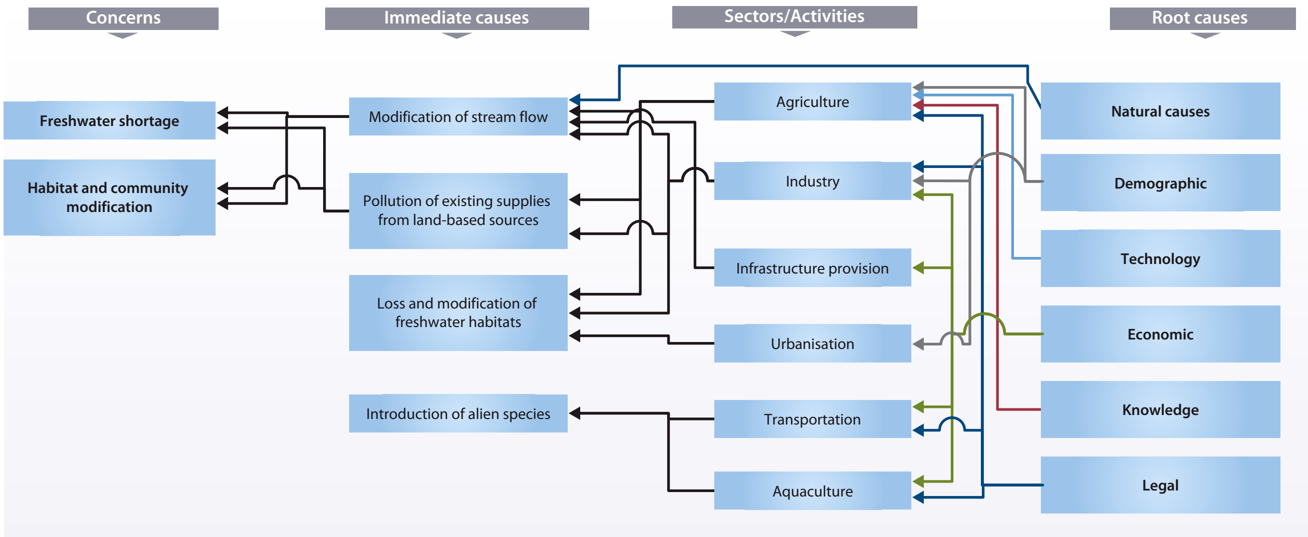

Figure 11 Causal chain diagram illustrating the causal links for habitat and community modification and freshwater shortage in the Yellow Sea region.

30 years. There has also been a measurable reduction in water flow in the major rivers on the Korean side of the region.

- More than 10% of the Huai River Basin on the Chinese side of the region has been polluted, causing habitat deterioration and an inability to support fish.
- Fish kills in many drainage basins of more than 25 000 km^2 have often been reported on the Chinese side of the region, e.g. Huai River, which is the most affected. Fish kills frequently also occur in rivers on the Korean side of the region during summer.
- More than 30% of the total area of freshwater marshlands, lakes, rivers, lagoons and muddy foreshores and 10% of rice fields have been lost over the past 30 years.
- More than 40% of the total area of sandy foreshores have been lost over the past 30 years.
- Significant losses of seagrass beds, e.g. *Zostera marina* has occurred in the Korean side of the region.
- Biodiversity and ecological functions of the neritic systems have been seriously modified.
- Volume and biodiversity of lakes and rivers have changed significantly.
- Muddy shores have been greatly modified with increased number and species of opportunistic organisms.
- Species population structure in estuaries has been greatly modified with increased dominance of red tide organisms.
- There has been obvious replacement of endemic with alien species such as the salt hay (*Spartina marina*) and biodiversity modification through disease introduction, for example disease caused by *Perkinsus* sp. in clams.

Immediate causes

Modification of stream flow

The changes of stream flow are mainly caused by increased diversion of water for irrigation, industrial and domestic uses as well as upstream damming and draining for flood control and increased agricultural activities. Main river basins or systems that contribute to the sources of freshwater supplies in the region include those associated with the Huai River (Huaihe), Yalu River (Yalujiang), Han River, Kum River and Yongsan River. Among them, the Yalu River Basin is the largest, and separates China from North Korea (WRI 1998a). The uneven distribution of water reserves in China has created severe shortages, even though the Yangtze and Yellow rivers together posses huge water reserves. For example the areas north of the Yangtze River, particularly the northwest region and the North China Plain, which account for 60% of China's land mass and half of the country's population, receive only 20% of the nation's water resources. The situation of freshwater shortage in northern China is further aggravated by serious soil erosion, deforestation, land conversion, excessive water usage for agricultural production and conversion of wetlands along lake shores into rice fields (SEPA 2003a,b).

Pollution of existing supplies from land-based sources

The region suffer from pollution through waste discharges high in nutrients, trace metals and organics from land-based point and non-point sources that alters the overall biodiversity of the ecosystems. More than 10% of the Chinese part of the Huai River Basin is polluted, mainly by discharges from various chemical and paper pulp factories located along the River. The number of factories in the Huai River Basin has increased from 365 in 1996 to 1 320 in 2002 (Wang et al 2003). Along the west coast of the Korean Peninsula, mass fish kills involving the death of thousands of fish each time have occurred in river basins more than twice each summer due to oxygen depletion, mainly as a result of industrial discharges and agricultural run-off (US-AEP 2003, MOE 2003).

Modification and loss of freshwater habitats

The main threat to the coastal habitats of the region is intensive coastal development and land reclamation, especially in estuaries and shallow bays. During the past decades, many sites have been reclaimed, resulting in the loss of approximately 25% of the total tidal flats in the region (Simard 1995). The waste materials and pollutants from industrial complexes, coastal cities, and tourism and recreational activities also degrade coastal habitats. Changes in freshwater inputs and discharges through increased diversion of stream waters for irrigation and building of tidal embankments that change stream flow rates, has also lead to losses of freshwater habitats. For example more than 30% of the mud bottom habitat in the region has been lost over the past 30 years due to increased mariculture activities, opening up of salt-pans, and increased agricultural activities, as well as land reclamation. Some damage also occurred to the estuaries at the mouth of Huai River (Li 2003). There is also evidence of heavy erosion of sandy foreshores on the Chinese side of the region. The erosion is mainly due to sand mining of the beaches, road construction, and recreational activities along the coastal plains (SEPA 2001). There has also been losses of sandy foreshores due to road construction on the Korean side of the Yellow Sea, however the extent of loss is not known (GEF 2001).

Introduction of alien species

The introduction of alien species and diseases have modified the population structures and has replaced endemic species. There has been a decrease in genetic diversity and species composition in clams and oysters in the region, mainly due to aquaculture and releases of hatchery-produced larvae, however this has not depleted the resources (NEPA 1994). A measurable decline of native populations due to the introduction of alien species has occurred in Korean reservoirs (Choi pers. comm.). Genetic differences in prawns as a result of the mass release of prawn larvae from aquaculture prawns have been observed in both Korean and Chinese waters (NEPA 1994). Pollution and diseases have caused decreases in production and species composition of bivalves, clams and cockles but not to the extent that they could cause resource depletion (Yuxiang pers. comm.).

Sectors

Agriculture

The agricultural sector is responsible of both changes in stream flow, pollution of existing supplies and modification of ecosystems. The increased farming and expansion of farmed areas have led to increased demands and uses of waters for irrigation. There has also been an excessive use of fertilisers and pesticides, which have polluted the nearby water basins and lead to a degradation of freshwater habitats. The increased or uncontrolled use of fertilisers and pesticides has resulted in agricultural run-off high in nutrients and organics, causing habitat modification in the region. The increased building of tidal embankments to protect crops and increased farming and expansion of farming areas has lead to changes in freshwater inputs and discharges, which has modified freshwater habitats in the region.

Industry

The increased industrial development in the region has led to increased reclamation of coastal land areas to be used for the establishment of factories or other industrial installations. This reclamation has destroyed a number of coastal habitats for example costal wetlands. Changes in the types of industries and increased human settlements following industrial development has increased the demand of freshwater in the region. Increased discharges of solid wastes and untreated and/or partially treated wastewater high in trace metals and other harmful pollutants from factories and other industrial installations have modified habitats in the region.

Infrastructure provision

The building of dams and dikes upstream in the river system for flood control has lead to changes in stream flow.

Urbanisation

Rapid urbanisation following the increased economic growth in the region has led to increased reclamation of more lands for human settlements, which has destroyed many of the natural habitats.

Transportation

Increase in shipping traffic in the region has raised the risk of introducing alien species in ballast water and/or by attachment to ship hulls, which can lead to changes in the endemic species population structure in several habitats of the region.

Aquaculture

Both the introduction of alien species for culture and the outbreak of diseases have been found to alter species composition in habitats near aquaculture facilities in the region.

Root causes

Demographic

Increased industrialisation in the region has been found to attract mass migration of the rural population to urban areas where more job opportunities exist. Population growth, particularly on the Chinese side of the region, is relatively rapid. This growth has resulted in the need to convert more lands for human settlements. At the same time, the increased population growth also increased the demand for food and agricultural products, resulting in the increased use of stream water for crop production as well as an increasing demand of fertilisers and pesticides.

Technology

Poor systems for crop irrigation are a relatively common in the region's agricultural sector. This has led to inefficient use, often loss, of the stream waters diverted from adjacent river systems.

Economic

Relatively fast economic growth has changed the economic structure in the region, which has led to an increase in industrial activities resulting in increased water demand. The increased human settlements in the region has resulted in not only elevated consumption of water resources but also the increased requirements for flood preventions. The increased economic growth has led to rapid industrial development that increases the needs to reclaim more coastal land areas for establishment of industrial centres; this reclamation has destroyed several coastal habitats, such as the coastal wetlands. The rapid industrial development has also increased discharges of harmful pollutants by industries, negatively affecting the nearby water habitats. Many industries in the region will require greater investment in the pollution prevention and wastewater treatment facilities to reduce the discharge of pollution wastes. The increased trade and energy demand has led to an increase in transportation in the region, resulting in an increased risk of introducing invasive species. The improved the standard of living so that the market demand for cultured fish has increased, leading to increased aquaculture development.

Knowledge

The excessive use of fertilisers and pesticides by farmers could be due to: (i) little access for farmers to technical and scientific information related to the efficient use of fertilisers and pesticides for crop production; and (ii) low education levels common to farmers, which in turn make it difficult for them to access useful information. Awareness of the environmental impacts of overuse of fertilisers is still lacking in the region. This can lead to indiscriminate use of fertilisers and pesticides by farmers, thus increasing agricultural run-off high in nutrients and other harmful pollutants. Profit-oriented farmers often disregard environmental impacts, which results in an excessive use of fertilisers and pesticides to enhance crop production.

Figure 12 The Yellow Sea.
(Photo: NASA)

Legal

The insufficient enforcement of regulations and laws has resulted in lack of control of waste discharge by industries in the region as well as use of fertilisers and crop farming practices. More efforts are needed to strengthen enforcementThere is also insufficient regulation and enforcement mechanisms to control the introduction of alien species, both via maritime traffic and aquaculture.

Natural causes

Typhoons, causing storms and floods, occur frequently in the region. Increased deforestation has further aggravated flood problems brought about by typhoons and El Niño. As a result, more flood-mitigation infrastructure, such as the building of dams and dikes, has been developed for protection of human life and property.

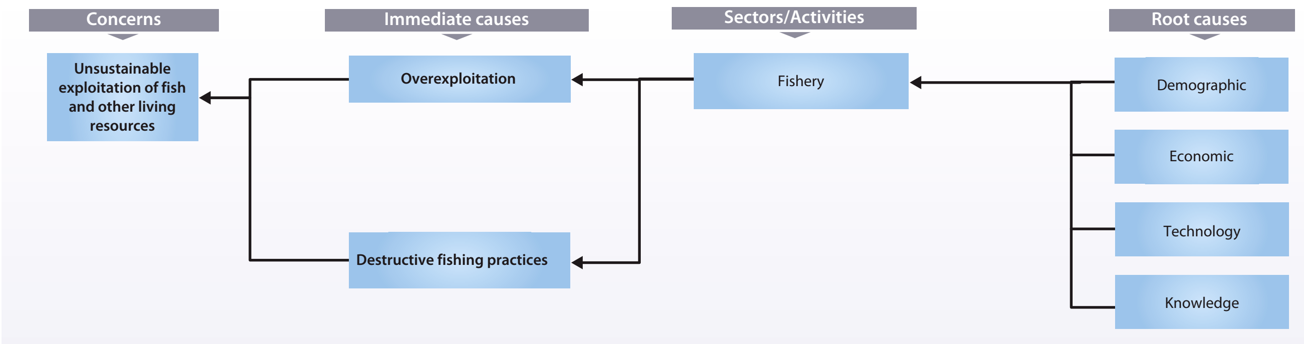

Figure 13 Causal chain diagram illustrating the causal links for unsustainable exploitation of living resources in the Yellow Sea region.

Unsustainable exploitation of fish and other living resources

The Yellow Sea region is one of the most intensively exploited areas in the world; many stocks were intensively exploited by Chinese, Korean, and Japanese fishermen following the introduction of bottom trawlers in the early 20th century (Tang 2003). The increase in fishing effort and its expansion has resulted in almost all major stocks being fully fished by the mid-1970s and overfished by the 1980s (Zhang & Kim 1999, Tang 2003). Catches of the major economic species such as prawns (*Metapenaeus joyneri*, *Parapenaeopsis tenellus*), Small yellow croaker (*Pseudosciaena polyactis*), and Hairtails (*Trichiurus brevis*), exceeding their MSY (maximum sustainable yield) levels has occurred in all coastal seas along the Chinese and Korean coasts of the region (GEF/UNDP 2000).

Common destructive fishing practices in the region include indiscriminate trawling along the coastal waters of Yellow Sea, fishing with explosives in lakes, and use of pesticides for fishing (Jin 2003, MOE 2003). As a result of these destructive fishing practices, aquatic habitats have been destroyed, leading to the collapse of fish populations and loss of biodiversity. The long-term implications for the protection of the environment and resource conservation after such destructive fishing practices are obvious.

Figure 13 illustrates the causal links for unsustainable exploitation of living resources in the Yellow Sea region.

Environmental and socio-economic impacts

Overexploitation and destructive fishing practices have led to the following environmental and socio-economic impacts (for more information and references see Assessment):

- Fisheries resources have been highly overexploited, exceeding their maximum sustainable yields (MSYs);
- Destruction of aquatic habitats and excessive catch of recruitment stocks have led to depletion of fish populations;
- Employment rates have decreased by 30-50% due to overfishing and environmental degradation with substantial impact on the local population;
- Business opportunities in the seafood processing industries have decreased by around 10% due to decreased catch per unit effort (CPUE) experienced by fishing fleets.

Immediate causes

Overexploitation

There has been an introduction of new, improved and more efficient fishing technologies in the region. The increase in fishing effort and it's the increasing number of fishing fleets have resulted in overexploitation of living resources, with almost all major stocks being fully fished by the mid-1970s and overfished by the 1980s (Zhang & Kim 1999, Tang 2003).

Destructive fishing practices

Destructive fishing practices is common in the region and include bottom trawling along the coastal waters of the Sea, use of pesticides for fishing and fishing with dynamite in lakes. These fishing practices are characterised by a low input of capital and high yields.

Root causes

Demographic

The increase in population growth has resulted in an increased demand for food, including seafood, which in turn promote increased fishing.

Economic

Profit motive in fishing, disregarding environmental consequences, has led to the uncontrolled entry of fishing vessels, resulting in overexploitation of the marine resources. There has also been an increased market demand for seafood in the region, which has led

Table 5 Summary of the causal chain analysis for the Yellow Sea region.

GIWA Concern	Immediate causes	Sectors	Root causes
Freshwater shortage	Modification of stream flow: Changes in stream water inputs due to increased diversion of stream waters for irrigation, industrial and domestic uses; and upstream damming/diking for flood control and for meeting the water requirements by the increased agricultural activities.	Agriculture: Increased crop farming activities and expansion in the farming areas.	Demographic: Increased population growth. Technology: Poor crop irrigation systems.
		Industry: Changes in the types of industries and increased human settlements following the industrial development.	Economic: Changes in economic structures. Economic: Increase in economic growth.
		Infrastructure provision: Building of dams and dikes upstream of the river systems for flood control.	Natural causes: Increased deforestation and incidence of natural disasters (e.g. typhoons and El Nino). Economic: Increase in economic growth.
	Pollution of existing supplies from land-based sources: Increased inputs of pollutants from land-based point and non-point source	Agriculture: Excessive use of fertilisers and pesticides by farmers.	Knowledge: Inadequate access to technical and scientific information. Knomledge: Lack of awareness on environmental impacts due to excessive use of fertilisers and pesticides.
		Industry: Increased discharge of treated and/or partially treated industrial wastewaters due to rapid industrial development.	Economic: Insufficient investment in facilities for pollution prevention and wastewater treatment. Legal: Insufficient enforcement of regulations and laws.
Habitat and community modification	Loss and modification of ecosystem: Reclamation of coastal land for industrial development and urbanisation leading to destruction of coastal habitats. Changes in freshwater inputs/discharges through increased diversion of stream waters for irrigation and building of tidal embankments that changed the stream flow rates, leading to loss of freshwater habitats such as the freshwater marshlands. Pollution through waste discharges high in nutrients, trace metals and organics from land-based point and non-point sources which alters the overall biodiversity of the ecosystems.	Industry: Increased industrial development leading to increased reclamation of coastal land areas to be used for establishment of factories or other industrial installations.	Economic: Increased economic growth. Demographic: Increased population growth. Legal: Lack of or insufficient regulations, policy or enforcement mechanism.
		Urbanisation: Rapid urbanisation following the increased economic growth leading to increased reclamation of more lands (with natural habitats) for human settlements.	Demographic: Mass population migration to urban areas. Demographic: Increased population growth.
		Agriculture: Activities include: (i) increased building of tidal embankments to protect crop production; (ii) increased or uncontrolled uses of fertilisers and pesticides by crop farms; and (iii) increased crop farming activities and expansion of farming areas, leading to increasing use of stream water for irrigation.	Demographic:Increased population growth Knowledge: Profit-oriented with disregard to environmental impacts attitudes of farmers.
	Introduction of alien species: Introduction of invasive species and diseases which modifies the species population structure and replacement of endemic with alien species.	Transportation: Increase in shipping traffic had raised the chances of introducing invasive species through ballast water and/or attachment to ship hulls.	Economic: Increased trade and energy demand. Legal: Lack of or insufficient regulations, policy or enforcement mechanism.
		Aquaculture: Both introduction of alien species for culture and outbreak of diseases have been found to alter the species population structure in habitats in the premises of aquaculture facilities.	Economic: Increased economic growth. Legal: Lack of or insufficient regulations, policy or enforcement mechanism.
Unsustainable exploitation of living resources	Overexploitation: Improved efficiency of fishing practices by introduction of improved fishing technology. Increased fishing efforts leading to overexploitation of living resources.	Fishery: Activities include the easy access to improved fishing technologies in the fisheries sector encouraging more efficient fishing practices, and increased number of fishing fleets entering the fishing industry leading to increased fishing efforts.	Deographic: Increased population growth. Technology: Profit motive in disregard of the environmental consequences. Economic: Increased market demands for seafood.
	Destructive fishing practices: Low capital input and high yield characteristics of the destructive fishing practices (e.g., bottom trawling and dynamite fishing) leading to frequent practices of such fishing gear.	Fishery: Activities include the technology and supplies related to the destructive fishing practices are readily available and of easy access to fishermen.	Knowledge: Lack of public awareness on the consequences of destructive fishing practices. Economic: Increased market demand for seafood.

to increased fishing activities, including the use of destructive fishing practices, without regard for the consequences related to the depletion of marine resources.

Technology

The easy access to improved fishing technologies has encourage efficient and destructive fishing practices, and has also increased the number of fishing fleets in the region.

Knowledge

The lack of public awareness of the consequences of destructive fishing practices has led to uncontrolled use of such destructive fishing techniques.

Conclusions

Table 5 summarise the immediate causes, sectors and root causes in for freshwater shortage, habitat and community modification as well as unsustainable exploitaion of living resources in the Yellow Sea region.

Policy options

YELLOW SEA

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

Definition of the problem

The assessment and Causal chain analysis have shown that the priority environmental concerns in the Yellow Sea region are freshwater shortage, habitat and community modification, and unsustainable exploitation of living resources. The region has experienced both significant reduction of water flow in the major river systems on both the Chinese and Korean side, as well as pollution of existing water resources, mainly from agriculture and industrial activities. There have been significant losses and modification of habitats in the region during the past 30 years. Increased industrialisation has attracted mass migration of the rural population to urban areas. This rapid population growth has resulted in the need to convert more lands for human settlement as well as an increase of discharge of harmful pollutants to the water bodies. At the same time, the population growth has increased the demand for food and agricultural products, resulting in the increased use of freshwater for crop production.

The Yellow Sea has been overexploitated since the 1980s. Fishing with destructive methods is common throughout the region and many aquatic habitats in have been destroyed and fish stocks have collapsed. Common destructive fishing practices in the region include indiscriminate trawling along the coastal waters of Yellow Sea, fishing with explosives in lakes, and use of pesticides for fishing.

The transboundary issues that need to be addressed are the management of marine resources, industrial pollution, and ecosystem health. Progress is being made in the introduction of ecosystem-based management for the LME (Zhang & Kim 1999). The GEF is supporting a Yellow Sea LME project involving China and South Korea. The long-term objective of the project is to ensure environmentally sustainable management and use of the Yellow Sea LME and its watershed by reducing development stress and promoting sustainable development of the ecosystem (Yellow Sea Project Brief 2000). In order to achieve its objective this project will prepare a Transboundary Diagnostic Analysis (TDA), National Yellow Sea Action Plans (NYSAPs), and a regional Strategic Action Programme (SAP). The project will also initiate and facilitate the implementation of the SAP. It will also build upon the institutional and programmatic framework put in place by the Northwest Pacific Action Plan (NOWPAP), the Tumen River Area Development Programme (TRADP). Management of the transboundary environmental issues in the region may be hindered by the following problems:

- Ineffective measures for the control of the overexploitation of coastal and marine fisheries, particularly the shared stocks in the Yellow Sea;
- Lack of strong political will on the part of riparian states bordering the Yellow Sea to arrest the continued degradation and destruction of coastal and marine habitats;
- Ineffective existing national and international efforts to prevent continued or imminent loss of endangered and threatened species;

- Ineffective existing national and international efforts to arrest degradation of coastal water quality due to discharge of pollutants from land- and sea-based activities;
- Inadequate and/or inefficient enforcement and compliance of national and international legal instruments/conventions such as the United Nations Framework Convention on Climate Change, Convention on Biodiversity, Global Programme of Action (GPA);
- Lack of effective regional cooperation to address and resolve transboundary environmental issues.

