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).

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

The arrow indicates the likely direction of future changes.

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

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)

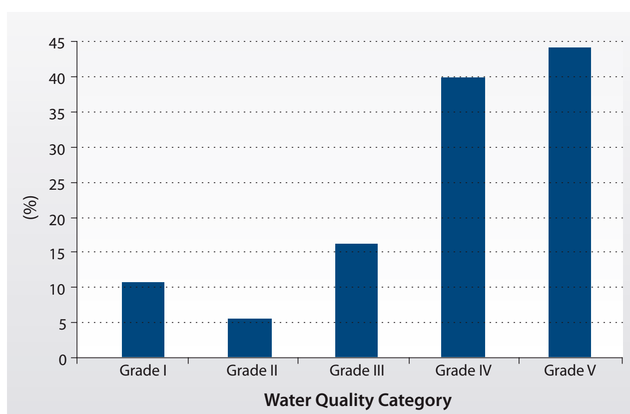

Figure 7 Water quality in the tributaries of Huai River, classified according the Chinese National Water Quality Standards

(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).

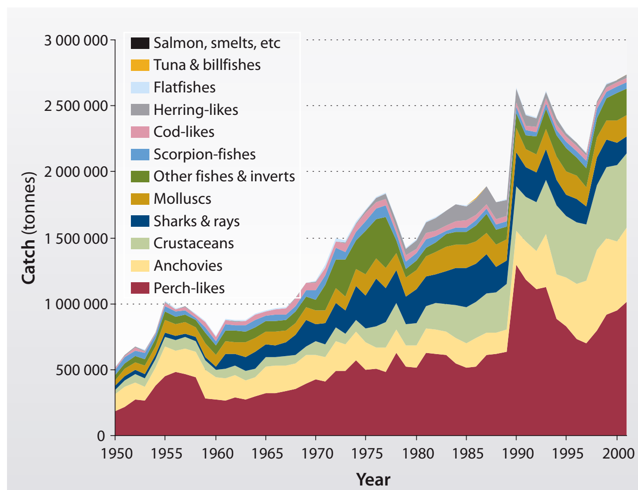

Figure 8 Fish catch in the Yellow Sea.
(Source: LME 2005)

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

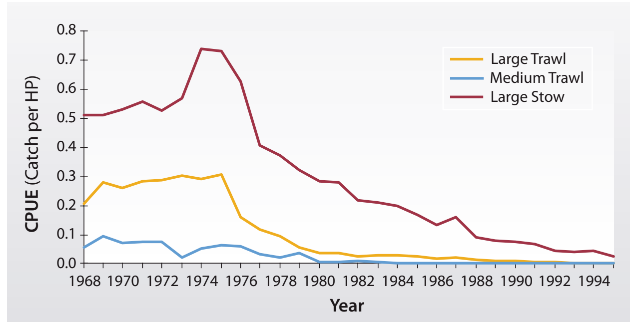

Figure 9 Catch per unit effort (horsepower) of three major fisheries on the Korean side of the region.
(Source: GEF/UNDP 2000)

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:

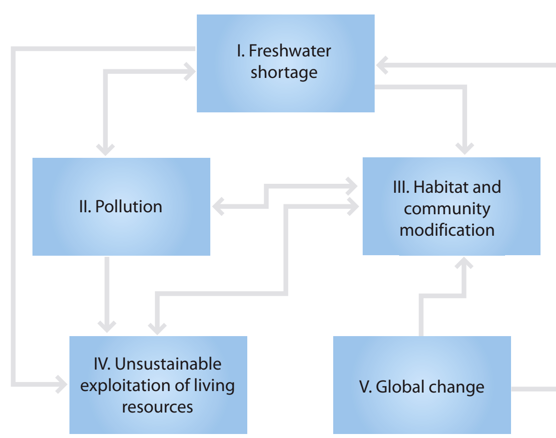

Figure 10 Linkage between the GIWA concerns in the Yellow Sea region.

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.