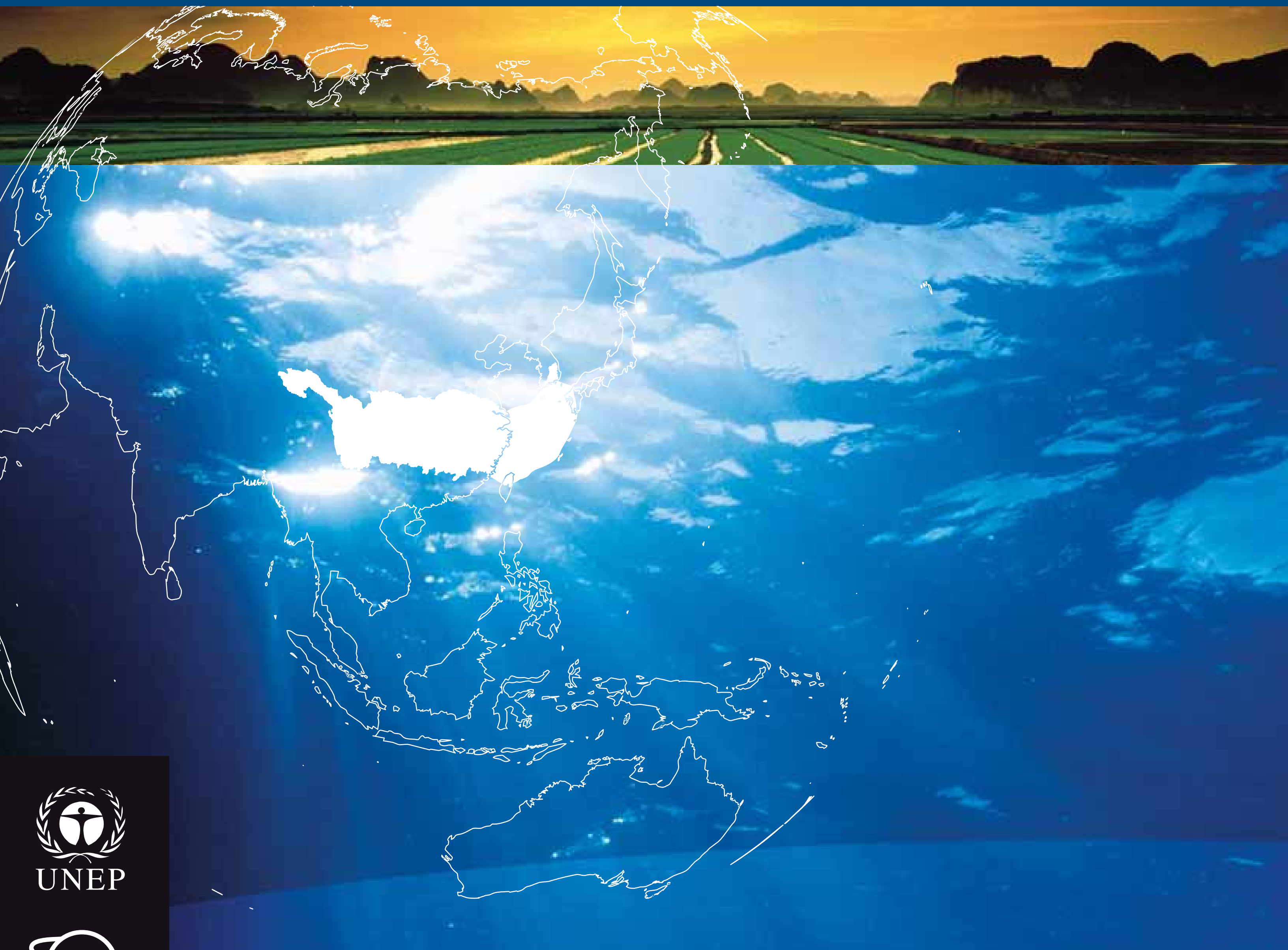
Global International Waters Assessment



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East China Sea

GIWA Regional assessment 36

Qu, J., Xu, Z., Long, Q., Wang, L., Shen, X., Zhang, J. and Y. Cai

Global International Waters Assessment

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Regional assessment 36
East China Sea

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Preface

The critical stage of the aquatic environment has become widely more apparent not only for experts and scientist, but also for the general public. Freshwater depletion, pollution, habitat destruction and the unsustainable exploitation of living resources are serious transboundary problems that have developed over a fairly short timeframe. Global climate change will also result in unpredictable transformations that will alter the Earth's freshwater and marine ecosystems.

Actions to reverse this negative trend are urgently needed. More than a billion people lack access to safe drinking water, depleted freshwater resources and the subsequent salinity problems impact negatively on agriculture and food production and overfishing threatens the vitality of large fish stocks. The UN Millennium Development Goals target these problems and have set forth an ambitious schedule to reduce them by 50% by 2015. UNEP is committed to work for the fulfillment of these goals.

The present report is one in a series of regional assessment carried out under the GIWA project. The East China Sea is unique in many respects and this is reflected in the assessment. The drainage basin of the East China Sea is one of the most densely populated areas on the Earth. Approximately 300 million people live in this area. Industrialisation and economic growth has been remarkably high during the last decades. One of the largest rivers on Earth, the Yangtze River, discharges into the East China Sea; and Shanghai at its mouth is one of the largest metropolises in the world. The infrastructure development in the river basin is also unique in its size. The Three Gorges dam is one of the largest dams ever constructed and so is the south-to-north water transfer scheme intended to bring water into the drought prone Yellow River basin and the parched north. Thus both the anthropogenic influences as well as the freshwater to marine interactions is more dominant in this region than in most other regions assessed by GIWA.