Policy options and strategic action programmes

Suggested policy options and their associated strategic action programmes to address the key root causes as identified in the previous section were formulated and reviewed by a panel of experts previously involved in the GIWA scaling/scoping as well as causal chain analysis workshops. The policy options and strategic action programmes for each of the key root causes in each of the environmental problem areas of the region are described in the following:

Freshwater shortage

Technology: Poor crop irrigation systems

Options:

- Integration of the development and management of agricultural irrigation systems with integrated river basin management programmes.
- Adoption and promotion of water-saving technologies for crop irrigation.

Strategic Action Programme (SAP):

- Implementation of relevant irrigation system(s) within the framework of integrated river basin management programmes for crop production.
- Selection and introduction of modern and water-saving irrigation technologies for crop production.

Natural causes: Increased deforestation and incidence of natural disasters

Options:

- Adoption of the Natural Forest Protection Programme (NFPP) to cope with uncontrolled deforestation.
- Adoption of integrated forest management practices.
- Adoption of efficient law enforcement mechanisms to prevent illegal logging and other destructive practices.
- Adoption of programmes for raising public awareness and participation in forest management and restoration.

Strategic Action Programme (SAP):

- Development, harmonisation and enforcement of a legislative framework for the implementation of the Natural Forest Protection Programme (NFPP).
- Implementation of integrated forest management practices for sustainable management of forest resources.
- Implementation of integrated land management and integrated coastal management programmes to cope with the occurrence of natural disasters.
- Development of relevant measures and practices to encourage public participation in the planning and implementation of development activities associated with forest management and restoration programmes.

Economic: Insufficient investment in facilities for pollution prevention and wastewater treatment

Options:

- Promotion of market incentive systems to encourage the use of green production technologies in the industry sector.
- Enhancement of laws and enforcement mechanisms related to pollution prevention and wastewater treatment practices.

Strategic Action Programme (SAP):

- Formulation and implementation of public awareness campaign programmes for good practices in agriculture.
- Development and implementation of market incentive programmes to encourage the use of green production technologies and to reduce discharge of polluting wastes.

Knowledge: Lack of awareness of environmental impacts due to excessive use of fertilisers and pesticides

Options:

- Adoption of laws, regulations and enforcement mechanisms to control the use and disposal of fertilisers and pesticides.
- Adoption of educational and public awareness campaign programmes for good agricultural practices.
- Adoption of sustainable soil management system(s) to improve the soil fertility and productivity.
- Adoption of efficient soil fertility improvement technology and crop irrigation systems to improve soil productivity.

Figure 14 Ricefield at dawn in Jiangsu Province, China.
(Photo: Corbis)

Strategic Action Programme (SAP):

- Development, harmonisation and enforcement of a legal framework to control the use and disposal of fertilisers and pesticides.
- Development and implementation of public education and awareness campaign programmes on good practices in agriculture.
- Analysis and selection of relevant sustainable soil management system(s) as well as development and implementation of the system(s) for improvement of soil fertility and productivity.
- Development and implementation of suitable soil fertility and irrigation improvement technologies to enhance soil productivity.

Habitat and community modification

Demographic: Mass population migration to urban areas

Options:

- Adoption of laws, regulations and enforcement mechanisms to restrict the population migration.
- Adoption of the development of small, rural-oriented urban centres in rural areas to cope with population migration.

Strategic Action Programme (SAP):

- Development and enforcement of a suitable legal framework to restrict mass migration of population from rural to urban areas.
- Development and implementation of small, rural-oriented urban centres in rural areas to cope with population migration.

Legal: Lack of or insufficient regulations, policy or enforcement mechanism

Options:

- Adoption of laws, regulations and enforcement mechanisms to promote good practices in agriculture including minimisation of the discharge of agricultural run-off high in harmful pollutants.
- Adoption of laws, regulations and enforcement mechanisms to restrict the introduction of alien and invasive species for aquaculture.
- Adoption of programmes related to raising public awareness of and participation in good practices in agriculture and recogniszing the environmental impact of introducing exotic and invasive species for aquaculture.

Strategic Action Programme (SAP):

- Development and enforcement of suitable laws and regulations to promote good practices in agriculture and to restrict the introduction of alien and invasive species for aquaculture.
- Creation and implementation of public awareness campaign and education programmes on good practices in agriculture and on recognising the environmental impact of introducing exotic and invasive species for aquaculture.

Knowledge: Profit-oriented farmers who disregard environmental impacts

Options:

- Adoption of programmes to raise public awareness of and participation in good practices in using fertilisers and pesticides.
- Adoption of sustainable agriculture production technologies that would minimise the use of fertilisers and pesticides.

Strategic Action Programme (SAP):

- Creation and implementation of public awareness campaign and education programmes for the effective use of fertilisers and pesticides.
- Selection and implementation of sustainable agriculture production technologies that could minimise the use of fertilisers and pesticides.

Unsustainable exploitation of living resources

Knowledge: Profit-oriented enterprises that disregard environmental consequences

Options:

- Enhancement of laws, regulations and enforcement mechanisms to restrict the entry of excessive fishing fleets and fishermen into the fishing industry.
- Adoption of alternative livelihood programmes for fishermen and other fisheries operators.
- Adoption of public awareness and education programmes on the environmental and social consequences of overexploitation of the fish resource.

Strategic Action Programme (SAP):

- Development of relevant policy and legal framework to restrict the practice of destructive fishing methods.
- Development and implementation of alternative livelihood programmes to reduce the entry of excessive number of fishermen into the fishing industry.
- Development and implementation of public awareness and education programmes on the environmental and social consequences of overexploitation of the fisheries resource.

Economic: Increased market demand for seafood

Options:

- Adoption of sustainable production practices to enhance fisheries and aquaculture production.

Strategic Action Programme (SAP):

- Development and promotion of sustainable fisheries and aquaculture production methods to enhance fisheries production to meet market demand for seafood.

Knowledge: Lack of public awareness of the consequences of destructive fishing practices

Options:

- Enhancement of law enforcement mechanisms to restrict destructive fishing practices.
- Adoption of public awareness campaigns and education programmes on the environmental and social consequences of destructive fishing practices.

Strategic Action Programme (SAP):

- Development and implementation of policy and law enforcement mechanisms to restrict destructive fishing practices.
- Development and implementation of public awareness and education programmes on the environmental and social consequences of destructive fishing practices.

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Regional definition

BOHAI SEA

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

Boundaries of the region

The GIWA region Bohai Sea is located in China and is bordered by the Yellow Sea (GIWA region 34) in the south, the Sea of Japan (GIWA region 33) to the east and the Sea of Okhotsk (GIWA region 30) to the north. The Bohai Sea is not a transboundary water by GIWA definitions and the report is therefore published as an appendix to the Yellow Sea regional assessment. Figure 1 shows the boundary of GIWA region Bohai Sea. The region includes the following sea, river basins, watersheds and their associated coastal and marine habitats:

- Bohai Sea, which consists of three bays: Liaodong Bay to the north, Bohai Bay to the west and Laizhou Bay to the south;
- Liaohe River Basin, coastal river basins in the Liaodong Peninsula, the Shuangtaizihe River Basin and their associated coastal and marine habitats in Liaodong Bay, north of the Bohai Sea;
- Hai River (Haihe) and Luan River (Luanhe) and their associated marine habitats in Bohai Bay west of the Bohai Sea;
- Yellow River (Huanghe) Basin, coastal river basins in the Shandong Peninsula and their associated coastal and marine habitats in Laizhou Bay, to the south of Bohai Sea.

Figure 1 Boundaries of the Bohai Sea region.

The Bohai Sea proper covers an area of 823 000 km^2, but the river basins that drain into it account for 1.6 million km^2, comprising about 15% the total land area of China, which is home to around 343.5 million people, amounting to 35% of the nation's total population (Wikipedia 2003). The region is part of the Bohai Bay Area , which covers the Bohai and Yellow seas and its adjacent provinces and municipalities, namely, the Liaoning, Hebei and Shandong provinces, and the cities of Beijing and Tienjin. The Bohai Bay Area is known as one of the major centres of economic development in China, and it experiences the downstream impacts of the region's freshwater systems and covers an area of more than 36 000 km^2. In 1999, the area accounted for some 22% of the nation's GDP. It functions as an important maritime outlet for the country's landlocked great west and northeast provinces. It is also a Euro-Asian transportation link. The "National Economic and Social Development Programme" for the next five years, as recently adopted by the National People's Congress, accords high priority to the Bohai Sea Environmental Improvement and Management Project.

Physical characteristics

The Bohai Sea

The Bohai Sea is a large internal sea of China. It is the innermost gulf of the Yellow Sea in northeastern China and covers an area of approximately 823 000 km^2 bordering the Liaoning Peninsula to the east and the Shandong Peninsula to the south. The Bohai Sea consists of three bays: Laizhou Bay to the south; Laiodong Bay to the north; and Bohai Bay to the west. Three large rivers, the Yellow River, the Liao River and the Hai River drain into the Bohai Sea. The provinces and municipalities bordering the Bohai Sea include: Shandong, Laioning and Hebei provinces and Tianjin Municipality. The major port cities surrounding the rim of Bohai Sea are: Dalian, Yingkou, Jinzhou, Qinhuangdao, Tanggu, Longkou and Yantai. In the past two to three decades, petroleum oil and natural gas deposits have been found in and around the Bohai Sea and are being exploited (Wikipedia 2003). The Bohai Sea is an ecologically important and stressed body of water. Its marine resources are important to China, Japan, and North and South Korea.

Fishery resources

The Bohai Sea is known as a "natural fishing ground" and harbours over 1 540 species, including 29 species of prokaryotes, 653 species of protists, 57 species of fungi, 96 species of plants and 705 species of animals. Apart from such sea treasures as prawn, sea cucumber and abalone, the Bohai Sea has over 100 species of major fishes among which the Small yellow croaker (*Pseudosciaena polyactis*) and the Hairtail (*Trichiurus haumela*) are the fish species with the largest fish production in the Bohai Sea and also among the four major fish products in China's seas. Other species like Mullet (*Mugil so-iyu*), catfish (*Silurus* sp.), Spanish mackerel (*Scomberomorus japonicus*), Left-eyed flounder (*Tanakius kitaharae*), Genuine porgy (*Pagrosomus major*), Prawn (*Penaeus orientalis*) and Jellyfish (*Rhopilema esculenta)* are also distributed in the waters of the Bohai Sea. There are a number of fishing grounds in the Bohai Sea, including Wanghuazai, Juhuadao and Daqinghe estuarine fishing grounds in the north, Longkou and Yellow River estuarine fishing grounds in the south, and Hai River estuarine fishing ground in the west (Tang and Jin 1999, Jin 2003).

With a wide expanse of tidal flats and shallow waters, the littoral area of the Bohai Sea provides favourable environmental conditions for the industry of mariculture and stock enhancement, and the major cultured varieties are kelp (*Laminaria* spp.), shellfish and prawn, sea cucumber (*Holothuria* spp.) and abalone (*Haliotis* spp.). In 1999, the Bohai Sea area had a mariculture area of 394 450 ha with a total yield of 1.96 million tonnes (PEMSEA 2004).

The Bohai Sea is also one of the most intensively exploited areas in the world (Wigan 1998). According to the China Oceanic Information Centre (Jin 2003), the output of fisheries and mariculture reported by the surrounding provinces and cities of the region has increased in recent years. The catch from Bohai Sea reached about 1.6 million tonnes, and mariculture production was just over one tonnes in 1999. At the same time, the ecosystem in the Bohai Sea has degraded because of overfishing and the adverse impacts of mariculture, in addition to pollution from other industries and city sewage.

River basins

Liao and Luan rivers

The Liao River Basin spans the provinces of Jilin and Liaoning, has a population of around 42 million, and is rich in natural resources, particularly oil and gas. The water resources in the Liao River Basin have been badly depleted and polluted by heavy industries (MOWR 2001). The Liao and Luan river basins drains the southern part of the Liao and Sungari plains of central Northeast China, in Liaoning Province and Inner Mongolia. The river system is about 1 345 km long with a drainage area of 230 000 km^2 and has an annual run-off of 14.8 billion m^3. The Liao and Luan river basins is very flat, and floods frequently in the summer. It is very heavily polluted from industrial sources, carrying a heavy load of silt. The Liao River Basin is the agricultural and industrial base of the Liaoning Province and is the most polluted river in China, followed by the Hai River. Efforts to control pollution include the closure of many factories with obsolete technology and the construction of wastewater treatment plants.

Hai River (Haihe)

The Hai River Basin is the historical heartland of China, and one of the most important agricultural and industrial regions in the country. Spread over the four provinces of Hebei, Henan, Shandong and Shanxi, and the municipalities of Beijing and Tianjin, the Hai River Basin is home to 117 million people and accounts for 15% of China's GNP. The Hai River Basin is also one of the most water-stressed basins in China and suffers from severe groundwater overdraft. The Hai River Basin covers an area of 264 000 km^2 of which 60% is mountainous and 40% plains, and has a mean annual run-off of 22.8 billion m^3.

The Hai River Basin is a network of the smaller Chao, Yungting, Taching, Tzuya, Zhangwei, Tuhai and Majia rivers, coming together at, or just upstream of, the city of Tianjin before discharging into the Bohai Sea. The River Basin generally has low gradients and extensive dikes have built up above the level of the surrounding land for flood control. Flows in the rivers are variable because of seasonal variations in rainfall, with low rainfall during the dry winters when the rivers often dry up and heavy rainfall during summer when floods always occur. The Hai River Basin itself is inadequate to carry the amount of floodwater discharged, and for centuries, destructive floods occurred annually. Since 1963, the Hai River Basin has been the subject of a comprehensive water-control programme. On the upper reaches of the river and its tributaries, some 1 400 dams have been constructed, several of which are over 1 billion m^3 and are designed as multi-purpose flood control, hydropower, and irrigation storage reservoirs. In the plain itself, the major rivers have been banked, and their channels cleared and channelised using massive mobilisation of local labour. As a result, many of the Hai River's tributaries have been directed into new channels and given separate outlets. The Hai River thus no longer has to carry the entire flow of all these rivers during floods. These works have been integrated with large-scale construction of subsidiary drainage and irrigation works designed to reduce flooding and ameliorate droughts. A huge number of wells have also been sunk to provide supplemental irrigation (MOWR 2001).

Yellow River (Huanghe)

The Yellow River Basin covers an area of 750 000 km^2 with a mean annual run-off of 59.2 billion m^3 and annual sediment transport of 1.6 billion tonnes. The Yellow River is the second largest river in China; 5 460 km long. It begins in the Kunlun Mountains in Qinghai Province and flows east, then northeast, through Gansu Province. It flows between the Ordos and Gobi deserts, and then south through steep valleys of yellow loamy soil (loess) between Shanxi and Shaanxi provinces. Silt picked up here gives the river its distinctive brown colour. It is estimated that the Yellow River picks up 1 billion tonnes of silt annually. The River then runs east through Henan and Shandong provinces, through a flat, heavily populated region. The Chinese have tried to control the Yellow River's flooding for millennia with the use of dikes. This, combined with the settling out of the loess sediment, has raised the level of the river above the surrounding land; in some places as much as 20 m. The Yellow River eventually reaches the Bohai Sea, creating a massive delta with its sediment (MOWR 2001).

The River is well known for its flood disasters, which occur mainly in its lower reaches. There are levees with a total length of about 1 000 km on the main stem and its tributaries. The riverbed of the lower reaches of the Yellow River is suspended 5-10 m over the ground outside of its two levees as a result of millennia of sedimentation. The average flow of the river in its lower course is 56 km^3/year and 17 km^3/year is lost from Mongolia downstream to Zhengzhou, as a result of percolation, evaporation, and diversion for irrigation. Another 10 km^3/year are drawn off across the North China Plain. In the Yellow River Basin more than 50% of China's wheat, cotton, and tobacco are cultivated.

The Chinese have managed to control normal floods in the Yellow River Basin, but they are only buying time. The really fundamental problems of the Yellow River are siltation and its corollary, upstream erosion, especially in the loess belt (Figure 2). The incredible erosion in the loess plateau is a natural phenomenon to some extent, but it has been greatly increased by human activity, especially deforestation, overgrazing, and overcropping. The upstream reservoirs in Shanxi Province are filling at a rate of 80 million m^3 of sediment per year, and are thereby losing not only volume but also the ability to absorb flood crests. The problem is getting worse rather than better. Perhaps 3 000 years ago, loess erosion was 1 billion tonnes per year from the plateau; it was 1.6 billion tonnes in the 1950s and was more than 2.2 billion in the 1970s. However, plans are being developed on conservation measures to reduce loess erosion sufficiently to mitigate the sedimentation problem.

The sediment load of the Yellow River averages 37.6 kg of silt per m^3 (compared with 0.07 for the Amazon and 0.6 for the Mississippi). Overall, the historic sediment load of the Yellow River since 1919 has been about 1.6 billion tonnes of silt per year. About 1.2 billion tonnes per year have been swept out into the Bohai Bay, and perhaps 0.4 billion tonnes have been deposited in the river bed in an average year, raising the bed another 10 cm. In the flood of 1933, 3.7 billion tonnes were deposited, and 0.9 billion tonnes in 1977. Given this background, a figure of only 0.2 billion tonnes deposited in 1986 can be seen either as a successful soil conservation or as the result of a dry year (MOWR 2001).

Figure 2 Yellow River on Quinghai Plateau, China.
(Photo: Corbis)

Climate

The hinterland of the region consists of the north, northeast and northwest regions of China. North China has no mountain ranges to form a protective barrier against the flow of air from Siberia, it thus experiences a cold and dry winter with temperatures that range from 3.9°C in the extreme south to about -10°C north of Beijing and in the higher elevations to the west in January. In July the temperature generally exceeds 26.1°C and, in the North China Plain, approaches 30°C. Almost all the annual rainfall occurs in summer. Annual precipitation totals are less than 760 mm and decrease to the northwest, which has a drier, steppe climate. Year-to-year variability of precipitation in these areas is great; this factor, combined with the possibility of dust storms or hailstorms, makes agriculture precarious. Fog occurs on more than 40 days per year in the east and on more than 80 days along the coast.

The climate of Manchuria is similar to, but colder than, that of north China. January temperatures average -17.8°C over much of the Manchurian Plain, and July temperatures generally exceed 22.2°C. Rainfall, concentrated in summer, averages between about 510 and 760 mm in the east but declines to about 300 mm west of the Greater Khingan Range.

Desert and steppe climates prevail in the Mongolian Borderlands and northwest China. January temperatures average below -10°C everywhere except in the Tarim Basin. July temperatures generally exceed 20°C. Annual rainfall totals less than 250 mm, and most of the area receives less than 100 mm. Because of its high elevation, the Tibetan Plateau has an arctic climate; July temperatures remain below 15°C. The air is clear and dry throughout the year with annual precipitation totals of less than 100 mm everywhere except in the extreme southeast (Anon. 2003).

General land forms

The land resources of the region encompass those in the northwest, north and northeast regions of China. The northwest region consists of two basins; the Dzungarian Basin (Junggar Pendi) in the north and the Tarim Basin in the south, including the lofty Tien Shan (Tian Shan). The Tarim Basin contains the vast sandy Takla Makan (Taklimakan Shamo), the driest desert in Asia. Dune ridges in its interior rise to elevations of about 100 m. The Turfan Depression (Turpan Pendi), the largest area in China with elevations below sea level, commands the southern entrance of a major pass through the Tien Shan. The Dzungarian Basin, although containing areas of sandy and stony desert, is primarily a region of fertile steppe soils and supports irrigated agriculture (Anon. 2003).

The north region lies between the Mongolian Borderlands on the north and the Yangtze River Basin on the south and consists of several distinct topographic units. The Mongolian Borderlands is located in north central China and is a plateau region consisting mainly of sandy, stony, or gravelly deserts that grade eastward into steppe lands with fertile soils. This is a region of flat-to-rolling plains, partitioned by several barren flat-topped mountain ranges. Along its eastern border is the higher, forested Greater Khingan Range (Da Hinggan Ling). The loess plateau to the northwest is formed by the accumulation of fine windblown silt (loess). The loosely packed loess is subject to erosion, and the plateau's surface is transected by sunken boats, vertical-walled valleys, and numerous gullies. The region is extensively terraced and cultivated. The North China Plain, the largest flat lowland area in China, consists of fertile soils derived from loess.

Most of the plain is under intense cultivation. Located to the east, the Shandong Highlands on the Shandong Peninsula consist of two distinct areas of mountains flanked by rolling hills. The rocky coast of the peninsula provides some good natural harbours. To the southwest are the Central Mountains, which constitute a formidable barrier to north-south movement. Located in north central China, the northeast region comprises of all of Manchuria east of the Greater Khingan Range and it incorporates the Manchurian Plain (Dongbei Pingyuan) and its bordering uplands. The plain has extensive tracts of productive soils. The uplands are hilly to mountainous, with numerous broad valleys and gentle slopes. The Liaodong Peninsula, extending to the south, is noteworthy for its good natural harbours (Anon. 2003).

The North China Plain, which falls within the region, is made of the deposits of the Yellow River and is the largest alluvial plain of eastern Asia. The plain is bordered on the north by the Yen mountain range and on the west by the Taihang mountain range. To the south it merges into the Yangtze River plain and from northeast to southeast it fronts the Bohai Sea, the highlands of the Shandong Peninsula and the Yellow Sea. The plain covers an area of about 409 500 km^2, most of which is less than 50 m above sea level. This flat yellow-soil plain is the main area of kaoliang, millet, maize and cotton productions in China. Wheat, sesame seed, peanuts and tobacco are also grown there. The plain is also one of the most densely populated regions in the world.

In addition, the fertile soil of the North China Plain gradually merges with the steppes and deserts of Central Asia and there are no natural barriers between these two regions. Although the soil of the North China Plain is fertile, the weather is unpredictable because of its location at the intersection of humid winds from the Pacific Ocean and dry winds from the interior. This makes the North China Plain prone to both flood and drought. Finally, the flatness of the North China Plain creates massive flooding when the River's flood control structures are damaged. In the opinion of many historians these factors encouraged the development of a centralised Chinese state to manage granaries, manage hydraulic works, and man fortifications against the steppe peoples (Anon. 2003).

Biodiversity

The biodiversity in the deltas of the region is substantial, this being an important stopover location for the Red-crowned crane (*Grus japonensis*) and the Siberian crane (*G. leucogeranus*). The rare Saunders' gull (*Larus saundersi*) uses the Huang He Delta as one of its four global breeding sites. It is estimated that at least 800 000 water birds use the 4 800 km^2 coastal wetland here, including at least 15 IUCN Red Data species. Although 1 500 km^2 of coastal wetland of the region has been declared a nature reserve, the Dongying Huang He Sanjiaozhou has already been severely disturbed (MacKinnon et al. 1996).

