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.
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 km², 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 km². 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).

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).
The primary productivity of the Yellow Sea varies from 68-320gC/m²/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/m³ and 950 000 cells/m³, 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 (*Thissa 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 km². 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 km³. 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 km³ 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 m³/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 m³ were completed in the 1960s, which had helped to relieve the problems of flooding in the Huai River Basin (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 km², 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 m³/s or 40 km³/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...
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 km² (including the portion in North Korea) and an annual run-off volume of 27.7 km³, 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 km². Some 44.6% (98,477 km²) 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 km². Other important islands include Ullung in the East Island, Cheju, lies off the southwest corner of the peninsula and has a land area of 1,825 km². 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 km², 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 kuirensis), and Japanese sea lion (Zalophus clyomianus japonicus) live in the region; the Striped dolphin (Stenella coerulea superba; 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 discus hannai), 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 activity centres in the region see Box 1.

#### 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 polyactis*), 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).
Overfishing has also caused a decline in stock abundance for Red seabream (Pagrosomus major), Jew-fish (Otolithoides miyu), 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 (Anopterurus species) and Pike-conger (Muraenichthys 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, Brachydonates), 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 fareri, Pecten spp.), sea cucumbers (Stichopus japonicus, Stichopus spp.) and Large chinese shrimp (Peneaus 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 (CAF 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

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

<table>
<thead>
<tr>
<th>Population centres</th>
<th>(population &gt;1 million)</th>
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<tbody>
<tr>
<td>- South Korea: Seoul, Inchon, Daejeon and Kwangju;</td>
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<tr>
<td>- North Korea: Pyongyang;</td>
<td></td>
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<tr>
<td>- China: Dandong, Dalian, Yantai, Weihai, Qingdao, Lianyungang and Rizhao.</td>
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**Ports and shipping routes**
The ports located along the coastal areas bordering the Yellow Sea are as follows:

- 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 Songgou Bay of the Shandong Peninsula; for scallops around the Changshan Island of Liaodong Peninsula; and for nori (Porphyra spp.), prawns and crabs in Haizhou Bay of the Jiangsu Province.

**Industrial complexes**

- China: Dalian and Qingdao 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: Zhang & Wang 2000)
(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 broughtoni), Pen shell (Atrina pectinata), and Hen clam (Macrta sulcataria). Seaweed is another important crop cultured commercially in the coastal areas of the Yellow Sea. Species of brown and red seaweeds cultivated 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'inn-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 Pyöngyang (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 km², 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
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 countries of Africa and Asia. Today the country’s GDP per capita was comparable with levels in the poorer 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).