The laboratory for estuarine research at the East China Normal University has studied these problem areas for a long time. GIWA has been able to draw on this accumulated experience.

The aim of this report is to give a better understanding of the driving forces in society that lead to environmental pressures and the causal relationships that underlay the deterioration of the aquatic environment. It is my hope that this report will be seen as a roadmap to sustainability and lead to the actions necessary to overcome the environmental challenges we all face.

Dag Daler
Scientific Director
UNEP/GIWA

Executive summary

The East China Sea is one of the largest marginal seas in the world. Its surface area covers ca. 770 000 km^2 with a broad shelf in the west part (70-75%) and the deep Okinawa Trough to the east. This region receives tremendous inflow of freshwater and terrestrial sediments, mainly from mainland China, of which the Yangtze River alone is responsible for ca. 90-95%. In the eastern part of the sea, the Kuroshio current, flows northward along the continental slope, effectively isolating the sea from the open Northwest Pacific Ocean. This provides the approximate limits of the region at 24°-30° N and 118°-130° E.

The East China Sea is bounded by China to the west and south, Korea to the north and Japan to the east. It connects with the South China Sea through the Taiwan Strait in the southwest, the Yellow Sea to the north and the Sea of Japan to the northeast. The connection between the East China Sea and the northwest Pacific Ocean is mainly through straits and/or channels. The most salient feature of the region in the context of the Global International Waters Assessment (GIWA) is the large population and rapid economic development in the countries over last two decades, particularly in China. The problem of keeping a balance between social and economic progress on the one hand and protection of marine ecosystems on the other is a very sensitive issue between neighbouring countries and in international trade. For instance, the majority of pollutants are generated on land and anthropogenic disturbances are in most areas constrained to drainage basins, but the subsequent pollution ends up in coastal and oceanic environments, resulting in degradation of ecosystems and economic impacts.

The natural landscape in the region's drainage basins has been greatly modified by the development and expansion of agriculture, which is dramatically accelerating soil erosion and riverine flux of nutrients and trace organics. The construction of dams has allowed for power production and irrigation and the control of floods, but dam development has also changed the seasonal and/or interannual natural variability of the hydrographic properties of downstream and coastal environments, which has had a profound influence on the evolution of these ecosystems. Urbanisation, particularly in the coastal area, changes land use from agricultural to a built environment, which as a whole results in problems as varied as inadequate sewage treatment capacity and deforestation. Aquaculture and coastal area reclamation alter natural wetlands and destroy spawning and nursery grounds in the East China Sea. Aquaculture may also result in the discharge of wastes into coastal waters and contamination of marine living resources at the genetic level. The traditional fishery in the East China Sea is based on the catch of species with high quality protein that usually have a long growth period. This has shifted to smaller-size and low quality; cheaper species, in part as a result of overfishing. As a consequence, pollution, destruction of habitats and overfishing are considered to be the most critical large-scale environmental concerns to be addressed in the East China Sea region.

Although the environmental and socio-economic impacts for each of the predefined GIWA issues and concerns are assessed in this report for the East China Sea region, the heterogenic character and dimensions of the region make it difficult to conduct a causal chain analysis and to develop policy options. The report places emphasis on data analyses that allow a comprehensive understanding of the efforts that will be needed for the mitigation of habitat and ecosystem modification, and transboundary pollution in the region, in view of its social and economic importance in Northeast Asia.

The failures by governments to provide for a sustainable fishery and protection of the environment in the East China Sea region have been due to the misconception that natural resources both on land and in the ocean are inexhaustible. This has led to a domino effect in terms of the damage that has been done to the ecosystem at various levels. Information is needed to implement actions to ensure

the sustainable use of water resources, and governments need to be aware of the environmental and social impacts of water and land-based activities in the marine domain and drainage basins. This can be done and realised through: (1) research to obtain new information, (2) dissemination of existing knowledge, and (3) conversations within and/or between governments to coordinate implementation of various conservation programmes, (4) training and education to improve public understanding, and (5) legislation and international agreements. It should be noted that the impetus for establishing a framework for the sustainable development of marine ecosystems in the East China Sea is more significant from a social perspective than the economics of such an endeavour. The increase in conflicts over various demands for the region's natural resources means that the political feasibility of any programme must be addressed as well. Otherwise, the political feasibility and success of the implementation will be threatened, or conflicts may become intensified and uncontrollable.

The GIWA assessment of the East China Sea region is marked by major data gaps in several areas, including demographic and economic sectors. Previous assessment work in this region has not included fisheries issues in combination with impacts from land-based perturbations. For instance, no consensus has been reached on the evolution of stock replenishment of threatened species in the East China Sea.