More than 265 bird species have been recorded in the region with total numbers estimated at more than 10 million. This includes seven species identified as meriting the Chinese first class of protection. There are an additional 40 species listed in CITES (Convention on International Trade in Endangered Species).

Socio-economic characteristics

Population and main urban areas

The total population in the region amounts 343.5 million. The region is very densely populated, especially in the coastal area (Figure 3).The region is the historical heartland of China, and one of the most important agricultural and industrial regions in the country. It consists of three basins: the Yellow River Basin, the Hai Basin and the Liao Basin. The Hai Basin spreads over four provinces, the Hebei, the Henan, the Shandong and the Shanxi, and two municipalities: Beijing and Tianjin.

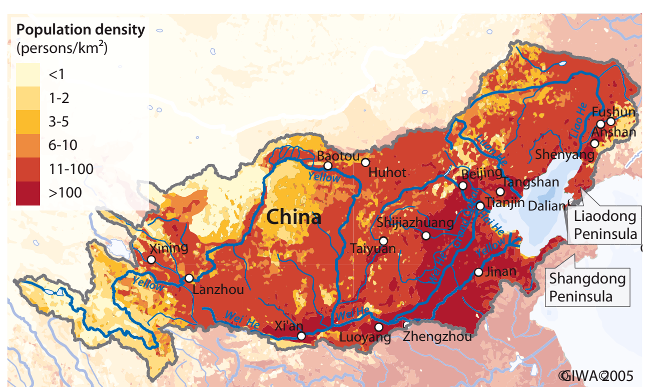

Figure 3 Population density in the Bohai Sea region.
(Source: ORNL 2003)

It is the home to 117 million people. The Liao Basin spans the provinces of Jilin and Liaoning, and has a population of around 42 million; it is rich in natural resources, particularly oil and gas (Wikipedia 2003). The Yellow River Basin, with a population of about 156 million, begins in the Qinghai Province and flows east, then northeast, through Gansu Province. It flows between the Ordos and Gobi Deserts, and then south between the Shanxi and Shaanxi provinces. Finally the river runs east through Henan and Shandong provinces.

Management of water resources

The major flood-prone areas along the major river basins of the region are presented in Figure 4. These include the following rivers:

Yellow River

The Yellow River is well known for its floods, which occur mainly in its lower reaches. There are levees with a total length of about 1 000 km on the main stream and tributaries. In the lower reaches of the River, the levees are much higher (5-10 m) than the surrounding lands because of sedimentation. On the upper and middle reaches of the Yellow River, 173 large and medium-sized reservoirs have been built with a total storage capacity of 55.2 billion m^3. Downstream of the Sanmenxia Reservoir, two large flood-retardation basins, the Beijinti and the Dongpinghu, have been constructed with a storage capacity of 2 billion m^3 each and detention areas of 2 316 km^2 and 627 km^2 respectively.

With regard to flow regulation of the River, 5 000 bank protection works totalling 585 km in length were built for controlling floods. They can withstand floods with a peak discharge of 22 000 m^3/s (the 1958 flood) at the Huayuankou hydrological station, corresponding to a 60-year return period. A large flood control reservoir, the Xiaolangdi Reservoir, with a storage capacity of 12.65 billion m^3, is under construction on the lower reach of the River. Once completed, it should protect the Yellow River downstream against frequent occurrence of floods (Zhang &Wen 2003).

Hai River

The main stream of the Hai River is only 70 km long with five tributaries confluent in the vicinity of Tianjin City, the industry centre of north China. Large amounts of floodwater from upstream along with inadequate discharge capacity in the middle and downstream sections often result in flood disasters. In 1963, an unusually big flood caused a catastrophe in this river basin. After that, a comprehensive flood-prevention programme was implemented by the Chinese government. Thus far, 140 large and medium-sized reservoirs have been built, with a total storage capacity of 25.3 billion m^3, equal to 92.7% of the River's annual upstream run-off. At present the Haihe River system can withstand a once-in-a-50-year flood.

Figure 4 Flood prone areas along the main rivers in the Yellow Sea and Bohai Sea regions.
(Source: Zhang & Wen 2003)

Liao and Luan River

The Liao and Luan river basins, which cover most of the Laioning Province, provides fertile areas for agriculture, while the coastal areas provide a good base for industries. Big floods in 1949, 1951, 1953 and 1960 hit the basins and flooded 3 to 5 million ha of cultivated land, resulting in substantial economic losses. As of 1993, 17 large reservoirs have been built with a total storage capacity of 12 billion m^3 and 11 000 km of levees have been strengthened or rebuilt. The levees along the rivers can withstand 10-to-20-year floods. Some important cities located along the rivers such as Shenyang and Fushun are protected against once-in-100-year floods.

Economic sectors

The region is located within the Bohai Bay Area, which includes provinces around the Bohai Sea and the Yellow Sea. In 1994, the Chinese government developed key points of the Programme for Economic Development of the Bohai Bay Area to the year 2000, and extended the area to the Shanxi Province and the Inner Mongolia Autonomous Region. The Bohai Bay Area lays in the centre of the Northeast Asian economic sphere and at the meeting place of the northeast, north and northwest regions. It has communications links with the Yangtze and Pearl river deltas, Hong Kong, Macao, Taiwan and Southeast Asian countries to the south, with the Republic of Korea and Japan to the east, and Mongolia, and the Russian Far East to the north.

As China's reform and opening to the outside world has expanded, the pace of economic development in the Bohai Bay Area has quickened. Currently it is the engine of economic development in North China, and is the area with third largest rate economic growth in the country, following the Pearl River and Yangtze deltas. In the future the Bohai Bay Area will benefit from its advantages of advanced communications, large number of large and medium-sized cities, strong contingents of scientific and technical personnel and wealth of natural resources. The development of the automobile, electronics, and new- and high-tech industries and other pillar industries will be emphasised, as well as the construction of energy bases and transportation channels. Relying on the coastal large and medium-sized cities, a comprehensive Bohai Bay economic circle will be formed with the Liaodong and Shandong peninsulas, Beijing, Tianjin and Hebei playing the leading role (MF 2003).

Fisheries and marine aquaculture

Fisheries and marine aquaculture in the Bohai Sea not only provide a source of seafood, but also sustain the livelihood of numerous fishermen around the Sea. Furthermore, the Bohai Sea is an important spawning and nursery ground for migratory species from the Yellow Sea and East China Sea. It is estimated that 40% of the fisheries resources in the Bohai Sea, Yellow Sea and the north area of East China Sea originate in the Bohai Sea. The Bohai Sea is the biggest mariculture base in China. The ecosystem in the Bohai Sea is fragile because of its nature as an semi-enclosed sea with long residence times. Both the excess fishing effort and the accumulating negative impacts from mariculture exert great pressures on the ecosystem. The fishing effort in terms of the number fishing vessels in China including the Bohai Sea has increased dramatically over the years. Numerous unregistered or unlicensed fishing vessels in a rapidly degrading ecosystem are the main problems with China fisheries. The illegal fishing and destructive fishing methods such as the use of electricity, explosives, toxins and other illegal fishing methods are often used because these methods usually have higher efficiency than conventional methods. Mariculture in the Bohai Sea, as an alternative supply of seafood for the large population around the Bohai Sea, is becoming more and more important (Dai 2001). At the same time, pollution from mariculture is accelerating as a result of the spatial expansion of aquaculture. The construction of mariculture areas damages natural spawning grounds and habitats, which exerts more pressure on wild fish stocks. The species that are introduced for mariculture, including genetically modified species, also pose a threat. Open-access fisheries and unregulated mariculture in the Bohai Sea impede the economic progress and the sustainability of the fisheries resource. The collapse of fish stocks in the Bohai Sea demonstrates that stakeholders in the fisheries and mariculture industries need to have a more conservation-oriented strategy in implementing their management (Jin 2003).

Salt making

The Bohai Sea provides an inexhaustible supply of table salt, thus making the salt industry an ancient and eternal marine industry in the littoral Bohai Sea. In 2000, the littoral area of the Bohai Sea had a total of 16 salt-fields with a total salt-pan area of 273 470 ha, a salt-pan production area of 240 750 ha and a sea-salt output of 664.76 million tonnes, making it the largest salt industrial production base in China. Among the four major sea-salt producing areas, three are located in the Bohai Sea region. These are the salt-producing areas of Liaodong Bay, Changlu and Shandong, of which the Changlu salt-producing area is the largest. The Changlu salt produced from this area has won recognition both domestically and internationally (PEMSEA 2004).

Port development and marine transport

The number of ports or harbours around the littoral area of the Bohai Sea ranks first in the country. In the littoral area of the Bohai Sea, 66 harbours have been completed, including 48 fishing harbours. Several key harbours in the region have a capacity greater than 31% of that of the major ports in China. Among them, the Dalian Harbour is an important outlet to the sea in the three provinces of northeast China as well as a focal foreign trade port of China; the Qinhuangdao Harbour is the largest energy-exporting port in the world and an important integrated foreign trade port; the Tianjin Harbour is the largest artificial harbour in China and also an international harbour. Thanks to its geographic location, it has become the gateway to the sea of Beijing, the capital of China, and is the largest commercial port in the north as well as an important port for ocean transportation. In addition, the Bohai Sea region also has small and medium-sized harbours, each with an annual handling capacity of over 1 million tonnes. The shipping capacity is complemented by more than 30 local harbours as well as a number of harbours that are being planned or are under construction. These concentrated harbours have led to the formation of a harbour group with the combination of large, medium-sized and small harbours (PEMSEA 2004).

In 2000, the Bohai Sea region had 13 first-class water transport ports, which can handle up to 265.4 million tonnes of cargo, accounting for 28.8% of the volume of freight handled by all the coastal ports. Ocean shipping constitutes not only the leading industry in the economy of the Bohai Sea, but also occupies an important position in the development of national economy (PEMSEA 2004).

Oil exploitation

The Bohai Sea is rich in offshore oil and gas resources. The major oilfields are the Shengli, Dagang and Liaohe Oilfields. On the 27th February 1997 China made a major breakthrough in oil exploration in the Bohai Sea, off the eastern part of China, by setting up the Chengdao Oilfield. The new field, which has an annual output of 1.05 million tonnes, is the largest offshore oilfield in the Bohai Bay, and has huge production potential. According to the China National Petroleum Corp (CNPC), the offshore oilfield was difficult to explore because of its complicated geological structure. To develop the Chengdao Field, a large array of new technology has been used, including a 3-D seismic survey and oil reserve tracking technology. The Bohai Sea area now has an annual output of 2.12 million tonnes of oil and 367 million m^3 of gas. Greater progress in oil and gas exploration in the Bohai Sea area can be expected in the coming years (PEMSEA 2004).

Tourism

The coastal areas of the Bohai Sea boast many beautiful natural spots, favourable environmental conditions, and a natural marine landscape characterised by seawater, sand-beaches and islands, which provide ideal resorts for tourism and leisure travel. There are now more than 20 tourist sites in the coastal area, among which the more famous ones include the Beidaihe seaside, Shanhaiguan Pass, Dabishan Mountain, Xingcheng City, the wetland tourist zone at the Liaohe River mouth and the Cangli Golden Coast Nature Reserve. The well-known cultural ancient relics include the ancient Great Wall, the Penglai Dengzhou Aquapolis of the Ming Dynasty, the Penglai Taoist Temple of the Song Dynasty, as well as the ruins of Emperor Qin Shi Huang's Palace, the ruins of the Japan-Russian War and the Memorial Hall of the Liaoxi-Shenyang Campaign (PEMSEA 2004).

Many coastal cities in the Bohai Sea region have devoted major efforts to developing modern commercial tourism by making the best of their rich and colourful marine, natural and human landscapes. For example, the Tianjin Municipality is visited by large tourist ships on a regular basis which anchor alongside its shore; the City of Dalian welcomes modern commercial tourism by "performing operas of economy and commerce on the stage put up by tourism", which has resulted in the Garment Festival, Sophora Flower Festival and Marathon, which have been well received by tourists at home and abroad. In 2000, the Bohai Sea region was visited by 947 350 tourists from abroad with foreign exchange earnings of over 600 million USD from international tourism (PEMSEA 2004).

Mineral resources

The Bohai Bay Area is rich in mineral resources, which are relatively evenly distributed and with favourable mining conditions. Statistics show that this area's reserves of iron, coal, petroleum, salt, natural gas and limestone account for 44, 40, 37, 50, 23 and 16% of China's totals, respectively. Shanxi is abundant in raw coal, its annual output accounting for 27% of the nation's total (MF 2003).

Agriculture

The Bohai Bay Area has well-developed agriculture, with 26.57 million ha of cultivated area, over one-fourth of the nation's total. Its grain yield accounts for more than 23% of the nation's total. In addition, the output of oil-bearing crops, aquatic products, pork, beef and mutton also constitute heavy percentages of the nation's total. Shandong, Hebei and Liaoning provinces are China's important production and supply bases for agricultural and sideline products. The Inner Mongolia Autonomous Region is the largest animal husbandry production base in China.

Industry

The Bohai Bay Area has a solid industrial foundation, where heavy and chemical industries are especially prominent. Some large-sized enterprises, such as the Anshan Iron and Steel Company in Liaoning, the Capital Iron and Steel Company in Beijing, the Taiyuan Iron and Steel Company in Shanxi and the Baotou Iron and Steel Company in Inner Mongolia, are located in this area. The Beijing Yanshan Petrochemical Group and Tianjin Bohai Chemical Group are China's two leading petrochemicals enterprises. In addition, Shenyang's heavy machinery and precision machine tool building industry, Beijing and Tianjin's electronic products and automobile industries, Shijiazhuang's cotton spinning, Hohhot's wool spinning and Taiyuan's mining machinery industries are all well known in China (MF 2003).

Legal and institutional framework

The international programmes and initiatives as well as the specific laws that form legal and institutional framework for the environmental management of the region are provided in Annex III and IV, respectively. Several institutions are involved in the flood control of the major rivers in China (Zhang & Wen 2003):

Ministry of Water Resources

The State Council was restructured and streamlined in 1998, with a view to streamlining government operations and clarifying the respective responsibilities of the ministries and departments under it. The function and responsibilities of the Ministry of Water Resources (MWR) were adjusted; the administrative role of the MWR in hydropower development was moved to the State Economic and Trade Commission, and groundwater management originally under the Ministry of Geology and Mineral Resources and urban flood control originally under the Ministry of Construction were moved to the MWR. The ministry was mandated to take over the responsibility of managing water conservation all over the country, as well as the planning and monitoring of the water environment and recommending protection measures to the government at different levels.

The MWR is appointed as the Department of Water Administration of the State and discharges the responsibility for the unified management of water resources. In accordance with the reform scheme of the State Council in 1998, the main responsibilities of the MWR are:

- The formulation of policy, development strategy and long-term plans, drafting of relevant laws and regulations, and supervision of their implementation;
- Unified management of water resources including surface water nd groundwater, formulation, supervision and implementation of the long-term water supply-and-demand plan and water allocation, assessment and verification of the available water resources and flood control measures, and implementation of water draw permit system and levy of a water resources fee, etc;
- Formulation and implementation of water conservation policy and plan;
- Water resources protection planning, water quantity and quality monitoring, evaluation and examination of pollution of water bodies;
- Water administration supervision and enforcement; mediation of water disputes;
- Formulation of economic regulatory measures in the water sector such as water pricing, taxation or loans;
- Issuance of technical guidelines, regulations, standards in the water sector, examination of proposal of large and medium-sized projects;
- Development and management of large rivers, large lakes and key projects crossing provincial boundaries;
- Water resource development and use in rural areas including hydroelectric projects and water supply;
- Soil and water conservation; and
- Undertaking the routine work for the State Flood Fighting and Drought Defying Headquarters (FFDDHS).

The river basin commissions

There are seven major river basin commissions that are agencies of the MWR and perform the function of water administration in the river basins. The main responsibilities of a river basin commission are:

- Execution of the Water Law, the Law of Water and Soil Conservation and related laws, regulations and rules;
- Mapping out strategic planning and mid- and long-term plans of a basin's water resource development;
- Working jointly with related departments and the relevant provincial authorities on the integrated river basin plan, relevant specialised plans and supervising their implementation;
- Unified management of the water resources of each basin;
- Unified management of the rivers, lakes, estuaries, tidal flats and that of key river reaches as authorised by the central government;
- Coordinating flood control and drought management;
- Mediation of water disputes;
- Comprehensive management of water and soil losses in key areas of the basin;
- Construction and management of trans-provincial water projects.

Local water resource management agencies

Local water resource management is comprised of four levels, i.e. provincial, prefecture, county and village or town. The main functions and responsibilities of local water management are: (i) to be the departments of the local governments at all levels responsible for water administration; (ii) to work out the local water resource development plan and long-term water supply-and-demand plan; (iii) to implement local water resource development projects; (iv) to carry out flood control and drought management, water and soil preservation, water resource protection and water project management, within their jurisdiction; and (v) to be responsible for urban and rural water supply and economical water use. It is worthy to mention that there are village (or town) water conservancy stations almost all over China. They are not only the agencies of the water administration, but also the water organisations at the grass-roots level that serve and keep close ties to the rural residents.

Assessment

BOHAI SEA

Table 1 Scoring table for the Bohai Sea region.

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

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

The arrow indicates the likely direction of future changes.

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

Bohai Sea	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	3.0* →	1 →	1 →	1 →	1.5	3
Modification of stream flow	3					
Pollution of existing supplies	3					
Changes in the water table	3					
Pollution	2.3* ↘	2 →	1 →	2 ↘	1.5	4
Microbiological pollution	2					
Eutrophication	3					
Chemical	2					
Suspended solids	1					
Solid waste	2					
Thermal	1					
Radionuclide	0					
Spills	3					
Habitat and community modification	2.6* ↘	3 →	1 ↗	3 →	2.5	2
Loss of ecosystems	2					
Modification of ecosystems	3					
Unsustainable exploitation of fish	2.6* →	3 →	2 →	3 →	2.7	1
Overexploitation of fish	3					
Excessive by-catch and discards	1					
Destructive fishing practices	2					
Decreased viability of stock	2					
Impact on biological and genetic diversity	3					
Global change	1.0* →	3 ↘	1 →	2 ↘	1.5	5
Changes in hydrological cycle	1					
Sea level change	1					
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. For further details see Detailed scoring tables (Annex II).

** This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).

*** 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 1.

Freshwater shortage

The naturally uneven distribution of water resources has created severe freshwater shortages in parts of the country (SEPA 2003). In the densely populated southern region of China, a relatively abundant water supply is provided by the Yangtze River and Pearl River basins. However, the areas north of the Yangtze River, particularly the northwest region and the North China Plain, which account for 60% of China's land mass and half of the country's population, only receive 20% of the nation's water resources; and there is severe freshwater shortage. The freshwater shortage in Northern China is further aggravated by serious soil erosion, deforestation, land conversion, excessive water usage for agricultural production and conversion of lakeshore wetlands into rice fields (SEPA 2003).

Environmental impacts

Modification of stream flow

The main river basins or systems that contribute to the source of freshwater supplies in the region include those associated with the Liao River, the Shuangtaizi River, the Hai River, the Luan River and the Yellow River. The Yellow River Basin is the largest among them, and covers an area of 940 065 km^2 in China (WRI 2003). The annual volumes in the Yellow River were greatly modified over the past decades due to serious water and soil erosion, which has led to frequent basin-wide drought in its upper and middle reaches, and tremendous flood disasters in its lower reaches (WAF 2003). The impact of this issue in the region has been considered to be severe.

Pollution of existing supplies

Fish kills frequently occurred in the major water basins associated with the Liao River, the Hai River, the Luan River and the Yellow River, covering a total area of 1 300 567 km^2. Pollution of the river basin waters was serious as evidenced by the fact that most of the surface waters that include more than 30% of the surface of these river basins did not meet WHO drinking water standards (see Annex V). The freshwater shortage situation is further worsened by inefficient use of the limited water supply. Studies have indicated that in China, only 20-30% of industrial water is recycled, and water consumption per industrial product is 5 to 10 times higher than that of industrialised countries. Additionally, only 25-30% of irrigation water is effectively used due to poor irrigation facilities (SEPA 2003). It is estimated that 2.5 million tonnes of grain yield are lost each year due to water shortages. The impact of this issue has been considered to be severe.

Changes in the water table

In several urban centres in the region, overextraction of groundwater for industrial and domestic uses has lowered groundwater tables. For example, in Beijing, water tables are dropping 1.5 to 2 m per year. A lower water table could not only aggravate water shortages, but also decrease water quality and increase the risk of earthquakes and landslides. Coastal aquifers are suffering salinisation over a wide area, particularly in the coastal, heavily populated cities along the coast of the Bohai Sea such as Dalian and Tienjin, as well as the adjacent Hebei Province, due to the extensive use of underground water for human consumption, agricultural and industrial activities. This heavy use has caused the water tables in these areas to subside, which has led to increased seawater intrusion. The impact of this issue has been considered to be severe.

Socio-economic impacts

Interruptions in the water supply for a few hours per week have frequent been reported in several of the coastal cities along the Bohai Sea such as Tienjin and Dalian. Water supplies affect societal stability, which is far more significant than economic and human health effects. Business costs increased over 10% as a result of using seawater or other alternatives to offset the freshwater shortage in satisfying business demands. This economic impact is considered less important than the social impact of the problem but more important than the human health impact. A slight increase in infectious diseases has occurred in the last decade, such as problems with teeth as a result of the need to drink saline water in seawater intruded areas. The impact was considered to be slight. A severe reduction of stream flow in major rivers (e.g. the Liao, Hai and Yellow rivers) has occurred over the past decades. The severe freshwater shortage has led to increased business cost by 10% and frequent interruptions in the water supply of the region.

Conclusion and future outlook

The trend of stream flow reduction in the region is unlikely to improve much in the future. The reduction problem may be alleviated if the planned national project to divert water from the country's south to north is implemented (See Box 2 in the Yellow Sea report). Further deterioration of water quality is unlikely in the future as some mitigation measures (e.g. control the discharge of agricultural run-off, industrial discharges, etc.) to improve water quality of the river basins were and are being undertaken by the Chinese government.

The accelerated urbanisation and shortage of surface water resources in the region are likely to exert continued pressure on the demand of underground water. The situation is unlikely to improve much in the future. Population growth will increase demand for freshwater. Freshwater shortages in the region will continue, which will significantly impact community welfare, much as is the case now. Business dependence on fresh water or its alternatives will increase, but the fresh water supply will not improve very much. This will increase business costs. The water resource status and water quality will improve, reducing the occurrence of diseases.

The Chinese government has recognised the vital need to address water shortage issues in order to maintain the nation's development. In 1988, China promulgated its Law of Water Resources, which provided a legal basis for water resource management. In 1993, further legal support to ensure efficient water use emerged as China adopted water resource licenses. By the end of 1995, nearly 90% of the nation's water utilities were registered and licensed. Since then, China's water supply is estimated to have increased 15 per year. The government is also promoting wastewater recycling by increasing investments in water pollution prevention and treatment facilities. Finally, efforts explore new water resources, such as seawater desalination, are being initiated.

Pollution

Environmental impacts

Microbiological

Incidents of bacterial gasteroenteric disorders in the population due to consumption of contaminated seafood or aquatic products caused by microbiological pollution in the coastal and inland waters of the region have been frequently reported over recent decades. However, in recent years, reports of human health problems caused by microbiological pollution have decreased due to measures taken by local governments (e.g. local government of Dalian City) to restrict the marketing of contaminated aquatic products for human consumption. Additionally, more wastewater treatment facilities have established in the large urban centres; these have greatly reduced incidences of microbiological pollution in the waters of the region. The impact of this issue has been considered to be moderate.

Eutrophication

There were reports of harmful algal blooms (HAB) due to eutrophication. The dinoflagellate *Gymondinium* sp. dominated these reports in August-September 1989 in the area offshore of Huang Hua. These blooms caused mass mortality of shrimps with heavy economic losses. A mass-scale HAB event occurred again in 1997, covering an area of 3 000 km^2 in Liaodong Bay of the Bohai Sea. High eutrophication caused by an increase of discharges of nutrient-rich sewage, agricultural and industrial wastes has resulted in frequent occurrences (e.g. more than 5-6 times per year) of HAB events along the coastal waters of the Bohai Sea (Cui & Song 1999). Eutrophication in the region has been considered severe. The issue is likely to have transboundary importance as the HAB organisms may be transported across national and international boundaries via ballast water and tank washing.

Chemical

Large-scale use of pesticides and insecticides in agriculture has resulted in agricultural run-off that is high in chemical pollutants. Increased industrial waste discharges have further added to incidences of chemical pollution in the region. Heavy metal pollution in Jinzhou Bay sediment has significantly changed benthic biodiversity. However, the impact of this issue the region has been considered to be moderate.

Suspended solids

There are reports of increased suspended solids in the river basins and coastal waters of the region as a result of increased construction of coastal roads and dams, and dredging and mud discharges from salt farms. For instance, the suspended solids contents were greater than 1 000 mg/l during high tides in the upper portion of the Liaodong Bay in the Bohai Sea. However, the problem of high suspended solids is localised around river mouths and its impact in the region is considered to be slight.

Solid wastes

On beaches and in the tourist sites of Jinzhou, Xingchen, Qinghuangdao and Dalian along the coastal areas of the Bohai Sea, litter has frequently been reported. The environmental impact of the issue has sometimes been significant enough to deter the public from recreational activities and is considered to be moderate.

Thermal

There are localised thermal problems caused by power plant discharges and offshore oil production, but there is no evidence that the biodiversity of the region has been altered by thermal pollution. The impact of the issue is considered to be slight.

Radionuclides

The environmental impact of this GIWA issue is unknown as, at the moment, there is no nuclear power plant in operation in the region.

Spills

There are four oil fields currently in operation in the region: Shengli, Bohai, Dagang and Liaohe oil fields. Small-scale (a few hundred tonnes) oil spills from these oil fields have frequently been reported (more than two to three spills per year). Oil tar balls have often been found on beaches in the coastal areas of the Bohai Sea. Avian mortality due to oil spills has also been reported often. The impact of oil spills on the region has therefore been considered to be severe.

Socio-economic impacts

Many rivers and coastal waters in the region are now not suitable for swimming. Commercial and recreational fishing activities have been reduced by 30-50% due to pollution impacts, particularly in freshwater systems. There have been reports of eye infections from swimming, as well as cases of PSP (paralytic shellfish poisoning), and gastroenteric disorders attributable to consuming contaminated aquatic products.

Conclusion and future outlook

More and more wastewater treatment facilities have been built or are being planned for the region's large urban centres, such as in the cities of Beijing, Tianjin and Dalian. The municipal sewage treatment rate is thus expected to grow from the current 25% to above 40% coverage over the next 5 to 10 years. Long-term improvement in the situation for microbiological pollution, particularly in the population centres in the region is expected in the future. The problems with eutrophication, and subsequent HABs are likely to decrease when measures taken by the Chinese government to improve the management of fertiliser and detergent uses are realised. More importantly, there are two government-funded ongoing environmental management projects, the "Bohai Sea Environmental Management Project" and the "Bohai Sea Clean Water Project", which are expected to greatly improve the future environmental conditions in the region.

The problem of chemical pollution is likely to be controlled with the implementation of the ongoing "Bohai Sea Environmental Management Project" and the "Bohai Sea Clean Water Project". No significant changes in the status of the suspended solid situation are expected in the future. The situation with solid waste will be improved with increased public awareness, the use of degradable wrapping materials and the implementation of GEF projects. More large-scale power plants may be constructed to meet the increased industrial development needs; offshore oil and gas development in the Bohai Sea will also be expanded. These are expected to aggravate the thermal pollution problem of the region in the future. With the expansion of offshore oil and gas development, particularly in the Bohai Sea, incidences of oil spills is expected to increase.

Pollution will be mitigated through the implementation of several environmental management projects currently ongoing in the region. Oil pollution will continue to be a threat to recreational activities as well as ecosystems and habitats. Pollution will continue to affect species of economic value. Associated economic losses may be unavoidable. Pollution through sediment re-suspension will continue to be a problem at levels similar to the present.

IMPACT Habitat and community modification

Habitat and community modification is a concern of high priority in the region. For example, the the Luan He estuary in the northeastern part of the region comprises a small area of saline meadows that has been modified. It supports a breeding site for Saunders' gull and passage for some migratory birds such as the Relict gull (Larus relictus). Otherwise this section of coast has been largely converted to shrimp ponds and salt pans.

The Dongying-Huang He Nature Reserve houses the second largest oil field in China; the Shengli Oilfield and oil industry is the primary industry of Dongying City. Other industries include chemical fertiliser manufacturing, textile, paper-making, cement manufacturing, salt chemical industry and food processing (MacKinnon et al. 1996). Threats to the Dongying-Huang He Sanjiaozhou Nature Reserve include hunting (36 000 to 52 000 shorebirds are trapped annually), pollution from nearby oil fields, and reclamation for the rapid commercial and industrial development that is occurring here (MacKinnon et al. 1996). Other threats include extensive marine aquaculture, particularly pond-rearing of shrimp.

Environmental impacts

Loss of ecosystems or ecotones

The types of habitats or ecosystems in the region that have been lost to various extents include:

- Marshlands: Surface area decreased by as much as 30% due to cumulative impacts of coastal and offshore oil fields development, e.g. in the Panjin area.
- Wetlands related to running water: Surface area decreased by more than 30% due to urbanisation and industrialisation.
- Periodic waters: Area of rice fields has increased but other periodic water areas reduced.
- Wetlands of saline habitats: Surface area decreased by more than 30%, due to various types of development activities.
- Running waters (rivers): Surface area decreased by up to 30% due to various types of development activities.
- Standing waters (e.g. lakes): Surface area decreased by more than 30%, mostly due to reclamation.
- Sandy foreshores: More than 30% of the area lost to sand mining and shrimp ponds, etc.
- Estuaries: Water surface area decreased by more than 30% due to reclamation, diking, reduction of stream flow and siltation.
- Rocky foreshores: Area decreased by up to 30% largely due to port development, particularly in East Liaodong Bay, northern Shandong Peninsula and Qinghuangdao.
- Mud bottom: Area decreased by some 50% due to development of shrimp ponds, salt fields and ports in areas such as Huanghua, Liaodong Bay, Bohai Bay and Laizhou Bay.
- Sand and gravel bottom: Area decreased by up to 30% due to sand mining in such areas as Bayuquan and Shuizhong.
- Rocky bottom: Some reduction due to port development (removal of reefs with explosives).

Modification of ecosystems or ecotones

The ecosystems or habitats in the region that have been modified, resulting in various degrees of changes in biodiversity, species composition and community structures include:

- Marshlands: Population structure, species composition and ecosystem functions changed.
- Wetlands related to running water: Population structure, species composition and ecosystem functions changed due to pollution and overexploitation of living resources.
- Periodic waters: Fish species have disappeared due to intensive use of pesticides, reduction of rainfall and stream flow.
- Wetlands of saline habitats: Significant reduction in crab abundance in Liaodong Bay. Most crabs in the market are cultured. Some migratory bird species have disappeared.
- Running waters (rivers): Population structure, species composition and ecosystem functions changed, particularly in Liaohe River, Haihe River and Yellow River.
- Standing waters (e.g. lakes): Population structure, species composition and ecosystem functions changed in Beiyangdian Lake.
- Sandy foreshores: Massive mortality of shellfish found in some areas, e.g. the massive mortality of the clam *Meretrix meretrix* occurred in 1997 in the Golden Beaches, Hebei Province. Population structure, species composition and ecosystem functions changed.
- Estuaries: Some species, e.g. Hairtail herring (*Coilia mystus*), have disappeared. Survey showed that the food chain in estuaries has been shortened.
- Rocky foreshores: Some species have disappeared or population abundance has been reduced, e.g. crabs and shellfishes, due to pollution, overexploitation and changed ecosystem functions.
- Mud bottom: Bottom trawling frequent, leading to reduced population abundance, species disappearance and changed ecosystem functions, e.g. crabs, fishes and shellfishes.
- Sand and gravel bottom: Changed population abundance and species disappearance due to artificial restocking of shellfishes.

Socio-economic impacts

Aquatic products of high economic value have been significantly decreased, biodiversity has been reduced, landscapes have changed, and the number of endangered species is on the increase. Many of these changes due to habitat loss or modification may be irrevocable or threatening to the preservation of biodiversity. Aquatic resources have been depleted and aquatic product processing business (e.g. for shrimps and shellfishes) affected. These have led to a loss of employment opportunities in over 50% of the concerned processing businesses. Aquatic raw materials that can be used for pharmaceutical industry have decreased by 10-20%.

Conclusion and future outlook

Future prospects for loss of ecosystems in the region are likely to be as follows:

- Marshlands: With increased urbanisation, the loss will continue.
- Wetlands related to running water: With urbanisation process, the loss will continue.
- Periodic waters: No significant changes in the current status expected.
- Wetlands of saline habitats: With urbanisation process, the loss will continue.
- Running waters (rivers): With urbanisation process, the loss will continue.
- Standing waters (e.g. lakes): Lake environments will be improved and reservoirs will increase.
- Sandy foreshores: Slight increase of sand mining is expected, but management will improve (e.g. alternative mining sites will be found). No large-scale mining of sandy foreshores will occur.
- Estuaries: Despite management measures, the losses may continue with continued reduction of stream flow.
- Rocky foreshores: No change in current status. A few experts expected a slight loss to port development.
- Mud bottom: No significant change in current status.
- Sand and gravel bottom: No significant change in current status.
- Rocky bottom: No significant change in current status.

Future prospects for modification of ecosystems in the region are likely to be as follows:

- Marshlands: The situation may be getting worse. Ecosystem restoration is difficult, and very slow if any.
- Wetlands related to running water: Changes in population structure and abundance will continue.
- Periodic waters: No change of current status is expected.
- Wetlands of saline habitats: Loss of some ecosystem functions is expected due to pollution and development activities.
- Running waters (rivers): Restoration of some ecosystem functions is possible with improved management of riverine environment and closure of polluting enterprises.
- Standing waters (e.g. lakes): Partial improvement of lake environments is possible, but effective ways to prevent lakes from being pollutant catchment areas has yet to be found.
- Sandy foreshores: No significant change in the current status.
- Estuaries: Ecosystem integrity will be impaired by coastal and offshore oil and gas development.
- Rocky foreshores: No significant change of current status is expected.
- Mud bottom: No significant change of current status is expected.

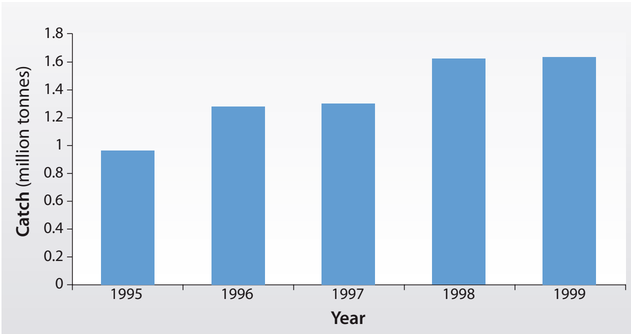

Figure 5 Total catch in the Bohai Sea, 1995-1999.
(Source: Dai 2001)

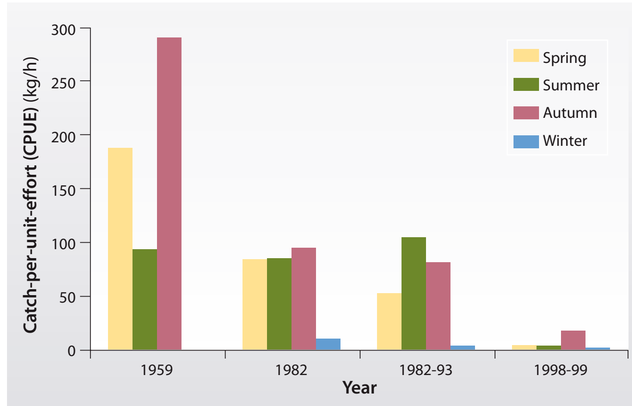

Figure 6 Catch per unit effort in the Bohai Sea.
(Source: Jin 2003)

- Sand and gravel bottom: No significant change of current status is expected.
- Rocky bottom: No significant change of current status is expected.

The number of species of high economic value will continue to decrease. Pressure on overexploited species of high economic value will remain. Restoration of damaged habitats takes time. Some damages are irrevocable. As natural aquatic resources are depleted, management and enforcement will focus on reducing harvesting efforts. This may mean that employment opportunities in harvesting natural aquatic resources will be reduced by 50%. Aquatic raw materials for pharmaceutical industry will continue to decrease.

IMPACT Unsustainable exploitation of fish and other living resources

Fisheries resources in the Bohai Sea have been dramatically decreasing since the 1980s. Compared with the fisheries resources in the early 1980s, the biomass of invertebrate animals in the Bohai Sea was reduced by 39% in 1992 and 1993 and the average weight of spawning fish reduced by 70%. The biomass of high value species such as Japanese sea perch (*Lateolabrax japonicus*), Chinese herring (*Ilisha elongate*), Genuine porgy (*Pagrosomus major*), Olive flounder (*Platichthys flesus*), Chinese prawn (*Penaeus chinensis*) and Swimming crab (*Portunus pelagicus*) decreased by 71%, and the total biomass of low value species was 2.4 times that of the early 1980s. A survey in 1998 indicated that the total biomass of fish stocks had been reduced by 89% compared to 1992 (Qiao 2001). The overexploited fisheries in the Bohai Sea are the result of failure to control access to the fisheries resource and failure to control the negative environmental impacts from mariculture. Inevitably, the fall in catch of high value species has been accompanied by a shift towards catches of low value pelagic species such as anchovies and sardines. The total catch from the Bohai Sea has increased in the 1990s (Figure 5), which is mostly due to the increasing fishing effort in Bohai Sea. In addition to the 75 000 locally registered fishing vessels and 290 000 fishermen from the Bohai Sea region, fishing vessels from other provinces further away (mainly Jiangsu Province, 16 460 tonnes in 1999) also fish in the Bohai Sea (Dai 2001).

The dominant species shifted from the late 1950s to the 1980s in the Bohai Sea; high valued, commercially important species such as Small yellow croaker (*Pseudosciaena polyactis*), Large-head hairtail (*Trichiurus lepturus*), and penaeid shrimps (*Penaeus* spp.) were replaced by low valued, small-sized species such as Japanese anchovy (*Engraulis japonicus*) and the Half-fin anchovy (*Engraulis* sp.). Although the dominant species has varied between years, the small pelagic fish, such as anchovy (*Engraulis* sp.), Half-fin anchovy (*Engraulis* sp.) and Gizzard fish (*Clupanodon punctatus*) have dominated the fishery resources since the beginning of the 1980s. However, in 1998-1999, the catch-per-unit effort (CPUE) of most fish species declined to a very low level (Figure 6). The CPUE of small pelagic fish and economically important invertebrates have sharply decreased, with reduced distribution areas that directly affect the growth of carnivorous fishes, such as Spanish mackerel (*Scomberomorus japonicus)* (Jin 2003).

Environmental impacts

Overexploitation

Yields of highly valuable fish in the region have drastically reduced. For instance, the annual production of Chinese prawn (*Penaeus chinensis*), which used to reach as high as 40 000 tonnes a decade ago, has now decreased to around 500 kg annually. The highest recorded annual production for the Threadfin fish (*Eleutheronema tetradactylum*) was around 40 000 tonnes two decades ago; it is now just 8 tonnes annually at current production. The catch of Yellow croaker (*Pseudosciaena* sp.) and Hairtail (*Trichiurus haumela*) fish are now so small that no fishing seasons for these fish have been identified. The impact of this issue on the region has been considered to be severe. This issue has transboundary importance in that many fish species in Bohai Sea are migrate to fishing grounds in the territorial waters of China, Korea and Japan.

Excessive by-catch and discards

There are occasional incidences of capturing protected or endangered species such as Spotted seals (*Phoca largha*) and Lancelets (*Branchiostoma belcheri*) by fishing fleets in the region. No discards are so far known. The impact can be considered to be slight.

Destructive fishing practices

The destructive fishing practices that are common in the region, as well as in the Yellow Sea region, include the indiscriminate trawling along the coastal waters of the Bohai Sea, fishing with explosives in lakes, and the use of pesticides for fishing. These destructive fishing activities have destroyed several benthic habitats, both spawning and fishing grounds, which in turn have resulted in reductions in both the fisheries resource as well as the recruitment of fish stocks. The impact is considered to be moderate.

Decreased viability of stock through pollution and disease

Several anadromous species such as the Hairtail herring (*Coilia mystus*) were once commonly caught in large quantities in Liao River estuary. These fish have disappeared over the past two decades, which might be a result of increased pollution. The impact of this issue on the region has been considered to be moderate. No significant changes in the current status are expected in the future.

Impact on biological and genetic diversity

There is evidence that the unsustainable exploitation of fish and other living resources has changed the biological and genetic diversities of aquatic organisms in the region. For instance, population declines, mass restocking of hatchery-produced post-larvae/fry and other environmental factors may have changed the genetic grouping of the Oriental prawn (*Penaeus orientalis*). The number of genetic polymorphous locations of wild oriental prawn is now just 20 as compared to only 15 in the cultured species. The impact of this issue in the region has been considered to be severe

Socio-economic impacts

Total catches of fish species with high economic value, e.g. Yellow croakers and prawns, has dropped by more than 50% over the past decades. The catch per unit effort (CPUE) for all species has also decreased by more than 50%. The economic impact of this GIWA concern is of primary importance because any decrease in catches means reduced employment opportunities for coastal and riverine communities. Unemployment that results from depleted fisheries resources may be alleviated with alternative working opportunities. There were many cases of diseases such as gastroenteric disorders attributed to the consumption of fish and other aquatic products in the past few decades. Some of these cases have caused epidemics.

Conclusion and future outlook

Measures like strict enforcement of fisheries management laws and restrictions on the number of fishermen allowed to enter the fishing industry to improve fisheries management are being implemented by the Chinese government. Effective controls on overfishing have yet to be undertaken. Overfishing problems are likely to exist but some improvements may be expected in the future. Incidence of by-catch of endangered species as well as the composition and quantity of by-catch is unlikely to increase in the future. Destructive fishing may decrease if appropriate control measures are taken by the government. The future fisheries management in the region is likely to focus on reducing fishing efforts, e.g. restricting the entry of fishing boats and fishermen to reduce fishing capacity to conserve the fisheries resource. The scale of reduction may have to be more than 50% of the current levels in order to achieve effective management of the fisheries resources. As an effective way to solve the overfishing problems has yet to be determined and implemented, overfishing may continue and the CPUE may continue to decrease.

IMPACT Global change

Environmental impacts

Changes in the hydrological cycle

The GIWA Experts anticipate that global change has already had some effect on the hydrological cycle. One example is the trend of declining rainfall in the region.

Sea level change

The GIWA Experts acknowledge that some studies had shown evidence of sea level rise in the region. For instance, the Ramsar Workshop on the vulnerability assessment of the Yellow River Delta, held in Beijing in January 1999, describes the threat of rising sea levels in the region as:

"The estimated relative sea level rise rate in the Yellow River Delta is 8 mm per year and the sea level rise will be 48 cm by the year 2050. This will lead to critical impacts such as the frequency of storm surges and El-Niño events to strengthen hydrodynamics, beach erosion, and landward retreat, wetland loss, saltwater intrusion, and land salinisation."

Increased UV-B radiation as a result of ozone depletion and Changes in ocean CO_2 source/sink function

The GIWA experts concluded that no observed evidence of increased UV-B radiation or changes in ocean CO_2 source/sink function could be found in the region.

Socio-economic impacts

Climate changes may cause changes in the status of various natural resources, which could result in user conflicts and disputes regarding property rights and administrative jurisdiction of those resources, thus affecting social stability. These problems are increasing. Economic restructuring, including improvements in resource management and use may help improve the situation.

Conclusion and future outlook

No significant changes in the current status of the environmental issues are expected in the future. Use conflicts and disputes over property rights and administrative jurisdiction of resources may be reduced with improved legislation and management actions taken by the government in the future. The many national and international environmental management and protection projects that have been or will be implemented in the region are likely to facilitate a search for sustainable environmental management and economic development in the region to cope with the consequences of global environmental changes.

Priority of concerns for further analysis

Based on the results of the assessment for the Bohai Sea region the GIWA issues that have been assessed as having severe environmental impacts were selected for further analysis and summarised in Table 2.

The GIWA concerns were ranked in descending order:

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

Table 2 Summary of environmental and socio-economic impacts of the prioritised GIWA concerns and issues in the Bohai Sea region.