Abbreviations and acronyms

BSA Bureau of Statistics of Anhui
BSF Bureau of Statistics of Fujian
BSJ Bureau of Statistics of Jiangxi
BSS Bureau of Statistics of Shanghai
BSZ Bureau of Statistics of Zhejiang
CCA Causal Chain Analysis
CCAR/HKUST The Hong Kong University of Science and Technology
CFM Chinese Forestry Ministry
CIGEM China Geological Environmental InfoNet
CNRD China Natural Resource Database
COD Chemical Oxygen Demand
COYEC China Ocean Yearbook Editor Committee
CPUE Catch Per Unit Effort
CWC Changjiang Water Commitment
DDT Dichloro-Diphenyl-Trichloroethane
DIN Dissolved Inorganic Nitrogen
DSP Diarrheic Shellfish Poisoning
EBM Ecosystem Based Management
ECSCC East China Sea Coastal Current
ENSO El Nino Southern Oscillation
FAO Food And Agriculture Organization of the United Nations
FBAM Fisheries Bureau of Agricultural Ministry
FOFA Fujian Ocean and Fishery Administration
GIWA Global International Waters Assessment
HAB Harmful Algal Blooms
HCH Hexachlorocyclohexane
HP Horse Power
IMO International Maritime Organization
MWRC Ministry of Water Resources of China
MWRC-TBA Taihu Drainage Basin Administration, Ministry of Water Resources of China
MSY Maximum Sustainable Yield
NBSC National Bureau of Statistics of China
NBSC-DPSSTS Department of Population, Social, Science and Technology Statistics National Bureau of Statistics of China
NBSC-RERT Rural Economics Research Team, National Bureau of Statistics of China
NMDIS National Marine Data And Information Service
PCB Polychlorinated biphenyls
PSP Paralytic Shellfish Poisoning
SCMC Shanghai Construction and Management Committee
SEPAC State Environmental Protection Administration of China
SEYEBS Shanghai Environment Yearbook Editorial Board and Staff
SOA State Oceanic Administration
SSTA Sea Surface Temperature Anomaly
TAC Total Allowed Catch
TN Total Nitrogen
TP Total Phosphorus
TSM Total Suspended Matter
ZOFA Zhejiang Ocean and Fishery Administration
ZPEPB Zhejiang Province Environment Protective Bureau

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Regional definition

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

Boundaries of the East China Sea region

The East China Sea forms the largest shelf region in the Northwest Pacific Ocean. It is located at 24°-30° N and 118°-130° E, with a surface area of 770 000 km^2 (Figure 1). The East China Sea has a total water volume of 398 000 km^3, with an average depth of 370 m. To the west, the East China Sea is bordered by China, with tremendous freshwater inputs and terrigenous sediment loads, notably from the Yangtze River. In the east the Kuroshio current, moves northward along the shelf edge with a water flow of 25-30 Sv (Su 1998). The East China Sea borders the Pacific Ocean along the Ryukyu Archipelago. In the north the East China Sea is separated from the Yellow Sea by a line from the northerly tip of the Yangtze River mouth to Cheju Island, and the East China Sea is connected with the Sea of Japan (i.e. the East Sea) through the Korean Strait. The East China Sea is connected with the South China Sea through the Taiwan Strait.

Figure 1 Boundaries of the East China Sea region.

Physical characteristics

Geography

The East China Sea is bordered by China, the Korean peninsula, and the Japanese islands of Kyushu and Ryukyu. It is named the East China Sea because of its location to the east of mainland China. The length from the northeast to southwest of the East China Sea is approximately 1 300 km. The width from the east to west is approximate 740 km (Qin & Zhao 1987).

Circulation

In the East China Sea, the northeast flow of the Kuroshio Current limits the transport of East China Sea shelf waters to the Northwest Pacific Ocean. The Kuroshio enters the East China Sea from the northeast region of Taiwan and flows along the Okinawa Trough; it then turns to the east and leaves the East China Sea, joining the North Pacific Ocean at about 30° N through the Tokara Strait (Figure 2).

The Taiwan Warm Current is formed by water from the Taiwan Strait and the upwelling of the Kuroshio at the northeast corner of Taiwan (Su 1998). The Taiwan Warm Current occupies the broad shelf of the East China Sea, and affects the region off the Yangtze River estuary at water depths of 50 m, inducing local upwelling along the coast in the summer when the south monsoon prevails.

Figure 2 Seasonal circulation patterns in the East China Sea.

Historically, the Yangtze River (Changjiang) carries 928.2 billion m^3/year of freshwater and 486 million tonnes/year of total suspended matter (TSM) to the East China Sea. In the north, the Yellow Sea Coastal Current affects the northern part of the East China Sea in the winter. In the winter, the effluent plumes from the Yangtze River, as limited by a salinity of 25-30‰, flow southward along the coast of China, forming part of the East China Sea Coastal Current (ECSCC), reaching the northern shelf of the South China Sea. In the summer when the Yangtze River floods, the freshwater effluent plumes disperse eastward over the broad shelf at the surface and can reach Cheju Island, affecting the southern part of the Korean coast, particularly when extreme flood events occur in the Yangtze River drainage basin.

Hydrology

Rivers

The rivers have significant influence on the hydrologic conditions of the East China Sea, particularly the Yangtze River, Qiantangjiang, and Mingjiang (Table 1).

Table 1 Characteristics of the rivers in the East China Sea.

Rivers	Drainage area (km^2)	Length (km)	Water discharge (billion m^3/year)	Sediment load (million tonnes/year)
Yangtze	1 807 200	6 397	928.5	486
Qiantangjiang	48 800	604	40.4	7.3
Minjiang	61 000	223	53.6	13.4
Jiulongjiang	14 100	245	13.9	2.5

(Source: Qin & Zhao 1987)

Yangtze River

The Yangtze River (Changjiang) is the longest river in China and one of the most famous rivers in the world. The Yangtze River is 6 397 km long and drains an area of 1.81 million km^2, of which 19% of is in China. The population in the Yangtze River catchment area is 40% of that of China and the Gross Domestic Product (GDP) of this area is more than 40% of entire country's GDP. Historically, the highest river sediment discharge has been 560 million tonnes/year. The deposition of river sediments has formed the basis of the modern Yangtze River Delta. The Yangtze River flows across 9 provinces and 167 counties in China. There are many important cities in this drainage, such as Chongqing, Wuhan, Nanjin and Shanghai (Zhu 1993), which form the most densely populated and economically developed areas in China.