Prioritised GIWA concern	Prioritised GIWA issue	Environmental and socio-economic impacts
Freshwater shortage	Modification of stream flow	Severe reduction of stream flow for major rivers (e.g. Liaohe, Haihe and Yellow Rivers) occurred over the past decades. Severe freshwater shortage had led to increased business cost by 10% and frequent interruption of water supply.
	Pollution of existing supplies	More than 30% of the major river basins in the sub-region have been polluted with surface waters below the WHO drinking water standards.
	Change in the water table	Large-scale salinisation (salt water intrusion) of coastal aquifers was observed over the past decades, particularly in some areas of the Chinese side of the sub-region (e.g. Hebei Province, and Dalian and Tianjin cities).
Habitat and community modification	Loss of ecosystems	Up to or more than 30% of the areas of critical habitats such as freshwater marshlands, running water wetlands, rivers, lakes, sandy foreshores, rocky foreshores, and sand & gravel bottoms were lost over the past decades. Some 50% of the areas of mud bottoms were lost during the past decades. Significant loss of freshwater and brackish habitats as well as seasonal drying up of Yellow River and other rivers occurred over the past decades. Significant loss of over 50% employment opportunities in the concerned aquatic product processing industries occurred over the past decades.
	Modification of ecosystems	Population structure, species compositions and ecosystem functions for habitats such as, (a) freshwater marshlands; (b) running water wetlands; (c) periodic waters; (d) saline habitat wetlands; (e) rivers; (f) offshore; and (f) lakes had greatly changed over the past decades. Modifications signified by species disappearance and reduction in population were obviously evidenced for habitats such as the sandy foreshores, estuaries, rocky foreshores, mud bottoms and sand & gravel bottoms were observed. Obvious increases in salinity (averaged 27 ppt in 1960s to around 31 ppt nowadays) in Bohai Sea due to decreased freshwater inputs from Yellow River had modified several coastal ecosystems were observed.
Unsustainable exploitation of fish and other living resources	Overexploitation	Yields of several stocks (e.g. *Penaeus chinensis*, *Eleutheronema tetradactylum*) drastically decreased over the past decades. Economic values of the fisheries sectors greatly decreased over the past decades due to decreased catch per unit efforts (CPUEs) and reduction in the total catches of some commercially important fish species.
	Destructive fishing practices	Include indiscriminate trawling along the coastal waters of the Bohai Sea, fishing with explosives in lakes and the use of pesticides.
	Impact on biological and genetic diversity	Genetic diversity of oriental prawn (*Penaeus orientalis*) has significantly changed over the past decades.

Causal chain analysis

BOHAI SEA

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

Based on the assessment results, the GIWA issues considered to have severe environmental impacts have been selected for the following analysis:

- Modification of stream flow;
- Pollution of existing supplies;
- Changes in the water table;
- Loss of ecosystems or ecotones;
- Modification of ecosystems or ecotones;
- Overexploitation;
- Destructive fishing practices.

These issues are analysed in two causal chain analyses; the first one targeting habitat and community modification as well as freshwater shortage problems, and the second targeting overexploitation and destructive fishing practices.

Habitat and community modification and freshwater shortage

Figure 7 illustrates the causal links for habitat and community modification and freshwater shortage in the Bohai Sea region.

Environmental and socio-economic impacts

Stream flows of the major river basin of the region such as, Liao, Luan, Hai and Yellow rivers have been found to be severely reduced and business costs have increased by 10% with frequent interruption of water supply. More than 30% of the major river basins in the region have also been polluted with the quality of their surface water below the World Health Organization (WHO) drinking water standards and large-scale salinisation of coastal aquifers has occurred over the past decades, particularly in places such as the Hebei Province, Dalian and Tianjin.

Over the past few decades, many critical ecosystems and habitats in the region have been lost mainly as a result of human activities. The extent of these losses is estimated to account to 30-50% of their total area. The lost ecosystems have been found to include freshwater marshlands, running water wetlands, saline habitat wetlands, rivers, lakes, sandy foreshores, rocky foreshores, sand and gravel bottoms and mud bottoms. As a result of this loss, more than 50% of employment opportunities in aquatic product processing industries have also been lost. There have also been losses of freshwater and brackish habitats as well as seasonal drying up of for example the Yellow River. Modifications of the ecosystems in the region, in terms of changes in species population structure and biodiversity, are also relatively severe. The ecosystems or habitats found to show severe modifications over the past decades include freshwater marshlands, periodic waters, saline habitat wetlands, lakes, sandy foreshores, estuaries, sand and gravel bottoms and mud

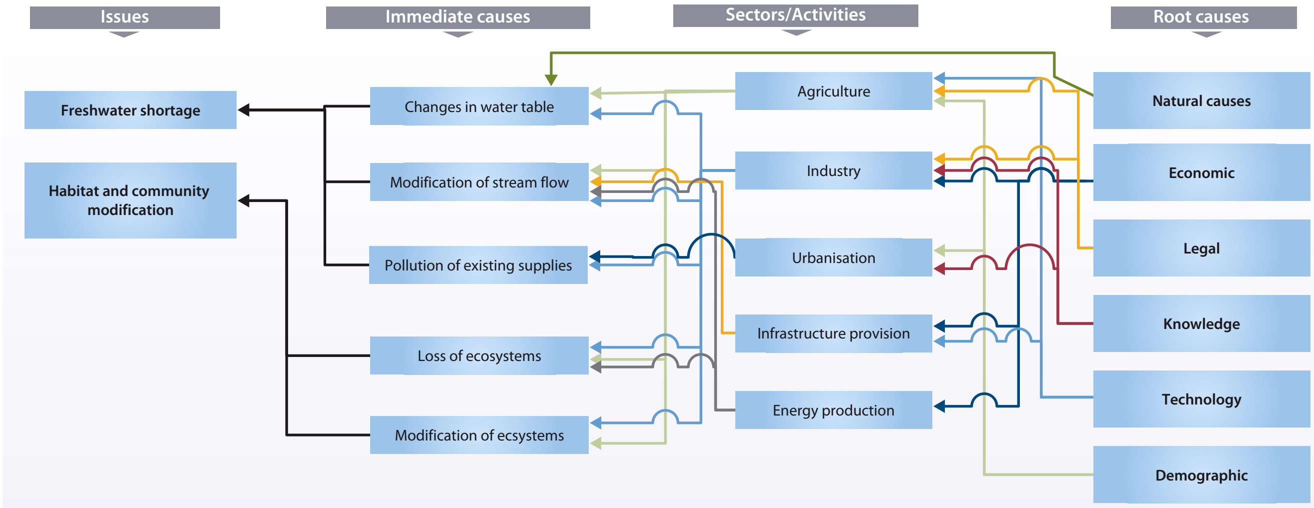

Figure 7 Causal chain diagram illustrating the causal links for habitat and community modification and freshwater shortage in the Bohai Sea region.

bottoms. There has been an obvious increase in salinity in the Bohai Sea, from around 27-28 ppt in the 1960s to the present 31 ppt, which has modified several coastal ecosystems in the region. This mainly is due to decreased freshwater inputs from Yellow River. Modification signified by species disappearance and reduction in population are easily observed in habitats such as sandy foreshores, estuaries, tocky foreshores, mud bottoms and san and gravel bottoms.

Immediate causes

Modification of stream flow

The changes in stream flow is mainly caused by upstream damming and draining for flood control and the establishment of hydroelectric plants, and increased diversion of water from river tributaries for industry, domestic and irrigation uses.

Pollution of existing supplies

There has been an increased input of pollutants of industrial and domestic waste in the region, affecting both the freshwater supply and the habitats.

Changes in the water table

The increased extraction of groundwater for agricultural and industrial uses has resulted in significant changes in the water table in many areas of the region.

Loss of ecosystems

Land use conversion such as the change of wetlands into rice fields has resulted in the loss of freshwater habitats in the region. The decreased input of freshwater due to seasonal drying up of major river systems in the region and diversion of river waters for agricultural and industrial uses, have also led to the losses of some freshwater ecosystems. Increased development of oil fields in the Bohai Bay has resulted in the loss of coastal habitats around in the Bay.

Modification of ecosystems

Land use conversion has resulted in not only loss but also modification of ecosystems in the vicinity of land use conversion areas. Decreased input from the Yellow River has resulted in increase in salinity in the Bohai Sea, leading to modification of several coastal habitats around the Sea. Pollution form oil, heavy metals and other pollutants has also modified several coastal habitats in the region.

Sectors

Agriculture

In the absence of alternative water supplies and decreases in rainfall, more groundwater has been extracted for increased crop production to meet the higher demand for food as a result of the rapid economic and population growth in the region. The increase in farming activities and expansion of farming areas in the region has led to increased demands for water for irrigation, causing modification of stream flow in the rivers. Agricultural activities have also lead to uncontrolled conversion of coastal wetlands or freshwater marshlands to rice fields, diversion of river waters for crop production, and discharge of run-off high in chemical pollutants.

Industry

In the region, changes in industrial activities and increased human settlements following industrial development over the past decades has led to increased extraction and consumption of freshwater. The rapid industrial development in the region has consequently led to an increased discharge of treated and/or partially treated industrial wastewaters high in harmful pollutants into river systems and coastal areas. The increased discharge of industrial wastewater high in chemical and oil pollutants has also substantially contributed to modification of a number of habitats in the region. The petrochemical industry has contributed to the conversion of coastal wetlands for the establishment of petrochemical plants in the region and has resulted in more conversion of coastal wetlands, leading to loss of such valuable habitats. Figure 8 shows oil drillling in the Bohai Sea.

Infrastructure provision

Building of dams and dikes for flood control upstream on the river systems of the region over the past decades has increased and this has led to changes in stream flows in these river systems.

Energy production

Building of dams and dikes upstream in the river systems, has also been intended to establish the hydroelectric plants in addition to flood control, which has led to substantial modification of stream flows in the region in the past decades. The energy production in the oil industry has increased the exploration and production of petroleum and natural gas in the region that has caused loss of ecosystems or habitats.

Urbanisation

Rapid economic growth and industrial development in the region have enhanced the process of urbanisation, resulting in discharge of treated and/or partially treated domestic sewage and storm water high in harmful pollutants into the river systems and coastal areas.

Root causes

Demographic

The increased population growth in the region has resulted in increased demand for food, thus increasing agricultural activities and the demand to extract more groundwater for crop production. The population growth combined with the mass migration of population from rural to urban centres has burdened sewage and domestic wastewater treatment facilities.

Figure 8 Oil drilling in the Bohai Sea.
(Photo: Corbis)

Technology
Inadequate access to crop farming technology has resulted in the inefficient use of freshwater in the region. the easy access to modern technology has a propelled industrial growth that requires more use of water.

Legal
There is inadequate enforcement of laws and regulations in the region to control the use of freshwater, leading to an overextraction of water resources. The current governmental policies to control industrial, domestic and agricultural water use as well as production are insufficient. For example, the region lack adequate land and water policies for land use conversion and use of water resources for agricultural activities.

Economic
Increase in economic growth has lead to rapid industrial development, increased energy demand and increased human settlements, all increasing the water consumption. There has also been an increased need to prevent floods for the protection of human lives and properties. The increased energy demand by industries and domestic uses in the region has resulted in increased production and exploration of petroleum and natural gas. The establishment and operation of more petrol-chemical plants leads to destruction of adjacent habitats. Low investment in waste treatment facilities has led to increased discharge of wastewater high in pollutants by certain industries.

Knowledge
A lack of public awareness on environmental impacts has led to an increase in the uncontrolled discharge of industrial and domestic wastewater into the river systems and coastal areas of the region. A deficiency in stakeholder participation and public awareness on environmental protection is notable throughout the region. Profit-oriented attitudes in for example the petrochemical industry that disregard environmental impacts has resulted in the consequences of uncontrolled conversion of coastal wetlands for petrochemical plants.

Natural causes
Decrease in rainfall has caused farmers and industrial operators to resort to excessive extraction of groundwater to meet the needs for crop and industrial production.

Unsustainable exploitation of living resources

Figure 9 illustrates the causal links for unsustainable exploitation of living resources in the Bohai Sea region.

Environmental and socio-economic impacts
Overexploitation of living resources in the Bohai Sea region were identified as having severe environmental impacts. Yields of several valuable stocks, e.g. Chinese prawn *Penaeus chinensis* and Threadfin fish *Eleutheronema tetradactylum* have drastically decreased over the past decades. The catch of yellow croaker (*Pseudosciaena* sp.) and Hairtail (*Trichiurus haumela*) fish are now so small that no fishing seasons for these fish have been identified. Economic values of the fisheries sector have greatly decreased over the past decades due to decreased catch per unit effort (CPUE) and reduction in the total catches of some commercially important fish species. The impact associated with changes on biological and genetic diversity was exemplified by the fact that the genetic diversity of Oriental prawn (*Penaeus orientalis*) has significantly changed over the past decades. The economic impacts of these issues are of primary importance because any decrease in catches means reduced employment opportunities for coastal and riverine communities. Unemployment that results from depleted fisheries resources may be alleviated with alternative working opportunities. There have been many cases of diseases such as gastroenteric disorders attributed to the consumption of fish and other aquatic products in the region.

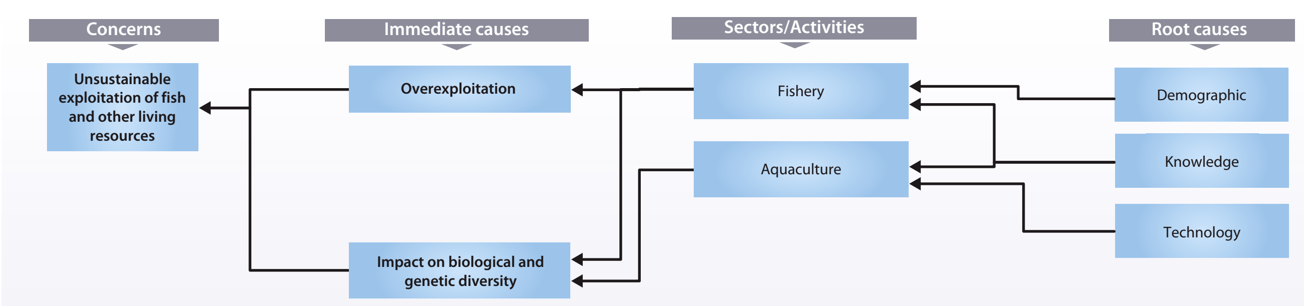

Figure 9 Causal chain diagram illustrating the causal links for unsustainable exploitation of living resources in the Bohai Sea region.

Immediate causes

Overexploitation

The introduction of new fishing technologies and increase in the number of fishing fleets and fishermen has resulted in the overexploitation of stocks. The uncontrolled expansion of aquaculture has led to an overexploitation of spawning fish and prawns, which has affected stock recruitment.

Impact on biological and genetic diversity

There has been a mass restocking of hatchery-produced juveniles which has resulted in changes of genetic diversity. Since 1985, 200 million juvenile oriental prawns have been released to the coastal areas of China, significantly changing the genetic diversity of the wild species.

Sectors

Fishery

An easy access to new fishing technologies has encouraged more efficient fishing practices in the region and an increasing number of fishing fleets and fishermen entering the fishing industry have increased fishing efforts. This have greatly contributed to the overexploitation of living resources in the region.

Aquaculture

On the other hand, the increased shift of fishermen from capture fisheries into aquaculture due to declining fish catches has also contributed to uncontrolled or over development of aquaculture. The overexploitation of spawning fish and prawn has affected recruitment and mass release of hatchery-produced juvenile fish and prawn has influenced the genetic diversity of wild stocks; both activities in the sector have contributed to unsustainable uses of the living resources in the region

Root causes

Demographic

Increase in population growth has resulted in increased demand for food, including seafood. This has enhanced fishing activity, leading to overexploitation of living resources. Shift in livelihood of fishermen from capture fisheries to aquaculture because of the consistent decline in fish catches has contributed to the uncontrolled or overdevelopment of aquaculture.

Knowledge

Profit-driven attitudes of fisheries operators that has led to uncontrolled entry of fishing boats and fishermen into the fisheries sector, resulting in overexploitation of living resources. Insufficient awareness of the consequences of uncontrolled releases of hatchery-produced juveniles and overexploitation of spawning fish have affected the genetic diversity of wild stocks.

Technology

Easy access to improved or new aquaculture technologies has propelled the increased development of aquaculture, leading to unsustainable use of living resources.

Conclusions

Table 3 summarise the immediate causes, sectors and root causes in for freshwater shortage, habitat and community modification as well as unsustainable exploitation of living resources in the Bohai Sea region.

Table 3 Summary of the causal chain analysis for the Bohai Sea region.

GIWA concern	Immediate Causes	Sectors	Root Causes
Freshwater shortage	Modification of stream flow:Changes in stream water inputs caused by: -upstream damming and diking for flood control and set-up of hydroelectric plants; - increased diversion ofwater from river tributaries for industry, domestic and irrigation uses.	Agriculture: Increased crop farming activities and expansion of farming areas in leading to increased needs of stream waters for irrigation	Demohgraphic: Increased population growth. Technology: Inadequate accesses to crop farming technology by farmers. Legal: Insufficient policies and inadequate enforcement of laws and regulations.
		Industry: Changes in industrial activities and increased human settlements following the industrial development leading to increased consumption of stream waters.	Economic: Increase in economic growth. Legal: Insufficient policies and inadequate enforcement of laws and regulations.
		Infrastructure provision: Building of dams and dikes for flood control upstream the river systems leading to changes in stream flows.	Economic: Increase in economic growth.
		Energy production: Building of dams and dikes upstream the river systems for setting up hydroelectric plants leading to substantial modification of the stream flows.	Demographic: Increase in energy demand.
	Pollution of existing supplies: Increased inputs of pollutants from industrial and domestic waste discharges	Industry: Rapid industrial development leading to increased discharge of the treated and/or partially treated industrial wastewaters high in harmful pollutants into the river systems and coastal areas.	Demographic: Increase in economic growth. Legal: Insufficient enforcement of laws and regulations for environmental protection. Knowledge: Lack of public awareness and deficiency in stakeholder participation on environmental protection.
		Urbanisation: Rapid economic growth and industrial development enhanced the process of urbanisation resulting in discharge of treated and/or partially treated domestic sewage and storm waters high in harmful pollutants into the river systems and coastal areas.	Demographic: Increased population growth and mass migration of population from rural to urban centers. Knowledge: Deficiencies in stakeholder participation and public awareness on environmental protection.
	Changes in the water table: Increased extraction of groundwater for agricultural and industrial uses resulting in significant changes in the water table in many areas of the region.	Agriculture: In the absence of alternative water supply and decrease in rainfall, more groundwater had been extracted to meet the needs for increased crop production.	Demographic: Increased population growth. Natural causes: Lacks of alternative water supply and decrease in rainfall. Legal: Lacks of adequate government policy, laws and regulations on groundwater utilisation.
		Industry: To increased extraction of groundwater for use by certain industries due to rapid industrial development.	Economic: Change in the economic and industrial structures. Legal: Lacks of adequate government policy, laws and regulations on groundwater utilisation.
Habitat and community modification	Loss of ecosystem: Land use conversion such as the conversion of wetlands into rice fields, resulting in the loss of the wetland habitats. Decreased input of freshwater due to seasonal drying up of the major river systems and diversion of river waters for agricultural and industrial uses leading to the loss of some freshwater ecosystems. Increased (progressive) development of oil fields in the Bohai Bay resulting in the loss of coastal wetlands.	Petrochemical industry: Increased conversion of coastal wetlands for the set-up of petrochemical plants.	Knowledge: Profit-oriented with disregard to environmental impacts attitudes. Economic: Increased energy demand by industries and domestic uses. Demographic: Increased population growth.
		Agriculture: Uncontrolled conversion of coastal wetlands and/or freshwater marshlands to rice fields. Diversion of river waters for crop production.	Legal: Lack of adequate government land and water utilisation policies, laws and regulations. Demographic: Increased population growth.
		Industry: Uncontrolled diversion of river waters for industrial production.	Economic: Increase in economic growth. Technology: Easy access to modern technology.
		Energy production (oil industry): Increased exploration and production of petroleum oil and natural gas causing loss of ecosystems or habitats.	Economic: Increased energy demand by industries and domestic uses.
	Modification of ecosystem: Land use conversion resulting in not only loss but also modification of the ecosystems in the vicinity of the land use conversion areas. Decreased input of freshwater particularly from Yellow River resulting in increase in salinity in Bohai Sea, leading to modification of several coastal habitats. Pollution by the presence of oil, heavy metals and other pollutants resulting in modification of several coastal habitats.	Petrochemical industry: Increased set-up of petrochemical plants resulting in increased conversion of coastal wetlands leading to loss of valuable habitats.	Knowledge: Profit-driven with disregard to environmental impacts attitudes. Economic: Increased energy demand by industries and domestic uses.
		Agriculture: Uncontrolled conversion of coastal wetlands and/or freshwater marshlands to rice fields. Uncontrolled diversion of river waters for crop production.	Legal: Lack of adequate government land and water utilisation policies, laws and regulations.
		Industry: Uncontrolled diversion of river waters for use in industrial production. Increased discharge of industrial wastewaters high in chemical and oil pollutants.	Economic: Increase in economic growth and low investment in waste treatment facilities. Technology: Easy access to modern technology.
		Agriculture: increased discharge of run-off high in chemical pollutants.	Legal: Lack of adequate government policies, laws and regulations for controlling discharge of agricultural wastes.
Unsustainable exploitation of fish and living resources	Overexploitation: Increased fishing efforts by introduction of new fishing technologies and increase in the number of fishing fleets and fishermen resulting in the overexploitation of living resources. Uncontrolled development of aquaculture resulting in overexploitation of fish and prawn spawners, affecting the stock recruitment.	Fishery: Activities include easy access to new fishing technologies encouraging more efficient fishing practices, and increasing number of fishing fleets and fishermen entering the fishing industry that increased the fishing efforts leading to overexploitation of the depleting living resources.	Demographic: Increase in population growth. Knowledge: Profit driven attitudes of the fisheries operators.
		Aquaculture: Increased entry of fishermen from fisheries into aquaculture due to declined fish catches.	Technology: Easy access to the improved or new aquaculture technologies. Economic: Shift in livelihood of fishermen from fisheries to aquaculture resulting in uncontrolled or overdevelopment of aquaculture.
	Impact on biological and genetic diversity: Mass restocking of hatchery-produced juveniles resulting in changes of genetic diversity.	Aquaculture: Enhancement of wild stock through mass release of hatchery-produced juveniles, overexploitation of wild spawners (e.g. spawners of *Penaeus orientalis*) for aquaculture use.	Knowledge: Insufficient awareness of fish farmers on the consequences of uncontrolled release of hatchery-produced juveniles and overexploitation of spawners, which could affect the genetic diversity of the wild stocks.

Policy options

BOHAI SEA

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

Definition of the problem

The impact assessment and causal chain analysis have shown that the priority environmental problems in the Bohai Sea region are freshwater shortage, habitat and community modification, and unsustainable exploitation of living resources. Increased discharges of untreated or partially treated industrial and domestic wastewater have resulted in that more than one third of the major water bodies in the region are polluted, with the quality of their surface water below World Health Organization's drinking water standards. Increased population growth and urbanisation have burdened sewage treatment facilities but also increased the demand for food which has increased agricultural activities. Stream flow in the large river basins such as Liao, Luan, Hai and Yellow have been severely reduced, manly due to agricultural and industrial activities, as well as building of dams for hydropower generation.

Over the past few decades, many critical ecosystems and habitats in the region have been lost mainly as a result of human activities. As a result of this loss, more than 50% of employment opportunities in aquatic product processing industries have been lost. There have also been losses of freshwater and brackish habitats as well as seasonal drying up of for example the Yellow River. Modifications of the ecosystems in the region, in terms of changes in species population structure and biodiversity, are also relatively severe. Lack of adequate land and water use policies, laws and regulations for land use conversion and use of water resources for agricultural activities have exaggerated the situation.

Economic values of the fisheries sector have greatly decreased over the past decades due to decreased catch per unit effort (CPUE) and reduction in the total catches of some commercially important fish species. The introduction of new fishing technologies and increas in the number of fleets are among the causes for overexploitation. The extended aquaculture industry has contributed to the change of genetic diversity of wild populations.

Policy options and strategic action programmes

Suggested policy options and their associated Strategic action Programmes (SAP) to address the key root causes as identified above were formulated and reviewed by a panel of experts who had been previously involved in the GIWA studies. The policy options and their associated strategic action programmes for each of the key root causes in each of the environmental problem areas are formulated and listed below:

Freshwater shortage

Legal: Insufficient policies and inadequate enforcement of laws and regulations

Options:

- Adoption of policies, laws, regulations and enforcement mechanisms to (i) control and promote the efficient use of river water for agricultural and industrial uses; (ii) control discharge of polluted wastewater from agricultural run-off and by the industry sector; and (iii) indiscriminate extraction of ground water for agricultural and industrial uses.
- Adoption of the introduction of green production technologies for agricultural and industry sectors to reduce discharge of polluted wastewater.
- Adoption and integration of the management of river water use in integrated river basin management programmes.

Strategic Action Programme (SAP):

- Strengthening the enforcement of policies, laws, regulations and enforcement mechanisms to, (i) control and promote the efficient use of river water for agricultural and industrial uses; (ii) control the discharge of polluted wastewater from agricultural run-off and by the industry sector; and (iii) indiscriminate extraction of ground water for agricultural and industrial uses.
- Promotion of the use of green production technologies in the industry and agricultural sectors.
- Implementation of the management of river water use with integrated river basin management programmes.

Knowledge: Lack of public awareness and deficiencies in stakeholder participation in environmental protection

Options:

- Adoption of public awareness campaign programmes on environmental and the social consequences of the uncontrolled discharge of polluted wastewater into river systems.
- Adoption of stakeholder participation and consultation programmes in association with environmental management.

Strategic Action Programme (SAP):

- Development and implementation of public awareness campaign programmes on the environmental and social consequences of uncontrolled discharge of polluted wastewater into river systems.
- Development and implementation of stakeholder participation and consultation programmes in association with environmental management.

Demographic: Mass migration to urban areas

Options:

- Adoption of policies, laws and regulations to restrict migration.
- Adoption of the development of small, rural-oriented urban centres in rural areas to cope with population migration.

Strategic Action Programme (SAP):

- Strengthening the enforcement of laws and regulations to restrict mass migration of population from rural to urban areas.
- Implementation of the development of small, rural-oriented urban centres in rural areas to cope with population migration.

Natural causes: Lack of alternative water supplies and decreases in rainfall

Options:

- Adoption of promotional programmes on the use of green technologies in the industry sector to reduce the use of groundwater.
- Adoption of the introduction of water-saving crop irrigation technologies in agriculture to reduce the use of groundwater for irrigation.

Strategic Action Programme (SAP):

- Development and implementation of promotional programmes on the use of green technologies in the industry sector to reduce the use of groundwater.
- Promotion of water-saving crop irrigation technologies in agriculture to reduce the use of groundwater for irrigation.

Habitat and community modification

Knowledge*:* Profit-oriented attitudes that disregard environmental impacts

Options:

- Adoption of policies, laws, regulations and enforcement mechanisms to restrict the conversion of coastal wetlands for industrial development.
- Adoption of public awareness campaign programmes on the environmental and social consequences of uncontrolled conversion of coastal wetlands for industrial uses.

Strategic Action Programme (SAP):

- Strengthening the enforcement of policies, laws, regulations and enforcement mechanisms to restrict the conversion of coastal wetlands for industrial development.
- Development and implementation of public awareness campaign programmes on the environmental and social consequences of uncontrolled conversion of coastal wetlands for industrial uses.

Economic: Increased energy demand by domestic and industrial use

Option:

- Adoption of policies, laws, regulations and enforcement mechanisms for regulating the exploration and exploitation of oil and mineral resources.
- Adoption of the programmes seeking alternative energy sources.
- Adoption of the introduction of technologies in the industry sector to reduce the use of petroleum.

Strategic Action Programme (SAP):

- Strengthening the enforcement of policies, laws, regulations and enforcement mechanisms for regulating the exploration and exploitation of oil and mineral resources.
- Development and implementation of the programmes to seek alternative energy sources.
- Promotion of efficient technologies in the industry sector to reduce the use of petroleum.

Legal: Lack of adequate government land and water use policies, laws and regulations

Options:

- Adoption and development of government land and water use policies, laws, regulations and enforcement mechanisms.

Strategic Action Programme (SAP):

- Strengthening the enforcement of government land and water use policies, laws, regulations and enforcement mechanisms.

Economic: Low investment in waste treatment facilities.

Options:

- Promotion of market incentive systems to encourage the industry sector to use green production technologies.
- Enhancement of policies and laws for pollution prevention and wastewater treatment practices.

Strategic Action Programme (SAP):

- Development and implementation of market incentive programmes to encourage the use of green production technologies to reduce discharge of polluting wastes.
- Strengthening the enforcement of policies and laws for pollution prevention and wastewater treatment practices.

Unsustainable exploitation of living resources

Demographic: Shift in livelihoods of fishermen

Option:

- Adoption of relocation programmes for fishermen to the aquaculture sector in line with sustainable aquaculture development strategies.
- Adoption of training programmes on sustainable aquaculture production technologies to educate fishermen entering the aquaculture sector.

Strategic Action Programme (SAP):

- Development and implementation of relocation programmes for fishermen to the aquaculture sector in line with sustainable aquaculture development strategies.

Knowledge: Insufficient awareness of the consequences of the uncontrolled release of hatchery-produced juveniles and over-exploitation of spawning fish.

Option:

- Adoption of public awareness programmeson the environmental and biotic consequences of the mass release of hatchery-produced juveniles for wild fisheries stocks.
- Adoption of biotechnological research programmes(e.g. development of a gene bank; species selection and hybridisation) to sustain biological and genetic diversity in aquaculture and wild fisheries stocks.
- Adoption of programmes that promote good practices in aquaculture.

Strategic Action Programme (SAP):

- Development of public awareness programmes on the environmental and biotic consequences of mass release of hatchery-produced juveniles for wild fish stocks.
- Development and implementation of biotechnological research programmes to sustain biological and genetic diversity of aquaculture and wild fish stocks.

Knowledge: Profit-driven attitudes of fisheries operators

Option:

- Adoption of alternative livelihood programmes to reduce the entry of excessive number of fishermen into the fisheries sector.
- Adoption of fisheries capacity reduction programmes to mitigate excessive fishing efforts and to reduce the entry of excessive number of fishermen into the fisheries sector.

Strategic Action Programme (SAP):

- Development and implementation of alternative livelihood programmesto reduce the entry of excessive number of fishermen into the fisheries sector.
- Development and implementation of fisheries capacity reduction programmesto mitigate excessive fishing efforts and to limit the entry of fishermen into the fisheries sector.

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Conclusions and recommendations

YELLOW SEA & BOHAI SEA

The GIWA assessment of the Yellow and Bohai Seas aimed to identify actions for remedial and mitigatory actions. The report investigates the ecological status, the causes of their degradation and the policy options available to improve their status. From an ecological perspective, the Bohai Sea proper is a large, shallow embayment of the Yellow Sea. The Yellow Sea, in turn, is a shallow continental sea of the northwest Pacific Ocean. These relationships are important because of the physical and biological links between these systems; in particular, the fish and shellfish stocks in the Yellow Sea are dependent on the Bohai Sea as a reproduction and nursery area. Given that the Bohai Sea is not a transboundary waterbody, the assessment report of the Bohai Sea is included in this report as an appendix to be used as a reference for further understanding of the Yellow Sea's environmental problems.

The GIWA assessment ranked modification of stream flow, pollution of freshwater supplies, loss and modification of ecosystems, overexploitation of fish resources and destructive fishing practices as having severe impacts and were considered the priority issues in the Yellow Sea region. The region has experienced both significant reduction of water flow in the major river systems on both the Chinese and Korean side, as well as pollution of existing water resources, mainly from agriculture and industrial activities. There have been significant losses and modification of habitats in the region during the past 30 years. Increased industrialisation has attracted mass migration of the rural population to urban areas. This rapid population growth has resulted in the need to convert more lands for human settlement as well as an increase of discharge of harmful pollutants to the water bodies. At the same time, the population growth has increased the demand for food and agricultural products, resulting in the increased use of freshwater for crop production.

The Yellow Sea is one of the most exploited areas in the world. The increase in fishing effort following the introduction of bottom trawler in the early 20th century resulted in that almost all major stocks were fully fished by the mid-1970s and overfished by the 1980s. Fishing with destructive methods is common throughout the region and many aquatic habitats in have been destroyed and fish stocks have collapsed. Common destructive fishing practices in the region include indiscriminate trawling along the coastal waters of Yellow Sea, fishing with explosives in lakes, and use of pesticides for fishing.

The transboundary issues that need to be addressed are the management of marine resources, industrial pollution, and ecosystem health. Progress is being made in the introduction of ecosystem-based management for this region.

However, policy options involving the management of transboundary issues in the region may be hindered by several factors such as the ineffectiveness of measures for the control of the overexploitation of shared stocks in the Yellow Sea and deficiency of existing national and international efforts to arrest degradation of coastal water quality due to discharge of pollutants from land- and sea-based activities.

In the Bohai Sea region, modification of stream flow, pollution of existing freshwater supplies, changes in the water table, loss and modification of ecosystems, overexploitation of living resources and impact of fisheries on biological and genetic diversity were ranked as severe and were considered the priority issues in the region.

Stream flows of the major river basin of the Bohai Sea region have been severely reduced and business costs have increased by 10% with frequent interruption of water supply. More than 30% of the major river basins in the region have also been polluted, resulting in a quality of their surface water that is below the World Health Organization (WHO) drinking water standards. Moreover, large-scale salinisation of coastal aquifers has occurred over the past decades.

Over the past few decades, many critical ecosystems and habitats in the region have been lost mainly as a result of human activities. The extent of these losses is estimated to account to 30-50% of their total area. The lost ecosystems have been found to include freshwater marshlands, running water wetlands, saline habitat wetlands, rivers, lakes, sandy foreshores, rocky foreshores, sand and gravel bottoms and mud bottoms. As a result of this loss, more than 50% of employment opportunities in aquatic product processing industries have also been lost.

Although policy options are defined for every specific root cause, some policy options are universally applicable, and could be recommended as the actions of highest priority for the Bohai Sea region. These are:

- Adoption of policies, laws, regulations and enforcement mechanisms;
- Introduction of green production technologies;
- Integration of river basin management;
- Adoption of public awareness campaign and stakeholder participation programmes;
- Development of small, rural-oriented urban centers in rural areas to cope with population migration;
- Finding alternative energy sources to reduce the use of petroleum;
- Training programmes on sustainable aquaculture production technology, and relocation programmes for traditional fishermen;
- Alternative livelihood programmes to reduce fisheries capacity.

The management of the Yellow Sea and the adjacent Bohai Sea is especially complicated in that it is surrounded by nations that share some historical and cultural aspects but differ in political systems, political and economic alignment, and levels of economic development. There are several agreements for bilateral regulation or development of the Yellow Sea Large Marine Ecosystem, however none of them are binding on all the nations and nor is any nation a party to all the agreements. In addition, many of the existing national management policies or bilateral management programme for the region have been designed and carried out with insufficient attention to transnational issues.

Annexes

YELLOW SEA & BOHAI SEA

Annex I
List of contributing authors and organisations

Yellow Sea

Name	Institutional affiliation	Country	Field of work
Mr. Ronald Bonifacio	Coastal Management Center, Manila	Philippines	Toxicology of marine fauna; technology development of seaweed culture and processing; Integrated coastal and marine management
Dr. Shang Chen	Key Laboratory for Science and Engineering of Ecological Environment, First Institute of Oceanography (FIO), State Oceanic Administration (SOA), Qingdao,	China	Marine ecosystems; Environmental modelling
Dr. Chung-Il Choi	Department of Earth and Marine Sciences, Hanyang University, Seoul	Korea	Ecology; Limnology; Conservation biology
Mr. Jingyao Deng	Yellow Sea Fisheries Research Institute, Qingdao	China	Fisheries stock assessment/ management
Dr. Rogelio O. Juliano	Coastal Management Center, Manila	Philippines	Aquaculture & Fisheries; Coastal Resource Management; Integrated Coastal and Marine Management
Dr. Daeseok Kang	Korea Maritime Institute, Seoul	Korea	Systems ecology; Coastal Management; Ecological Economics
Dr. Dong-Young Lee	China-Korea Joint Ocean Research Center, Qingdao	China	Coastal engineering, Marine meteorology
Dr. Daoji Li	Institute of Estuarine and Coastal Research, East China Normal University, Shanghai	China	Marine Environmental Science
Mr. Fengchao Liu	Dalian Polytechnical University, Dalian	China	Regional economics
Prof. Hongbin Liu	Shandong Marine Economics Research Institute, Qingdao,	China	Socio-economics
Mr. Qiming Ma	Qingdao Ocean University, Qingdao	China	Environmental engineering
Mr. Minghui Ma	NMEMC, Dalian	China	Marine ecology
Dr. Gyung-Soo Park	West Sea Fisheries Research Institute National Fisheries Research and Development Institute, Bupyung-Gu	Korea	Marine ecosystem; Ecology; Marine pollution
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Mr. Baodong Wang	First Institute of Oceanography, Qingdao	China	Marine chemistry
Mr. Xiulin Wang	Oingdao Ocean University, Qingdao	China	Marine chemistry
Dr. Dong-Beom Yang	Marine Environment and Climate Change Laboratory, Korea Ocean Research & Development Institute	Korea	Environmental management (Yellow Sea); Marine chemistry and water quality
Prof. Chang-cheng Ye	Marine Fisheries Research Institute, Dalian	China	Fishery resource enhancement/ assessment

Prof. Chun Ye	Chinese Research Academy of Environmental Sciences, Beijing	China	Ecological engineering
Dr. Huming Yu	China Institute for Marine Affairs, Beijing	China	Coastal management; fisheries management
Prof. Qingdong Yu	Qingdao University, Qingdao	China	System engineering
Dr. Yueli Yuan	First Institute of Oceanography, Qingdao	China	Physical oceanography and modelling
Ms. Shu Zhang	Dalian Water Conservancy Bureau, Dalian	China	Fresh water resources assessment
Mr. Xuelei Zhang	First Institute of Oceanography,Qingdao	China	Marine ecosystems
Dr. Mingyuan Zhu	Key Laboratory for Science and Engineering of Marine Ecological Elements, First Institute of Oceanography, Qingdao	China	Coastal resource management; marine ecology
Prof. Kelin Zhuang	Qingdao Marine Geological Institute, Qingdao	China	Marine geology
Mr. Zhenyue Zhuang	Qingdao Ocean University, Qingdao,	China	Marine sedimentation and environment

Bohai Sea

Name	Institutional affiliation	Country	Field of work
Mr. Ronald Bonifacio	Coastal Management Center, Manila,	Philippines	Toxicology of marine fauna; technology development of seaweed culture and processing; Integrated coastal and marine management
Mr. Zhenxing Dou	National Marine Environmental Monitoring Center, Dalian	China	Physical oceanography; water quality modeller
Mr. Zhijie Fan	NMEMC, Dalian	China	Marne pollution monitoring
Dr. Rogelio O. Juliano	Coastal Management Center, Manila	Philippines	Aquaculture & Fisheries; Coastal Resource Management; Integrated Coastal and Marine Management
Mr. Jianguo Lin	College of Environmental Science and Engineering, Dalian Maritime University	China	Ocean dynamics, marine transportation
Ms. Xinzhen Lin	NMEMC, Dalian	China	Science and technology management
Mr. Fengchao Liu	Dalian Polytechnical University	China	Regional economics
Prof. Hongbin Liu	Shandong Marine Economics Research Institute, Qingdao,	China	Socio-economics
Prof. Guohai Liu	Liaoning Normal University, Dalian	China	Marine economics; Geography
Mr. Deyi Ma	NMEMC, Dalian	China	Marine chemistry; environmental impact assessment
Mr. Qiming Ma	Qingdao Ocean University, Qingdao	China	Environmental engineering
Mr. Minghui Ma	NMEMC, Dalian	China	Marine ecology
Dr. Elina Rautalahti-Miettinen	GIWA Core Team, UNEP-GIWA Co-ordination Office	Sweden	Environmental management; Coastal and marine resources management
Prof. Yufang Song	Shengyang Applied Ecology Institute, Chinese Academy of Sciences	China	Ecology
Prof. Yuxiang Tang	Physical Oceanography Division, First Institute of Oceanography, State Oceanic Administration, Qingdao	China	Physical oceanography; Global climate change
Dr. Seng-Keh Teng	Coastal Management Center, Manila	Philippines	Aquaculture & Fisheries; Coastal Resource Management; Integrated Coastal and Marine Management
Prof. Ling Tong	Yellow Sea Fisheries Research Institute, Qingdao	China	Fisheries stock assessment/management
Mr. Jin Xia	Dalian Environmental Science Institute, Dalian	China	Water environment and resources protection
Mr. Xueren Xu	NMEMC, Dalian	China	Oil pollution monitoring and assessment
Prof. Chang-cheng Ye	Marine Fisheries Research Institute, Dalian	China	Fishery resource enhancement/ assessment
Dr. Huming Yu	Chinise Institute for Marine Affairs, Beijing	China	Coastal management; fisheries management
Ms. Shu Zhang	Dalian Water Conservancy Bureau, 32,Gorky Road, Xigang District, Dalian 116011, P. R. CHINA. Tel: +86 4113634098(o); +86 411 4216995(H).	China	Fresh water resources assessment
Dr. Mingyuan Zhu	Key Laboratory for Science and Engineering of Marine Ecological Elements, First Institute of Oceanography, Qingdao	China	Coastal resource management; marine ecology
Prof. Kelin Zhuang	Qingdao Marine Geological Institute, Qingdao	China	Marine geology
Mr. Zhenyue Zhuang	Qingdao Ocean University, Qingdao	China	Marine sedimentation and environment

Annex II
Detailed scoring tables: Yellow Sea

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	3	40	Freshwater shortage	2.6
2. Pollution of existing supplies	3	20		
3. Changes in the water table	2	40		

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

Note: N/a = Not applied.

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	2	10	Pollution	1.9
5. Eutrophication	3	35		
6. Chemical	1	10		
7. Suspended solids	1	20		
8. Solid wastes	2	10		
9. Thermal	1	5		
10. Radionuclides	N/a	N/a		
11. Spills	1	10		

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

Note: N/a = Not applied.

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	3	50	Habitat and community modification	3.0
13. Modification of ecosystems or ecotones, including community structure and/or species composition	3	50		

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

Note: 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	50	Unsustainable exploitation of fish	2.6
15. Excessive by-catch and discards	1	5		
16. Destructive fishing practices	3	20		
17. Decreased viability of stock through pollution and disease	1	5		
18. Impact on biological and genetic diversity	2	20		

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

Note: N/a = Not applied.

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	40	Global change	1.4
20. Sea level change	1	60		
21. Increased UV-B radiation as a result of ozone depletion	N/a	N/a		
22. Changes in ocean CO_2 source/sink function	N/a	N/a		

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

Note: N/a = Not applied.

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts: Environmental score		Economic score		Human health score		Social and community score		Overall score	Rank
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Freshwater shortage	2.6	1	1	2	1	0	2	1	1.3	5
Pollution	1.9	2	3	2	1	1	2	2	1.9	3
Habitat and community modification	3.0	3	1	1	2	1	3	3	2.1	2
Unsustainable exploitation of fish and other living resources	2.6	2	1	2	3	2	2	3	2.2	1
Global change	1.4	2	1	2	1	1	2	2	1.6	4

Detailed scoring tables: Bohai Sea

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	3	40	Freshwater shortage	3.0
2. Pollution of existing supplies	3	40		
3. Changes in the water table	3	20		

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

Note: N/a = Not applied.

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	2	20	Pollution	2.3
5. Eutrophication	3	35		
6. Chemical	2	10		
7. Suspended solids	1	10		
8. Solid wastes	2	15		
9. Thermal	1	5		
10. Radionuclides	N/a	N/a		
11. Spills	3	5		

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

Note: N/a = Not applied.

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	2	40	Habitat and community modification	2.6
13. Modification of ecosystems or ecotones, including community structure and/or species composition	3	60		

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

Note: 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	45	Unsustainable exploitation of fish	2.6
15. Excessive by-catch and discards	1	5		
16. Destructive fishing practices	2	10		
17. Decreased viability of stock through pollution and disease	2	20		
18. Impact on biological and genetic diversity	3	20		

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

Note: N/a = Not applied.