The landscape of the Yangtze River drainage basin is quite diverse. The area of altiplano, mountain, hill, and basin accounts for 84.7% of the total, with plains accounting for 11.3%, and rivers and lakes occupying 4% (Jiang & Peng 1999). Storm-related floods occur frequently in the drainage basin, resulting in substantial annual economic losses. According to statistical data for 2002, 150 million people were affected by floods, 1 819 persons died in flood-related disasters and 120 000 km^2 of farmland were damaged, with 1 460 000 houses destroyed; the direct economic losses combined to approximately 10 billion USD (84 billon Yuan) (MCA-DSD 2003).

Qiantangjiang

The Qiantangjiang is the biggest river in Zhejiang Province and is 604 km long with a drainage basin of 4.88 million km^2. The Qiantangjiang has its source in Anhui Province and empties into Hongzhou Bay. Qiantangjiang is rich in water resources. To date, four reservoirs and twelve water and electricity stations have been built (Zhu 1993).

Mingjiang

The Mingjiang flows across the middle of Fujian Province and is 223 km in length, with a total basin area of 61 000 km^2. The basin is located in a subtropical area and the adjacent coastal area is well-vegetated, with a resulting high coverage ratio of forest over the watersheds. Mingjiang has a low sediment content, with the average sediment discharge at 5.70 million tonnes/year (Zhu 1993).

Lakes

Lakes in the area are closely linked to rivers, but are more susceptible to anthropogenic effects. The plain in the middle of the Yangtze River has one of the densest areas of lakes in China (Table 2).

Table 2 Characteristics of the main lakes and reservoirs in the East China Sea region.

Lakes	**Area** (km^2)	**Storage** (km^3)	**Depth** (m)
Poyanghu	2 933	14.96	6.5
Dongtinghu	2 432	15.54	6.4
Taihu	2 425	5.14	2.3
Chaohu	770	2.07	2.7
Qiandaohu	573	17.84	34

(Source: Wang & Dou 1998)

Poyanghu

Poyanghu Lake is the largest freshwater lake in China and is located in Jiangxi Province. The hydrographic parameters of the lake change sharply during the year. In the flood season, the water level is 21.69 m above sea level, and the lake's average width is 17.3 km, with an acreage of 2 933 km^2 and a maximum depth of 29.19 m. But years with the average lowest water level, the acreage is only 146 km^2, or only 5% of the largest acreage (Wang & Dou 1998).

Because of human activities such as land reclamation, sedimentation is affecting the flood storage capacity of the Poyanghu and its ecosystems have deteriorated. According to a national report, the acreage of Poyanghu decreased from 5 000 km^2 in the 1950s to 2 933 km^2 at present, and the loss of flood storage capacity is about 490.5 m^3 (Wang & Dou 1998).

Dongtinghu

Dongtinghu lake is the second largest freshwater lake in China and is located in Hunan Province. Dongtinghu is 143 km long, 17 km wide and 6.4 m deep, with an average acreage of 2 432 km^2 and a storage capacity of 15.54 km^3. The area of Dongtinghu has also decreased from 6 000 km^2 in 1825 to 2 691 km^2 at present because of human activities such as land reclamation (Wang & Dou 1998).

Taihu

Taihu lake is the third biggest freshwater lake in China and is located in Jiangsu Province. The acreage of Taihu is 0.38% of China's area. The population of this area accounts for 3.08% of that of China. This area is highly developed and populated, and is called "the Golden Triangle", including Shanghai. Taihu is 68 km long, 35.7 km wide and 2.3 m deep, with an average acreage of 2 425 km^2 and a storage capacity of 5.14 km^3 (Wang & Dou 1998).

Chaohu

Chaohu Lake is the fifth biggest freshwater lake in China and is located in Anhui Province. Chaohu is 61.7 km long, 12.47 km wide and 2.7 m deep, with an average acreage of 770 km^2 and a storage capacity of 2.07 km^3 (Wang & Dou 1998).

Qiandaohu

Qiandaohu Lake is located in Zhejiang Province. It covers 573 km^2 and has an average depth of 34 m. The water transparency is 7-9 m, which is considered to be firstclass water quality by the local government (Qiandao Lake Online 2004).

Dianshanhu

Dianshanhu Lake is located in Shanghai, and is Shanghai's freshwater fishing area. Dianshanhu is 12.8 km long, 4.98 km wide and 2.5 m deep, with an average acreage of 47.5 km^2 and a storage capacity of 0.16 km^3 (Wang & Dou 1998).

River input

The total riverine input to the East China Sea amounts to 1 200 billion m^3/year of freshwater and 500 million tonnes/year of suspended sediments, of which the Yangtze River accounts for 90-95% of both.

Riverine inflow to the East China Sea is highly variable with respect to water and sediment loads and water quality. The river drainage from the land and islands shows important seasonal patterns, under the influence of climate zones from sub-tropical in the south to temperate in the north, and anthropogenic perturbations, such as changes in land use, which may mean that nutrient concentrations from various rivers may differ by 5-10-fold (Zhang 2002). Concentrations of nutrients, particularly nitrogen, are higher in the catchments with extensive land development, particularly agriculture. Consequently, the nutrient species ratio can be up to 100-500 for N:P in the rivers emptying into the East China Sea, which is considerablly higher than in European and North American river systems. Other water quality parameters, such as chemical oxygen demand (COD) and *Escherichia coli* counts have also been identified as problematic in coastal waters affected by land drainage.