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	50	Global change	1.0
20. Sea level change	1	50		
21. Increased UV-B radiation as a result of ozone depletion	N/a	N/a		
22. Changes in ocean CO_2 source/sink function	N/a	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	3	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	N/a
Weight average score for Economic impacts		**3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	N/a
Degree of severity	Minimum – Severe 0 1 2 3	1	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	N/a
Weight average score for Health impacts		**1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	N/a
Degree of severity	Minimum – Severe 0 1 2 3	2	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	N/a
Weight average score for Other social and community impacts		**2**	

Note: 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	3.0	3	1	1	1	1	1	1	1.5	3
Pollution	2.3	1	2	2	1	1	2	1	1.5	4
Habitat and community modification	2.6	2	3	3	1	2	3	3	2.5	2
Unsustainable exploitation of fish and other living resources	2.6	3	3	3	2	2	3	3	2.7	1
Global change	1.0	1	3	2	1	1	2	1	1.5	5

Annex III
List of important water-related programmes and assessments

North Pacific Marine Science Organisation (PICES)

PICES is an intergovernmental scientific organisation established in 1992 with Canada, People's Republic of China, Japan, Republic of Korea, the Russian Federation, and the United States of America as its participating members. PICES was established to promote and coordinate marine research in the North Pacific and adjacent seas at latitudes of 30 degrees north. Its activities are to advance scientific knowledge about the ocean environment, global weather and climate changes, living resources and their ecosystems, and the impacts of human activities as well as to promote the collection and rapid exchange of scientific information on these issues. Website: http://pices.ios.bc.ca/

UN Economic and Social Commission for Asia and the Pacific (ESCAP)

Water-related activities in Asia and the Pacific Region are carried out under ESCAP's "Water Resources Programme", Environment and Natural Resources Development Division. The UN ESCAP organises seminars and workshops in tackling various issues including those related to: (a) Water resources assessment; (b) Integrated water resources development and management; (c) Protection of water resources, water quality and aquatic ecosystems; (d) River basin development and management; (e) Promotion of infrastructure development and investment for drinking water supply and sanitation; (f) Water pricing and promotion of private investment in the water sector; (g) Water demand management, water saving and economic use of water; and (h) Mitigation of water-related natural disasters, particularly flood loss reduction. Website: http://www.unescap.org/

UNEP Regional Office for Asia and the Pacific (ROAP)

ROAP reports directly to the Division of Regional Co-operation and Representation of UNEP's headquarters in Nairobi. It was established to adopt global environmental policies to meet the regional priorities and needs, putting particular emphasis on building partnerships with regional and subregional and intergovernmental agencies, other UN agencies, national governments, NGOs, the private sector, academic and research institutions, civil society and the media. ROAP also acts as a catalyst, coordinator, facilitator and mobiliser of resources to support these activities. Website: http://www.roap.unep.org/

Northwest Pacific Action Plan (NOWPAP)

NOWPAP was initiated by UNEP through its regional seas programme to assist China, Japan, Russia and Korea to co-operatively manage the ocean and sea environment shared by these four countries. The goal of NOWPAP is to achieve sustainable use, development and management of the coastal and marine environment so as to obtain the utmost long-term benefits for the human populations of the region, while protecting human health, ecological integrity and the region's sustainability for future generations. In order to enhance the execution and implementation of the action plan, a core center, the Northwest Pacific Region Environmental Cooperation Center (NPEC), was established in 1997 for initiating the cooperation among the countries and regions involved for the environmental protection in the Sea of Japan and Yellow Sea. The Center became a public service corporation under the Japanese Environment Agency in 1998 and was also designated to be one of the Regional Activity Centers of Northwest Pacific Action Plan in 1999. NPEC functions as a Special Monitoring and Coastal Environmental Assessment Centre for NOWPAP. Website: http://www.npec.or.jp/english/index.htm

Nautilus Institute for Security and Sustainable Development

The Nautilus Institute is a policy-oriented research and consulting organisation that promotes international cooperation for security and ecologically sustainable development. The Institute has programmes that address both global and regional issues on marine environment, sustainable development and environmental cooperation, focusing on those in the Northeast Asia and Asia-Pacific regions. Nautilus produces reports, organises seminars, and provides educational and training services for policymakers, media, researchers and community groups. Website: http://www.nautilus.org/

Partnership in Environmental Management for the Seas of East Asia (PEMSEA)

PEMSEA is a GEF project with goals of building partnership within and among governments as well as with the public and private sectors of the East Asian Seas region in the environmental management and in reducing or removing barriers to effective environmental management such as the inadequate or inappropriate policies, disparate institutional and technical capabilities and limited investment in environmental facilities and services. PEMSEA is working based on two management frameworks, namely, the integrated coastal management (ICM) framework for coastal area management and the risk assessment/management framework for assessing the impacts of human activities on marine ecosystems in sub-regional sea areas. Six ICM demonstration sites (one each in Vietnam, Cambodia, Indonesia, Thailand, DPR Korea and Malaysia) and two sub-regional sea environmental management demonstration sites, one each in the Gulf of Thailand and the Bohai Sea were established to test and validate the implementation of PEMSEA's environmental management frameworks. Website: http://www.pemsea.org/

UNEP Regional Seas Programme

The UNEP Regional Programme, established in 1974, is a global programme for sustainable management of the coastal and marine environment areas on a regional basis. The Programme includes 14 regional seas (Mediterranean, Red Sea and Gulf of Aden, ROPME Sea Area, Wider Caribbean, East Asian Seas, South-East Pacific, East Africa, West and Central Africa, South Pacific, Black Sea, North-West Pacific, South Asian Seas, North-East Pacific) and five partner seas (Baltic, North-East Atlantic, Arctic, Antarctic and Caspian) involving 140 coastal states worldwide. Each regional sea and partner sea may have a Regional Action Plan, which is formulated according to the needs and priorities of the region as perceived by the concerned governments. Regional Seas Conventions are in place for several regional sea areas. The Regional Seas Convention provides the legal framework for the Regional Action Plan. It expresses in clear terms the legal commitment and political will of governments to tackle their common environmental problems. Website: http://www.unep.ch/seas/rshome.html

Wetland Biodiversity Conservation and Sustainable Use Programme, China

The Programme and the National Wetland Conservation Action Plan provide the foundation for the conservation and better management of the wetland resources in China. The Programme aims to reduce the barriers that deter effective conservation of wetland biodiversity in China; these barriers include: i) a lack of integration of wetland management and biodiversity conservation into development planning; ii) no institutional mechanisms for multi-sectoral wetland management; iii) limited awareness of wetland values and functions at all levels; iv) lack of examples of sustainable development of wetland resources and involvement of local communities; and v) lack of technical capacity at national and local levels to manage and conserve wetlands and their biodiversity. The proposed project will remove these barriers at four demonstration project sites (Sanjiang Plain, Ruoergai Marshes, Yancheng Coast and Dongting Lakes) with high global biodiversity importance. Each demonstration site represents a different ecosystem. A national coordination unit works to ensure that lessons learned from this project will be appropriately transferred to other wetlands throughout the country. Website: http://edcnts2.cr.usgs.gov/gef/gef.asp?fipscode=623

Large Marine Ecosystem Project

The Large Marine Ecosystem Project is a global effort initiated by the World Conservation Union (IUCN), the Intergovernmental Oceanographic Commission of UNESCO (IOC), other United Nations agencies, and the US National Oceanic and Atmospheric Administration (NOAA). The project aims to improve the long-term sustainability of resources and environment of the Large Marine Ecosystems (LMEs) worldwide. The project provides scientific and technical assistance to developing countries committed to advancing new policies and actions for eliminating causes of trans-boundary environmental and resource-use practices leading to serious degradation of coastal environment, linked watersheds, and losses in biodiversity and food security from exploitation in LMEs located around the margins of the Pacific, Indian and Atlantic Oceans. The Yellow Sea has been studied by this project and designated as one of the global "Large Marine Ecosystems" (LME), the LME #48. Website: http://na.nefsc.noaa.gov/lme/project.htm

Yellow Sea LME Project

The Yellow Sea LME Project is a GEF project recently approved for implementation with the involvement of the People's Republic of China and the Republic of Korea. The project was developed as a comprehensive response to the key environmental problems facing the region with GEF helping to address the priority transboundary issues. The long-term objective of the project is: "Ecosystem-Based, Environmentally-Sustainable Management and Use of the YSLME and its Watershed: Reducing Development Stress and Promoting Sustainable Development of the Ecosystem from a Densely Populated, Heavily Urbanised, and Industrialised Semi-Enclosed Shelf Sea". In order to achieve its objective this project will prepare a Transboundary Diagnostic Analysis (TDA), National Yellow Sea Action Plans (NYSAPs), and a regional Strategic Action Programme (SAP). This project will also initiate and facilitate the implementation of the SAP. The SAP will consist of a series of legal, policy and institutional changes and investments to address the priority transboundary issues identified in the TDA/SAP formulation process. Website: http://www.gefweb.org

Green Vision 21 of Republic of Korea (1995 - 2005)

Green Vision 21 presents the policy approach to provide advanced environmental administrative services and make the environment of the land and waters in the Republic of Korea ecologically sound for future generations. The vision includes the idea of "Environmentally Sound and Sustainable Development (ESSD)", environmentally friendly consumption and business management.

Website: http://www.me.go.kr:8080/me/environment/html/polices/president.htm#seoul

Blue Sea Action Plan for Bohai Sea

The action plan was ratified by the State Council in 1999, when the comprehensive treatment project of Bohai Sea was kicked off. The project covers three provinces and one municipality surrounding Bohai Sea (Hebei, Liaonin and Shandong Provinces and Tianjin Municipality) and participated by the provinces and municipalities in the economic zone surrounding Bohai Sea. The overall targets of the project are the natural resource exploration of Bohai Sea, sustainable development of ecological environment and sustainable, healthy development of the social economy in the economic zone surrounding the Bohai Sea. The main focuses are pollution control, environmental treatment, restoration of natural resource environment, ecological environmental remedy and disaster prevention and control. The key actions are estuary wetland protection and ecological remedy, pollution prevention in the bay, healthy aquatic farming, habitat remedy in the tidal areas and warning and prevention of red tides, oil spillage and marine ice. Website: http://www.zhb.gov.cn/english/SOE/soechina1999/sea/seadown.htm

Other water-related programmes

Other completed or on-going water-related programmes in the region include:

- Stock Monitoring in the Yellow Sea (1998-2000);
- Yellow Sea and East China Sea GLOBEC (1999-2004);
- Sino-Norway Joint "Bei Dou" Project (1998-2004);
- Water Circulation of China Seas and its Impacts on Environmental Resources (1999-2004);
- Marine Biodiversity Action Plan (1999-2004);
- Harmful Algal Bloom Monitoring Study (1999-2004);
- Blue Sky and Clean Sea Action Plan (1999-2004);
- Survey on the Marine Living Resources in the Yellow Sea (ongoing);
- Survey on the Oceanographic Conditions in the Yellow Sea (ongoing);
- Community Structure of the Fisheries Resources in the Yellow Sea (ongoing); and
- Changes in Oceanographic Conditions and Ecosystems in the Kunsan Waters (ongoing).
- Bohai Sea GLOBEC (1997-2000);
- Fishery Biodiversity and its Conservation in the Bohai Sea (1997-2000);

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

People's Republic of China

Laws, regulations and rules

Administration Law on the Use of Ocean Space of the People's Republic of China, effective as of January 1, 2002

This Law seeks to use a property rights and quasi-exclusive ownership approach to manage the principal ocean uses and ocean resources present in the Chinese territorial sea. The Law sets out a framework for classifying uses of ocean space and granting licenses to use ocean space according to the functions classified. Persons who wish to use ocean space may apply for a license to use such space and may have their rights of use registered in a central registry. It seeks to promote the rational development and sustainable utilisation of ocean space by bringing the majority of ocean uses under one umbrella and employing an integrated approach to management. This is a new law with the objective of strengthening and preserving:

- Administration of the use of ocean space in China;
- Ownership of the country's ocean space;
- Lawful benefits of the users of ocean space.

Law of the People's Republic of China on the Territorial Sea and the Contiguous zone, effective as of 25 February 1992

This law fixes the breadth of the territorial sea of the People's Republic of China at 12 nautical miles as measured from the baseline of the territorial sea (Art. 3). It also establishes a contiguous zone adjacent to and beyond the territorial sea (Art. 4). Article 2 of the law lists all the archipelagos and islands over which the People's Republic of China exercises its sovereignty. Article 6 grants innocent passage to foreign civilian vessels. However, foreign military ships must seek permission from the Government of China before entering the territorial sea. All foreign ships passing through the territorial sea must comply with laws and regulations in force at the time. All international organisations, foreign organisations or individuals must also obtain approval from the Chinese government before carrying out scientific research or other activities in the territorial sea. Further provisions set out the enforcement powers of the Chinese authorities under this Law.

Decision of the Standing Committee of the National People's Congress on approval of the United Nations Convention on the Law of the Sea. Date of text: 15 May 1996

The Decision signifies the full adoption of UNCLOS treaty norms by China, including particularly the concept of the 200 nm EEZ and a Continental Shelf generally limited to 200 nm. The statement declares that "in accordance with the provisions of the Convention, the People's Republic of China proclaims that it has sovereignty and jurisdiction over its exclusive economic zone and continental shelf of 200 nautical miles". Additionally, the Decision states that the People's Republic of China shall delimit a demarcation line between China's maritime jurisdiction and the maritime jurisdictions of China's neighbouring or facing countries, and shall have sovereignty over all archipelagos and islands listed in article 2 of China's Law on the Territorial Sea and the Contiguous Zone of 25 February 1992. This text is significant given the contested status of some of the islands off the coast of China.

People's Republic of China Exclusive Economic Zone and Continental Shelf Law of 26 June 1998

This Law contains 16 articles and demonstrates the further implementation of UNCLOS norms by China. It defines the EEZ and the continental shelf of PRC China and specifies the jurisdictional powers that China will exercise in these maritime areas. Article 5 states that foreign fishing in the EEZ requires the approval of responsible authorities. The responsible authorities also have the right to conserve and manage straddling fish stocks, highly migratory fish stocks and marine mammals in the EEZ. China also asserts rights over anadromous fish originating in rivers in China and catadromous species that spend the greater part of their life cycle in the waters of China: Article 6. Article 10 specifies the powers of the responsible authorities with respect to prevention and control of marine pollution.

Fisheries Law of the People's Republic of China

This Law came into effect on 1 July 1986 and was extensively amended in October 2000 (see below). It seeks to:

- Enhance the protection, proliferation, exploitation and rational utilisation of fishery resources,;
- Develop artificial cultivation;
- Ensure the lawful rights and interests of fishery workers; and
- Boost fishery production to meet the needs of the country and the people.

Decision amending the Fisheries Law of the People's Republic of China of December 2000

This Decision consists of 25 amendments to the Fisheries Law of the People's Republic of China. A key amendment is in Article 9 which limits the commercial role of the State as follows: "'the Department of Fishery Administration or superintendence department or any members of the Department of Fishery Administration or superintendence shall not be engaged in any fishery production or marketing activities". Other amendments seek to modernise the rules relating to fishing methods, fishing licenses, fishing areas, and vessels. More extensive offences and penalties reflecting concepts of responsible fishing are also provided for.

Regulations on fishing licence management, 1989

These Regulations aim to protect and rationally utilise fishery resources, regulate fishing intensity, maintain production order and safeguard the legitimate rights and interests of fishing operators whilst promoting fishery development. Three types of licences are provided for: fishing licences (including licences for fishing in coastal waters, high seas and inland waters); special fishing licences and; temporary fishing licences. Licensing authorities, procedures and conditions attached to each type of licence are defined. It still remains to be fully worked out how the licensing system under these Regulations relates to the Law on Use of Ocean Space.

Regulations of the People's Republic of China for the implementation of wild aquatic animal protection of October 1993

These Regulations aim at the management and conservation of wild aquatic animal resources. The responsible Departments of Fishery Administration at the central and local level are required to carry out surveys of wild aquatic animals on a regular basis, to support preparation and revision of lists of wild aquatic animals that require special protection by the State or local authorities. The catching or killing of all wild aquatic animals under special protection is prohibited by this Law. The Law states that the catching of wild aquatic animals may only be allowed under license and for the following purposes: scientific research or production of medicines; education or exhibitions; domestication or breeding of wild aquatic animals; other special reasons. Other provisions cover inter alia: (a) applications for special licences for catching wild aquatic animals; (b) obligations of licence holders; (c) the sale, purchase or utilisation of wild aquatic animals under special State protection; (e) a supervision and inspection system; (f) the transport or carrying of wild aquatic animal or products thereof to be effected out of the county; (g) the export of wild aquatic animals under special protection; (h) awards and penalties.

Law of the People's Republic of China on the Protection of Wildlife 1988

The purpose of this Law is to lay down the general principles of wildlife protection and administration of wildlife in the PRC, and to provide for the protection of species of wildlife that are rare or near extinction; the protection, development and rational use of wildlife resources and the maintaining of ecological balances. The basic principle is that wildlife resources are owned by the State (art. 3).

Mineral Resources Law of the People's Republic of China

This Law covers the development of the mining industry and promotes the exploration, development, utilisation and protection of mineral resources in the present and the long term. Offshore oil and gas licenses are granted under this Law and more detailed and specific production contracts are authorised. Environmental control issues are addressed under the Marine Environment Protection Law. It remains to be seen how the new law on Use of Sea Areas will be integrated with this Law.

The Environmental Protection Law of the People's Republic of China of 26th December 1989

The Environmental Protection Law of the People's Republic of China came into effect on 26 December 1989. This Law is a general environmental protection statute but has implications for marine environmental protection in that it was formulated to protect and improve the environment, prevent and control pollution, safeguard human health and facilitate development and modernisation. The objectives of this Law are to protect and improve the environment, to prevent and remedy pollution, to safeguard human health, and to promote modern development. The Law provides for: (i) the integration of environmental protection into development planning; (ii) the promotion of environmental education; (iii) the obligation of individuals and units to protect the environment; (iv) the responsibilities of government bodies, at the central, provincial, regional and municipal levels, in respect of supervision and administration of environmental protection activities.

The Marine Environment Protection Law of the People's Republic of China 1983 (revised December 25, 1999; revision effective from 1st April 2000)

The Marine Environment Protection Law of the People's Republic of China first came into effect in 1983. This Law applies to all zones under Chinese jurisdiction: internal waters, the territorial sea, the exclusive economic zone and the continental shelf and any other sea areas under the jurisdiction of China. The Law also extends to any areas beyond the jurisdiction of China where activities cause pollution in areas within China's jurisdiction. The law establishes a coordinated system of pollution management between the various government ministries charged with controlling pollution. Its overall purpose is to protect and improve the marine environment, conserve marine resources, prevent pollution damage, maintain the ecological balance, safeguard human health and promote sustainable economic and social development. The Law also formally establishes an EIA system.

Regulations of the People's Republic of China on the prevention of vessel-induced sea pollution of 1983

These Regulations implement provisions of the Marine Environmental Protection Law. The text consists of 56 articles divided into 12 Chapters: General provisions (I); General stipulations (II); Documents and equipment (III); Oil operations and discharge of oil-polluted water by vessels (IV); Dangerous goods carried by vessels (V); Other polluted water from vessels (VI); Garbage from vessels (VII); Use of vessels to dump waste (VIII); Surface and submerged projects of ship repair, ship building, ship salvage and ship scrapping (IX); Compensation for harm from pollution accidents caused by vessels (X); Supplementary provisions (XII). These Regulations are applicable to all Chinese and foreign vessels, ship owners and other individuals within the sea areas and harbours under the jurisdiction of the PRC (art. 2). The State fishing administrations and organs of supervision and control of fishing harbours shall exercise the functions and powers of the organs in charge as stipulated in these Regulations in fishing harbour water areas (art. 54).

Regulations of the People's Republic of China on control over dumping of wastes in seawater of 06 March 1985

The term "dumping" as used in these Regulations refers to discharging wastes and other substances into the ocean by means of vessels, aircraft, platforms, and other manmade structures used on the sea. In addition it also refers to the discharge of wastes and other substances caused by submarine exploration and exploitation of mineral resources and related maritime processing (art. 2). These Regulations apply to: (a) dumping of wastes into the sea areas under jurisdiction of the PRC; (b) loading of wastes on land or in harbours of the PRC for the purpose of dumping; (c) transport and burning of wastes in sea areas under jurisdiction of the PRC (art. 3). The areas of dumping shall be designated by the National Oceanographic Bureau (art. 5). Units that wish to dump waste into the ocean shall apply for permission with the Bureau or one of its agencies (art. 6). Bringing waste from foreign countries into the sea areas under the jurisdiction of the PRC shall be prohibited (art. 7). Waste matters fall into three categories in view of their toxicity, content of harmful elements and impact upon the marine environment (art. 11). Dumping of wastes listed in Annex I is prohibited; dumping of wastes as listed in Annex II shall require a special permit; wastes other than listed in Annex I or II require an ordinary permit. The remaining provisions deal with procedures of dumping, monitoring and testing in dumping areas, and offences and penalties. (24 articles and 2 Annexes)

Regulations of the People's Republic of China on the prevention of pollution damage to the marine environment by land-sourced pollutants: 22 June 1990

These Regulations further implement the Marine Environment Protection Law. They focus on strengthening the supervision and administration of land pollution sources and preventing pollution damage to the marine environment by land-sourced pollutants. They require that the discharge of land-sourced pollutants into the sea by any organisation or individual be conducted in compliance with the standards for discharge of pollutants and the relevant regulations promulgated by the State or the relevant locality. The control of pollutants discharging and treating facilities is entrusted to the environmental protection department in the place where the organisation or individual concerned is located.

Seawater Quality Standard of the People's Republic of China – entry into force on July 01, 1998

This Standard classifies seawater quality into four grades, and gives quality standards for each grade of seawater. It implements the relevant provisions of the Environment Protection Law and the Marine Environment Protection Law. It provides guidance on standards to be used to prevent and control seawater pollution, protect marine biological resources and other marine resources, and preserve the marine ecosystem generally.

Law of the People's Republic of China on Prevention and Control of Water Pollution of 1984

This Law aims at the prevention and control of pollution of rivers, lakes, canals, irrigation channels, reservoirs and other surface water bodies and groundwater. As such it is crucial to control of pollution in the marine zone. It has seven Chapters as follows:

- Chapter I - General Provisions;
- Chapter II - Establishment of Water Environment Quality Standards and Pollutant Discharge Standards;
- Chapter III - Supervision and Management of the Prevention and Control of Water Pollution;
- Chapter IV - Prevention of Surface Water Pollution;
- Chapter V - Prevention of Groundwater Pollution;
- Chapter VI - Legal Liability;
- Chapter VII - Supplementary provisions.

Rules for implementation of the Law of the People's Republic of China on the prevention and control of water pollution (2000)

These Rules implement article 61 of the Law on the Prevention and Control of Water Pollution. Article 2 establishes the content of unified plans based on river basins or regions, in line with Article 10 of the Law. Further provisions concern the supervision and management of the prevention and control of water pollution (a) when projecting the minimum discharge of a dam on large or medium-sized reservoirs; (b) with regard to the planning and adjustment of various water body reserves; (c) with regard to construction projects using imported technologies or equipment and discharging pollutants into water bodies; (d) in the case of discharge of pollutants in excess of the national or local pollutant discharge standards.

Decision of the State Council on several issues concerning environmental protection of 3 August 1996

The Decision aims at strengthening the prevention and control of water pollution in rivers, lakes, reservoirs and coastal waters. It deals with those situations where attempts to control discharged water pollutants within prescribed standards still fail to meet national prescribed standards for water environment quality. It establishes a system of control over maximum quantities major pollutants that can be discharged into water as well as a verification procedure.