Chemical parameters

In the East China Sea, a high concentration of riverine nutrient species can be identified in the surface waters. The influence of land-source nutrients can be seen at the surface over a distance of up to 250-300 km away from the coast. High dissolved inorganic nitrogen/phosphorus (DIN/P) and dissolved inorganic nitrogen/silicon (DIN/Si) ratios resulting from land run-off affect a region that is more than about 400-450 km off the Yangtze River (Zhang 2002).

In offshore waters, the concentration of nutrients is relatively low, both for surface and near-bottom samples, and a gradient of nutrient species can be established from the coast to the broad shelf. The Kuroshio Current has a significant impact on the nutrient budget of the East China Sea. The concentration of nutrients (N, P and Si) in deep waters can be one order of magnitude higher than at the surface in the region of the Kuroshio. Nutrient concentrations of the Kuroshio subsurface waters are 5 to 10-fold higher (N, P and Si) than those from the middle shelf area, which provides a signature of its upwelling across the entire continental slope. The Kuroshio sub-surface waters have relatively high P/N and Si/N ratios compared to land-sourced discharges. Thus the Kuroshio waters that intrude onto the shelf compensate for the nitrogen-rich and phosphorus-depleted freshwater effluent in coastal areas, such as off the Yangtze River delta, and consequently support high primary productivity in the water column. The change from phosphorus-limited environments on the coast to nitrogen-limited environments further offshore can be seen across the broad shelf.

Climate and climatic variability

Climate and hydrographic characteristics

The East China Sea is under the strong influence of a monsoon climate. In winter, a northerly wind prevails, stimulating subsurface surges over the broad shelf, so that the vertical structure of hydrographic parameters shows mixed profiles in the water column. The southern monsoon starts in the spring and reaches its maximum in the summer and early autumn. The water column of East China Sea shelf becomes stratified in summer with respect to salinity and temperature, particularly in the middle shelf, most likely due to an increase in freshwater input and surface heating by radiation.

In the East China Sea, about 70% of the surface area has a water depth of up to 200 m, and deep water is limited to the open boundary at the Okinawa Trough, where the water depth is up to 2 719 m. In the coastal region (water depth: up to 50 m), salinity and temperature both have seasonal features: that is, surface water salinity is lower in summer (20-32.5‰) than winter (30-34.5‰). Particularly in the region adjacent to the Yangtze River estuary, the surface water temperature can reach 25-30°C in the summer, but can drop to 10°C in winter. In the broad shelf where water depths average 50-150 m, the water column's hydrographic parameters are affected by plumes of riverine effluent and the Taiwan Warm Current, which show as patches of various water masses. The flush period of the East China Sea Shelf is rather short (1-2 years), so that the patchy character of hydrographic parameters can be expected to be more important in the East China Sea than in coastal oceans that have relatively long residence times.

At the shelf edge, the exchange of shelf water with the Kuroshio Current has an important influence on the hydrodynamics of the East China Sea. The incursion of the Kuroshio waters illustrates the upwelling, particularly off the northeast coast of Taiwan, and the episodic intrusion of surface and sub-surface waters onto the continental shelf. Filaments and frontal eddies from these incursions have been observed at the shelf edge.

The climate of the Yangtze River Basin can be divided into three sections as summarised in Table 3: the southwest plateau subregion, the southwest subtropical monsoon subregion and the East Asia subtropical monsoon subregion. Two-thirds of the Yangtze River Basin belong to the subtropical monsoon subregion. Due to the influence of the high Qinghai-Tibet Plateau, the southwest plateau subregion has a long and cold winter but a short summer. The southwest tropical monsoon subregion, influenced by the air currents from the Indian Ocean, is warm and moist in the summer and mild in the winter, because the high mountains of this region block cold air masses from the north. Influenced by the hot air currents from the Pacific Ocean, the East Asia subtropical monsoon subregion is warmer and humid in summer, but colder and drier in winter because of the influence of Mongolian high-pressure systems.

The Zhe-Ming drainage basin belongs to the middle subtropical monsoon climate zone. It is warmer in the Zhe-Ming Basin than in the Yangtze River Basin. The annual mean temperature is about 20°C. The monthly average temperature is over 0°C in January and 20-30°C in July. The average annual rainfall in the Zhe-Ming Basin is more than 1 000 mm and increases from north to south.

Temperature

The temperature of the Yangtze River Basin is influenced by many factors, such as solar radiation, East Asian atmospheric circulation, the

Qinghai-Tibet plateau, local landforms and so on. The temperature range over the entire Yangtze River Basin is not too large, with annual mean temperature varying from 15-19°C. But in the upper reaches of the Qinghai-Tibet plateau, the mean annual temperature is about -4°C and in the lower and middle regions, the annual mean annual temperature is 16-18°C. The maximum monthly temperature is in July with temperatures exceeding 28°C, with the minimum monthly temperature of 4-6°C in January.

Precipitation

Mean annual rainfall exhibits great spatial variation throughout the Yangtze River Basin, ranging from 400 mm to 1 600 mm. Annual precipitation decreases from east to west. In the headwaters of the Yangtze River Basin, the annual average precipitation is below 400 mm, but other areas receive 800-1 600 mm of rain per year. At the mouth of the river, the annual average rainfall is about 1 000 mm. On average, about 60-80 % of rainfall occurs in the summer.