Law of the People's Republic of China on Water and Soil Conservation Date of 29 June 1991

This Law supports the decrease of land-based pollution of the marine zone. It addresses a broad spectrum of concerns such as the prevention and control of soil erosion, the protection and rational utilisation of water and soil resources, the mitigation of disasters from floods, drought and sandstorms, the improvement of the ecological environment and the development of production. This statute has six chapters as follows:

- Chapter I - General Provisions;
- Chapter II - Prevention of erosion and other forms of damage;
- Chapter III - Rehabilitation;
- Chapter IV - Supervision and administration;
- Chapter V - Legal Responsibility, offences and penalties.
- Chapter VI - Supplementary Provisions.

Maritime Code of the People's Republic of China of 7 November 1992

This Code governs commercial transactions to do with shipping and navigation. It aims to regulate relations arising from maritime transport and those pertaining to ships, to secure and protect the legitimate rights and interests of the parties concerned, and to promote the development of maritime transport, economy and trade (art. 1).

Rules of the People's Republic of China governing vessels of foreign nationality 18 September 1979

These Rules are formulated in order to safeguard ports and coastal waters, ensure the safety of navigation and prevent the pollution of waters.

Conventions and treaties

Name of Convention/Treaty	Conclusion	Entry into Force	Ratification	Accession
Convention on the Liability of Operators of Nuclear Ships	25/05/1962		25/05/1962	
Convention concerning the Protection of the World Cultural and Natural Heritage	16/11/1972	12/03/1986		12/12/1985
International Convention for the Safety of Life at Sea (SOLAS)	01/11/1974	25/05/1980	20/06/1975	07/01/1980
United Nations Convention on the Law of the Sea	10/12/1982	07/07/1996	10/12/1982	07/06/1996
Protocol to amend the International Convention on Civil Liability for Oil Pollution Damage	25/05/1984		25/05/1984	
Protocol relating to the International Convention for the Safety of Life at Sea (SOLAS PROT 1988)	11/11/1988	03/02/2000	11/11/1988	
Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	22/03/1989	05/05/1992	22/03/1990	17/12/1991
Convention for establishing a marine scientific organisation for the North Pacific Region (PICES)	12/12/1990	30/10/1992	22/10/1991	31/08/1992
Protocol to the Antarctic Treaty on Environmental Protection	04/10/1991	14/01/1998	04/10/1991	02/08/1994
Convention on Biological Diversity	05/06/1992	29/12/1993	11/06/1992	05/01/1993
Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982	28/07/1994	07/07/1996	29/07/1994	07/06/1996
Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks	04/08/1995		06/11/1996	
Amendment to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	22/09/1995			01/05/2001
Comprehensive Nuclear Test - Ban Treaty	10/09/1996		24/09/1996	
Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972	07/11/1996		23/03/1998	
Kyoto Protocol to the United Nations Framework Convention on Climate Change	11/12/1997		29/05/1998	
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	10/09/1998		24/08/1999	
Cartagena Protocol on Biosafety to the Convention on Biological Diversity	29/01/2000		08/08/2000	
Stockholm Convention on Persistent Organic Pollutants	22/05/2001		23/05/2001	

Republik of Korea

Laws, regulations and rules

Law, Regulations and Rules	Date of enactment
Water Supply Act	1961.12.31
Sewerage System Act	1966. 8. 3
Act Relating to Protection of Birds, Mammals and Hunting('67. 3.30)	1983.12.30
Waste Clean Act ('61.12.30) – Waste Management Act ('86.12.31)	1991. 3. 8
Act relating to toxic and Hazardous Substance('63.12.13) - Toxic Chemical Control Act	1996. 8. 1
Natural Park Act	1980. 1. 4
Compound Waste Treatment Corporation Act	1979.12.28
Korea Resource Recovery and Reutilisation Corporation Act	1993.12.27
Environmental Pollution Prevention Corporation Act	1983. 5.21
Environmental Management Corporation Act	1993.12.27
Social Pollution Prevention Act	1963.11.5
Environment Preservation Act	1977.12.31
Basic Environmental Policy Act	1990.8.1
Air Quality Preservation Act	1990.8.1
Water Quality Preservation Act	1990.8.1
Act Relating to Water Resources in Han River and Community Support	1999.2.8
Special Act on Nakdong River's Watershed Management	2002. 1.14
Special Act on Geum River's Watershed Management	2002. 1.14
Special Act on Yeongsan and Seomjin River's Watershed Management	2002. 1.14
Indoor Air Qualities Management Act	1996.12.30
Noise and Vibration Control Act	1990. 8. 1
Environmental Dispute and Settlement Act	1990. 8. 1
Acts Relating to Punishment for Environmental Crime	1991. 5.31
Natural Environment Preservation Act	1991.12.31
Act Relating to the Special Accounting for Environmental Improvement	1994. 1. 5
Act Relating to Environmental Technology Support and Development	1994.12.22
Special Act on the Ecosystem Preservation of Islands such as Dokdo Island	1995. 1. 5
Wetland Preservation Act	1997.12.13
Environmental Impact Assessment Act on Environment, Transportation and Natural Disaster	1999. 2. 8
Soil Environment Preservation Act	1991.12.31
Act Relating to the Treatment of Sewage, Night Soil and Livestock Wastewater	1999.12.31
Act Relating to Promotion of Resources Saving and Reutilisation	1995. 1. 5
Act Relating to Transboundary Movement of Waste and Their Disposal	1991. 3. 8
Act Promotion of Waste Treatment Facilities and Local Community	1992.12. 8
Act Relating to the Establishment and Operation of Sudokwon Landfill Site Management Corporation	1992.12. 8

Conventions and treaties

Conventions and Treaties	Date of Signature	Date of ratification/ accession(a)	Date of entry into force
International Convention for the Prevention of Pollution of the Sea by Oil, 1954(as amended in 1962 and in 1969)	-	31 07 78(a)	31 10 78
International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 relating thereto	-	23 07 84(a)	23 10 84
International Regulations for Preventing Collisions at Sea,1960	-	-	-
1972 Amendments to the 1960 International Regulations for Preventing Collisions at Sea	-	29 07 77(a)	29 07 77
International Convention for the Safety of Life at Sea, London, 1974	-	31 12 80(a)	31 03 81
International Convention on Civil Liability for Oil Pollution Damage, 1969, Brussels	-	18 12 78(a)	18 03 79
International Convention on the Establishment of an International Fund for Compensation of Oil Pollution Damage, 1971, Brussels	-	08 12 92(a)	08 03 93
Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matters, 1972, London	-	21 12 93(a)	20 01 94
Convention on International Trade in Endangered Species of Wild Flora and Fauna, 1973, Washington	-	07 09 93(a)	07 10 93
United Nations Convention on the Law of the Sea, 1982, Montego Bay	14 03 83	29 01 96	28 02 96
United Nations Framework Convention on Climate Change, 1992, New York	13 06 92	14 12 93	21 03 94
Convention on Biological Diversity, 1992, Rio de Janeiro	-	03 10 94(a)	01 01 95

Annex V
WHO Guidelines for drinking-water quality or standards

Drinking-water quality

Element/substance		Normally found in fresh water/ surface water/ground water	Health guideline
Aluminium	Al		0.2 mg/l
Ammonia	NH_4	< 0.2 mg/l (up to 0.3 mg/l in anaerobic waters)	No guideline
Antimony	Sb	< 4 µg/l	0.005 mg/l
Arsenic	As		0.01 mg/l
Asbestos			No guideline
Barium	Ba		0.3 mg/l
Beryllium	Be	< 1 µg/l	No guideline
Boron	B	< 1 mg/l	0.3 mg/l
Cadmium	Cd	< 1 µg/l	0.003 mg/l
Chloride	Cl		250 mg/l
Chromium	Cr^{+3}. Cr^{+6}	< 2 µg/l	0.05 mg/l
Colour			Not mentioned
Copper	Cu		2 mg/l
Cyanide	CN-		0.07 mg/l
Dissolved oxygen	O_2		No guideline
Fluoride	F	< 1.5 mg/l (up to 10)	1.5 mg/l
Hardness	mg/l $CaCO_3$		No guideline
Hydrogen sulphide	H^2S		No guideline
Iron	Fe	0.5 - 50 mg/l	No guideline
Lead	Pb		0.01 mg/l
Manganese	Mn		0.5 mg/l
Mercury	Hg	< 0.5 µg/l	0.001 mg/l
Molybdenum	Mb	< 0.01 mg/l	0.07 mg/l
Nickel	Ni	< 0.02 mg/l	0.02 mg/l
Nitrate and nitrite	NO_3. NO_2		50 mg/l total nitrogen
Turbidity			Not mentioned
pH			No guideline
Selenium	Se	< 0.01 mg/l	0.01 mg/l
Silver	Ag	5 – 50 µg/l	No guideline
Sodium	Na	< 20 mg/l	200 mg/l
Sulphate	SO_4		500 mg/l
Inorganic tin	Sn		No guideline
TDS			No guideline
Uranium	U		1.4 mg/l
Zinc	Zn		3 mg/l

(Note: Are set up in Geneva, 1993 and are the international reference point for standard setting and drinking-water safety)

Organic compunds

Group	Substance			Health guideline
Chlorinated alkanes	Carbon tetrachloride		$C Cl_4$	2 µg/l
	Dichloromethane		$C H_2 Cl_2$	20 µg/l
	1,1-Dichloroethane		$C_2 H_4 Cl_2$	No guideline
	1,2-Dichloroethane		$Cl CH_2 CH_2 Cl$	30 µg/l
	1,1,1-Trichloroethane		$CH_3 C Cl_3$	2000 µg/l
Chlorinated ethenes	1,1-Dichloroethene		$C_2 H_2 Cl_2$	30 µg/l
	1,2-Dichloroethene		$C_2 H_2 Cl_2$	50 µg/l
	Trichloroethene		$C_2 H Cl_3$	70 µg/l
	Tetrachloroethene		$C_2 Cl_4$	40 µg/l
Aromatic hydrocarbons	Benzene		$C_6 H_6$	10 µg/l
	Toluene		$C_7 H_8$	700 µg/l
	Xylenes		$C_8 H_{10}$	500 µg/l
	Ethylbenzene		$C_8 H_{10}$	300 µg/l
	Styrene		$C_8 H_8$	20 µg/l
	Polynuclear Aromatic Hydrocarbons (PAHs)		$C_2 H_3 N_1 O_5 P_{13}$	0.7 µg/l
Chlorinated benzenes	Monochlorobenzene (MCB)		$C_6 H_5 Cl$	300 µg/l
	Dichlorobenzenes (DCBs)	1,2-Dichlorobenzene (1,2-DCB)	$C_6 H_4 Cl_2$	1000 µg/l
		1,3-Dichlorobenzene (1,3-DCB)	$C_6 H_4 Cl_2$	No guideline
		1,4-Dichlorobenzene (1,4-DCB)	$C_6 H_4 Cl_2$	300 µg/l
	Trichlorobenzenes (TCBs)		$C_6 H_3 Cl_3$	20 µg/l
Miscellaneous organic constituents	Di(2-ethylhexyl)adipate (DEHA)		$C_{22} H_{42} O_4$	80 µg/l
	Di(2-ethylhexyl)phthalate (DEHP)		$C_{24} H_{38} O_4$	8 µg/l
	Acrylamide		$C_3 H_5 N O$	0.5 µg/l
	Epichlorohydrin (ECH)		$C_3 H_5 Cl O$	0.4 µg/l
	Hexachlorobutadiene (HCBD)		$C_4 Cl_6$	0.6 µg/l
	Ethylenediaminetetraacetic acid (EDTA)		$C_{10} H_{12} N_2 O_8$	200 µg/l
	Nitrilotriacetic acid (NTA)		$N(CH_2COOH)_3$	200 µg/l
	Organotins	Dialkyltins	$R_2 Sn X_2$	No guideline
		Tributil oxide (TBTO)	$C_{24} H_{54} O Sn_2$	2 µg/l

Pesticides

Substance		Formula	Health guideline
Alachlor		$C_{14}H_{20}ClNO_2$	20 µg/l
Aldicarb		$C_7H_{14}N_2O_4S$	10 µg/l
Aldrin and dieldrin		$C_{12}H_8Cl_6/C_{12}H_8Cl_6O$	0.03 µg/l
Atrazine		$C_8H_{14}ClN_5$	2 µg/l
Bentazone		$C_{10}H_{12}N_2O_3S$	30 µg/l
Carbofuran		$C_{12}H_{15}NO_3$	5 µg/l
Chlordane		$C_{10}H_6Cl_8$	0.2 µg/l
Chlorotoluron		$C_{10}H_{13}ClN_2O$	30 µg/l
DDT		$C_{14}H_9Cl_5$	2 µg/l
1,2-Dibromo-3-chloropropane		$C_3H_5Br_2Cl$	1 µg/l
2,4-Dichlorophenoxyacetic acid (2,4-D)		$C_8H_6Cl_2O_3$	30 µg/l
1,2-Dichloropropane		$C_3H_6Cl_2$	No guideline
1,3-Dichloropropane		$C_3H_6Cl_2$	20 µg/l
1,3-Dichloropropene		$CH_3CHClCH_2Cl$	No guideline
Ethylene dibromide (EDB)		$BrCH_2CH_2Br$	No guideline
Heptachlor and heptachlor epoxide		$C_{10}H_5Cl_7$	0.03 µg/l
Hexachlorobenzene (HCB)		$C_{10}H_5Cl_7O$	1 µg/l
Isoproturon		$C_{12}H_{18}N_2O$	9 µg/l
Lindane		$C_6H_6Cl_6$	2 µg/l
MCPA		$C_9H_9ClO_3$	2 µg/l
Methoxychlor		$(C_6H_4OCH_3)_2CHCCl_3$	20 µg/l
Metolachlor		$C_{15}H_{22}ClNO_2$	10 µg/l
Molinate		$C_9H_{17}NOS$	6 µg/l
Pendimethalin		$C_{13}H_{19}O_4N_3$	20 µg/l
Pentachlorophenol (PCP)		C_6HCl_5O	9 µg/l
Permethrin		$C_{21}H_{20}Cl_2O_3$	20 µg/l
Propanil		$C_9H_9Cl_2NO$	20 µg/l
Pyridate		$C_{19}H_{23}ClN_2O_2S$	100 µg/l
Simazine		$C_7H_{12}ClN_5$	2 µg/l
Trifluralin		$C_{13}H_{16}F_3N_3O_4$	20 µg/l
Chlorophenoxy herbicides (excluding 2,4-D and MCPA)	2,4-DB	$C_{10}H_{10}Cl_2O_3$	90 µg/l
	Dichlorprop	$C_9H_8Cl_2O_3$	100 µg/l
	Fenoprop	$C_9H_7Cl_3O_3$	9 µg/l
	MCPB	$C_{11}H_{13}ClO_3$	No guideline
	Mecoprop	$C_{10}H_{11}ClO_3$	10 µg/l
	2,4,5-T	$C_8H_5Cl_3O_3$	9 µg/l

Disinfectants and disinfectant by-products

Group	Substance		Formula	Health guideline
Disinfectants	Chloramines		$NH_nCl^{(3-n)}$	3 mg/l
	Chlorine		Cl_2	5 mg/l
	Chlorine dioxide		ClO_2	No guideline
	Iodine		I_2	No guideline
Disinfectant by-products	Bromate		BrO_3^-	25 µg/l
	Chlorate		ClO_3^-	No guideline
	Chlorite		ClO_2^-	200 µg/l
	Chlorophenols	2-Chlorophenol (2-CP)	C_6H_5ClO	No guideline
		2,4-Dichlorophenol (2,4-DCP)	$C_6H_4Cl_2O$	No guideline
		2,4,6-Trichlorophenol (2,4,6-TCP)	$C_6H_3Cl_3O$	200 µg/l
	Formaldehyde		$HCHO$	900 µg/l
	MX (3-Chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone)		$C_5H_3Cl_3O_3$	No guideline
	Trihalomethanes	Bromoform	$CHBr_3$	100 µg/l
		Dibromochloromethane	$CHBr_2Cl$	100 µg/l
		Bromodichloromethane	$CHBrCl_2$	60 µg/l
		Chloroform	$CHCl_3$	200 µg/l
	Chlorinated acetic acids	Monochloroacetic acid	$C_2H_3ClO_2$	No guideline
		Dichloroacetic acid	$C_2H_2Cl_2O_2$	50 µg/l
		Trichloroacetic acid	$C_2HCl_3O_2$	100 µg/l
	Chloral hydrate (trichloroacetaldehyde)		$CCl_3CH(OH)_2$	10 µg/l
	Chloroacetones		C_3H_5OCl	No guideline
	Halogenated acetonitriles	Dichloroacetonitrile	C_2HCl_2N	90 µg/l
		Dibromoacetonitrile	C_2HBr_2N	100 µg/l
		Bromochloroacetonitrile	$CHCl_2CN$	No guideline
		Trichloroacetonitrile	C_2Cl_3N	1 µg/l
	Cyanogen chloride		$ClCN$	70 µg/l
	Chloropicrin		CCl_3NO_2	No guideline

The Global International Waters Assessment

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

The need for a global international waters assessment

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

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

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

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

International call for action

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

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

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

The Global Environment Facility (GEF)

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

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

United Nations Environment Programme (UNEP)

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

UNEP work encompasses:

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

University of Kalmar

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

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

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

The conceptual framework and objectives

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

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

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

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

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

International waters and transboundary issues

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

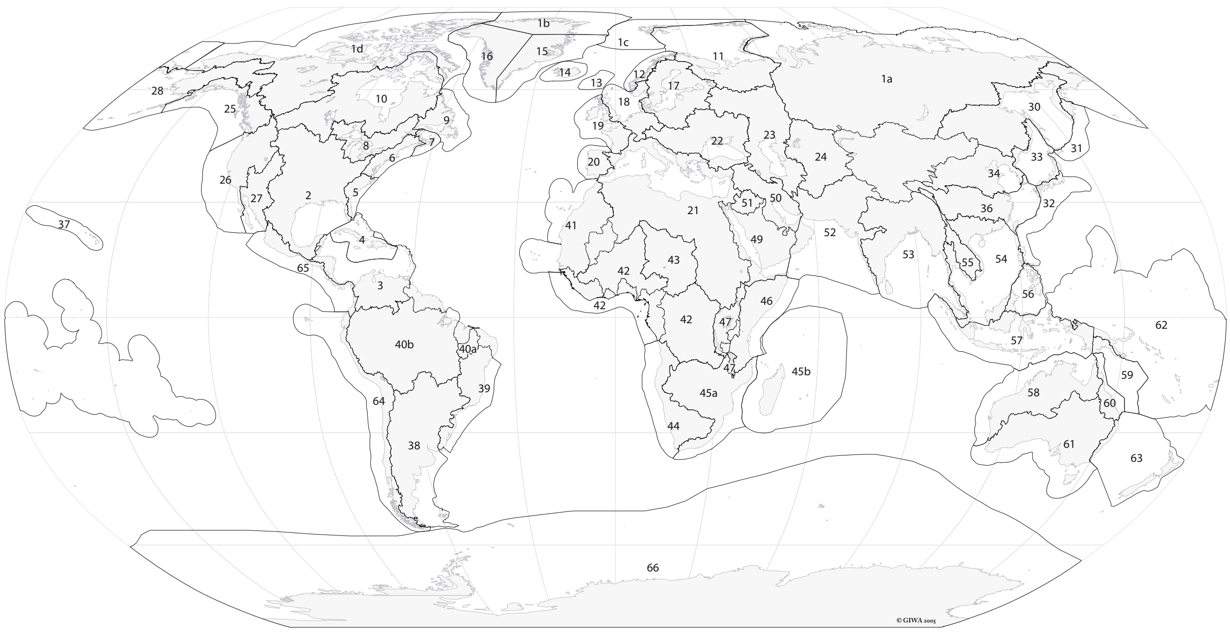
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and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

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

The organisational structure and implementation of the GIWA

The scale of the assessment

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



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

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

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

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

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

Large Marine Ecocsystems (LMEs)

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

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

The global network

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

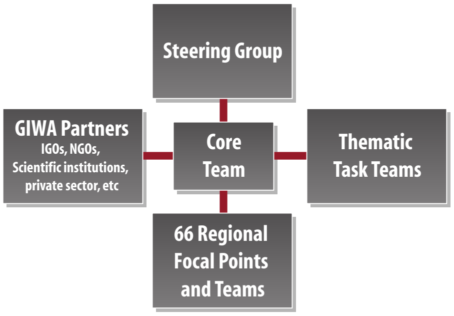


Figure 2 The organisation of the GIWA project.

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

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

GIWA Regional reports

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

UNEP Water Policy and Strategy

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

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

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

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

Global International Waters Assessment

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The GIWA methodology

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

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

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

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

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

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

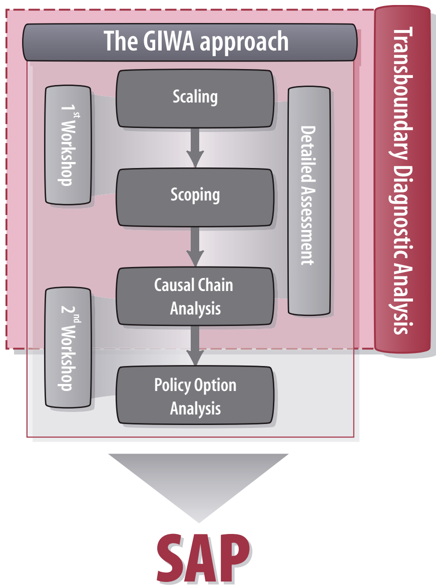

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

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

Scaling – Defining the geographic extent of the region

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

Scoping – Assessing the GIWA concerns

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

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

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

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

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

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

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

Table 2 Example of environmental impact assessment of Freshwater shortage.

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

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

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

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

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

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

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

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

(Types of impacts)

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

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

Causal chain analysis

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

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

Conceptual model

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

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

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

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

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

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

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

Policy option analysis

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

Construct policy options

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

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

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

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

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

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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.

GIWA

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

Broad Transboundary Approach

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

Regional Assessment – Global Perspective

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

Global Comparability

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

Integration of Information and Ecosystems

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

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

Priorities, Root Causes and Options for the Future

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

This Report

This report presents the results of the GIWA assessment of the Yellow Sea region and the adjacent Bohai Sea sub-system. The Yellow sea is a semi-enclosed water body bordering the Chinese mainland to the west and the Korean Peninsula to the east. Results from the assessment of the Bohai sub-system, which is entirely located within China and therefore not considered transboundary, is also presented. Freshwater shortage, habitat and community modification and unsustainable exploitation of fish and other living resources were assessed to be the priority concerns in both sub-systems. The past and present status and future prospects are discussed, and the transboundary issues are traced back to their root causes. Increased population growth and mass migration to urban areas is a major root cause in this region. Policy options have been recommended to mitigate environmental and socio-economic impacts and to secure the region's future prosperity.

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