Vegetation

The Yangtze River basin can be divided into four vegetation regions: the eastern humid evergreen broad-leaved forest region, the southwestern semi-humid evergreen broad-leaved forest region, the subtropical mountainous cold temperate coniferous forest and the Qinghai-Tibet Plateau alpine meadow and grassland region. A short description of climate and vegatation types is shown in Table 3.

Fisheries resources

The freshwater economic fishes, listed in Annex VII, are widely distributed and valuable species in China. Some are fresh and salt species, for example, *Coilia mystus,* and *Coilia ectenes*. The reason that they are listed here is that they are also widely distributed in freshwaters and have important economic value.

Annex VIII lists the main economic fishes of the East China Sea. These species have adapted to different kinds of environments and consequently have large populations or have considerable economic value. Many of these fishes are species that can be netted by fishing boats, such as *Sardinella aurita; Sardinella lemurur; Engraulis japonicus; Argentina semifasciata; Decapterus maruadsi; Larimichthys polyactis; Trichiurus lepturus;* and *Scomber japonicus*.

Freshwater area

In China, freshwater aquaculture accounts for approximately 95% of the total freshwater fisheries products. As a result of evolution and differentiation of species, the fish found in the Yangtze River, Qiantangjiang and Minjiang are subdivided into general types or groups (Table 4).

Marine waters

The fishes living in the East China Sea are divided into 4 groups; the first group is composed of tropical species, which represents 61.0% of the total species identified. The second group is the warm water species, which represents 37.0% of the total. The third group is cold-temperate species, of which there are just eight species. These species represent 1.8% of the catch of the East China Sea. The fourth group is the cold-water species, which includes only *Cololabis saira*. Fishes living in the East China Sea belong to the fauna of the China-Japan subdivision of the India-Western Pacific Ocean Division, which is characterised by a subtropical climate.

Brackish water species, also called estuary fish, live their entire life cycle in the waters of the Yangtze River estuary. These include *Mugil cephalus Linnaeus, Liza haematocheila, Liza carinatus, Lateolabrax japonicus, Cynoglossus* spp., and members of the *Tetraodontidae*. Anadromous fishes inhabit coastal waters or offshore areas, swimming from the sea to estuaries or the upper reaches of rivers to spawn. After spawning, the parent fish die and the offspring go back to coastal waters or offshore to breed and grow. There are more than 10 such species, such as *Acipenser sinensis* Gray, *Coilia mystu, Coilia ectenes Jordon et Seale, Salangidae,* and *Macrura reevesii*.

Table 3 Climate and vegetation of the Yangtze and Zhe-Ming river basins.

River basin	Average temperature (°C)	Mean precipitation (mm)	Climate	Vegetation
Yangtze River	15-19	1 067	East Asia subtropical monsoon climate	Eastern humid evergreen broad-leaved forests. *Castanopsis* sp. (southern part), *Cyclobalanopsis* sp. and *Quercus* sp. (northern part)
			Southwest subtropical monsoon climate	Western semi-humid evergreen broad-leaved forests. *Cyclobalanopsis delavayi*, *Castanopsis delavayi*, *Quercus* sp. and *Pinus* sp.
				Subtropical mountains cold temperate coniferous forests. *Piceaasperanta, Abies fabri* and *Pinus densata*
			Southwest plateau climate	Qinghai-Tibet Plateau alpine meadow and grassland. *Kobresia pygmea, K. capillifolia* and *K. humilis*
Zhe-Ming	~20	1 000-2 000	Sub-tropical monsoon climate	Southern subtropical evergreen broad-leaved forests

(Source: CWC 2003)

Table 4 General groups of fish in the freshwater part of the East China Sea region.

General fish groups	Species	Ecology
Survived from the Miocene Epoch and even earlier	*Psephurus gladius; Cyprinus carpio; Carassius auratus; Squaliobarbus curriculus; Pseudorasbora parva; Misgurnus anguillicaudatus; Siluriformes, Parasilurus asotus L.;* and *Siniperca chuatsi.*	Live in areas with slow currents or inshore waters. In addition, these species usually spawn on grass and gravel, and even in the coelome (body cavity) of molluscs. Omnivores and carnivores.
River and plains fish cohorts	*Ctenopharyngodon idellus; Mylopharyngodon piceus; Hypophthalmichthys molitrix; Aristichthys nobilis; Elopichthys bambusa; Coreius heterodon; Xenocyprininae; Megalobrama terminalis; Culter erythroculter; Pseudolaubuca sp.; Parabramis sp.; Hemiculter leucisculus; Aphyocypris* and *Saurogobio dabryi.*	Distributed in the middle and lower reaches of rivers and reservoirs with their spawning timed to the flood. Most represented.
Fish cohorts in middle Asian mountains	*Schizothoracinae* and *Noemacheilus*	Distributed in the upper reaches of drainage areas.
Northern piedmont campestris fish cohorts	*Acipenser sinensi, Acipenser dabryanus, Hucho taimen* and *Cobitis linnaeus*	Likes living in the gravel bottoms of clear running waters and hyperoxygenated streams with low temperatures. These fish mainly eat aquatic hexapods and benthos species.
Indian campestris fish	*Channa argus, Clarias fuscus, Macropodus, Eleotris, Mastacembelus aculeatus, Orysias latipes, Ctenogobius giurinus, Ctenogobius cliffordpopei, Monopterus albus, Bagridae,* and *Cyprininae*	Distributed in the middle and lower coastal reaches of rivers, or estuaries and reservoirs, and live together with fish from the river and plains cohorts, and inhabit tussocks with slow currents or stationary waters. Some species have secondary respiratory organs to enable them to survive anaerobic conditions.
Fish in the Sino Indian mountains	*Homalopteridae, Glyptothorax fukiensis, Vanmanenia, Crossostoma stigmata* and *Sisoridae*	Many species have specially adapted organs such as mouths or pectoral fins that have evolved to take the shape of suckers to survive in rapid currents. Their main foods are aquatic insects and affixed algae.
Mountainous fishes to the south	Economically important, and which live in the upper river, such as *Saurogobio dumerili, Acrossocheilus fasciatus, Acrossocheilus (Lissochilichthys) wenchowensis, Varicorhinus (Scaphesthes) barbatus, Sinibrama macrops, Pelteobagrus fulvidraco* and *Parabotia maculosa*	Fishes are small and tend to inhabit the upper river where the water is clean, turbulent and rich in oxygen. Many of the species lay eggs in gravel.
Plains fishes to the north	*Cobitis sinensis* and *Carassius auratus*	*Cobitis sinensis* likes oxygen and has a strong resistance to cold weather while *Carassius auratus* is a polyphageous species with a strong ability to survive in an environment that is low in oxygen.

Migrating fishes spend most of their lives in rivers, lakes or streams, migrating to coastal waters or offshore to spawn. These species include *Trachidermus fasciatus* and *Anguilla japonica,* which die after spawning. Non-migratory fish in shallow inshore waters fishes spend all of their lives in the Yangtze River estuary or the waters of the coastal region. There are more than 10 species, including *Periophthalmus cantonensis,* and members of the Gobiidae. Fishes in coastal waters usually live in the sea. During migration for propagation and feeding offshore of the Yangtze River estuary, they may enter the estuary and the shallow sea. These fishes include many species, such as *Ilisha elongata, Nibea albiflora, Argyrosomus argentatus, Larimichthys crocea, Larimichthys polyactis, Scomberomorus niphonius, Trichiurus lepturus,* and *Pampus argenteus.* Fishes on the edge of the continental shelf are dominated by *Thamnaconus hypargyreus* and *Ovalipes,* occupying 26.3% of the catch. *Priacanthus macranthus, Carangoides* E *quula, Tsaius tumifrons,* Ommastrephidae, and *Daicocus peterseni* each represent an additional 7.07-4.67% of the catch. *Cubiceps squamiceps* and *Argentina semifasciata* are the dominant species among fishes in the middle and upper part of the continental slope, followed by *Priacanthus macranthus, Scombrops boops, Dasyatis microphthalmus, Doederleinia berycoides, Squalus brevirostris,* mini-shrimp, *Moridae,* and *Macrourida. Moridae* and *Macrouridae* are the most important dominant species among the fishes in the lower part of continental slope and Kuroshio, followed by *Congridae, Rajiformens, Squalus mistsukuris,* and *Synagrops argyrea.*

Biodiversity and habitats

Land

The Yangtze River Basin has a long history of reclamation. Most forests have been converted into farmlands. At present, the remnant primary forest is mainly found in remote mountain areas. Much secondary forest is recovering under the government's protection policies. These different types of ecosystems provide various habitats for a large number of organisms (birds, insects and fishes).

There are 2 653 families and almost 15 000 species of seed plants in the Yangtze River Basin, which account for 66.7% and 50% respectively of the numbers found in the country as a whole (Dong 2003).

Poyanghu Lake is the biggest freshwater lake in China. The region contains 350 higher plant species, belonging to 200 genera representing 75 families. The wetland vegetation may be divided into four vegetation types: aquatic community, marsh, meadow, and sandbank, and more than 60 formations (Wang & Wan 2000).

In Fujian Province, there are 4 703 vascular plant species (including 382 ferns, 70 gymnosperm plants and 4 251 angiosperm plants), which account for approximately 18% of the whole country. Among them woody plants represent 1 700 species. The number of terrestrial vertebrate species is 812 (44 amphibians, 155 reptiles, 543 birds, 110 animals), which account for approximately 28.6% of the whole country. The province also contains 5 000 insect species, along with a number of lower plant species, zooplankton and fishes. The region's forests cover 60.52% of the area, with this the top ranked amount in China (CNUS 2003).

Zhejiang Province has high plant diversity, and has been dubbed the "Plant species treasure of southeastern China". There are 1 400 woody plant species, of which 53 are listed in the rare protection inventory for Zhejiang Province. There are 635 animal species including animals, birds, reptiles and amphibians (ZPEPB 2003). The forest coverage of Zhejiang Province is 59.4%.

Freshwater

The Yangtze River's fishery diversity and habitat are exemplified by an analysis of the Tianegudao waters of the Yangtze River, in which there were 8 orders, 18 families and 77 species. Among these, *Cypriniforms* represents 52 species (67.5%), *Perciforms* represents 13 species (16.9%); the other orders represent only 1-2 species. In these families, *Cyprinidae* contains 43 species, which is the maximum number and which represents 55.8% of the total. The family *Cobitidae* contains the second largest number of species, with 6 species accounting for 7.8% of the sum. The Shannon diversity index is 3.7. Fishes species are abundant in the Yangtze River system, which has 370 species. This is the most of any drainage basin in China (Table 5).

The Yangtze River has the largest fisheries resource of all the drainage basins in China. The maximum catch from the river in 1954 was 450 000 tonnes, which was 72% of the country's total freshwater catch. The minimum was 180 000 tonnes in 1978, which was still 60% of the freshwater catch in China. From 1988 to 1994, the fry production in the Yangtze River was 63% of the total in China. Endemism dominates the ecological habits and characteristics of fish in the Yangtze River. The main stem of the Yangtze River contains more than 20 species that spawn with drifting eggs. *Ctenopharyngodon idellus, Mylopharyngodon piceus, Hypophthalmichthys molitrix,* and *Aristichthys nobilis* produce a particularly large number of eggs. The four major Chinese carps spawn in 36 areas in a 1 695 km stretch along the mainstream of the Yangtze River from Chongqing to Pengze in Jiangxi Province. There are 30 spawning grounds of the four major Chinese carps in the 1 695 km along the mainstream of Yangtze River from Chongqing to Wuxue of Hubei province, of which 11 spawning grounds lie in between Chongqing and Sandouping, 11 between Yichang and Chenglingji, and 8 between Chenglingji and Wuxue (Yu 2004). These species of fishes reproduce in the main stream of rivers, and the spawning behaviour of adults is stimulated by water current. The eggs hatch in slow moving water, then mature to the larval stage, during which they drif in the stream. This kind of life history has, however, been influenced by human activity (e.g. damming) in the middle part of Yangtze River (Li 1989). The Yangtze River is the primary production area for such dominant species as *Mylopharyngodon piceus, Ctenopharyngodon idellus, Hypophthalmichthys molitrix, Aristichthys nobilis, Acipenser sinensis, Salangidae, Macrura reevesii, Anguilla Japonica,* and *Eriocheir sinensis*. At present, there are 59 species of freshwater fishes in Yangtze River, including 24 introduced from abroad and 26 native species, and 9 species from other parts of China.

Table 5 Fish species in some rivers in Asia.

River	**Length** (km)	**Area** (km^2)	Genus	Species
Yangtze River	6 300	1 800 000	37	370
Zhujingjiang	2 100	440 000	49	262
Yellow River	5 464	750 000	27	150
Heilongjiang	4 370	1 840 000	23	113
Red River	1 200	15 000	24	110
Mekong River	4 000	790 000	17	255

(Source: Li 2001)

The total number of fish species found in the Qiantangjiang basin is 202, which belong to 55 families. *Cyprinidae* has 79 species, representing 39.11% of the total. The family *Bagridae* has 12 species, which is the second largest number and which represents 5.94% of the total. Fifty-three other families contain another 111 species for 54.95% of the total. Six species of aquicolous wild animals are listed in the national protection project: these species are *Acipenser sinensis, Psephurus gladius, Trachidermus fasciatus, Andrias davidianus, Neophocaena phocaenoides,* and *Psephurus gladius*. Some have almost disappeared, the other species are in severe danger. Fish in the Qiantangjiang tend to be distributed according to the following three patterns. Small fish species that are capable of withstanding high velocity flows and that feed on benthic organisms are typically found in the upper reaches of the river that are stream-like. Some of these species are found in the vicinity of Kaihua and Xiuning, such as *Acrossocheilus (Lissochilichthys) wenchowensis, Distoechodon tumiros, Sinibrama macrops, Zacco platypus,* and *Siniperca ronlei*. Some widely distributed families and species such as *Cyprinidae* and *Carassius auratus* are also found in this habitat. In the middle reaches of the river, where the river is broad and slow flowing with many shoals or bars, larger size fish that feed on benthic species are found, such as *Xenocypris argentea, Spinibarbus hollandi, Megalobrama terminalis, Squaliobarbus curriculus, Cyprinus carpio,* and *Carassius auratus*. In the lower reaches of the river near the estuary the water is wider and deeper with slower flows, and is often affected by the tide. Some large fish species can be found here, including some species that feed on benthos, plankton, or organic detritus, such as *Ctenopharyngodon idellus, Mylopharyngodon piceus, Hypophthalmichthys molitrix, Aristichthys nobilis, Megalobrama terminalis, Plagiognathops microleps, Cyprinus carpio,* and *Carassius auratus*.

There are 160 fish species in the in Minjiang system, including 118 pure freshwater species, of which most belong to the Cyprinoids family and river aquatic fishes. Minjiang is the main fishing area for freshwater fishes in Fujian Province. Cyprinoids and *Cyprinus carpio* are the main fish of economic importance. More than 20 species are commercially fished in the upper reaches of Minjiang, Jianxi, such as *Carassius auratus, Cyprinus carpio, Ctenopharyngodon idellus, Squaliobarbus curriculus, Distoechodon tumiros, Plagiognathops microleps, Cirrhinus molitorella, Spinibarbus caldwelli, Acrossocheilus* (Lissochilichthys) *wenchowensis, Abbottina rivularis, Rhinogobio typus, Sinibrama macrops, Silurus asotus, Pelteobagrus fulvidraco* and *Leiocassis* spp. Other fishes have lower commercial value than those listed previously. These are *Myxocyprinus asiaticus, Opsariichtys bidens, Zacco platypus, Elopichthys bambusa, Hemibarbus labeo, Saurogobio dabryi, M. terminalis, Pseudolaubuca sinensis, Anguilla japonica* and *Channa asiatica*. The dominant species in upper reaches of the Minjiang are *Xenocypris argentea, Cyprinus carpio, Carassius auratus* and *Silurus asotus*. The dominant fish species in the middle reaches of the Minjiang are *Cyprinus carpio, Xenocypris argentea, Anguilla japonica, Culter erythropterus, M. terminalis,*and *Pelteobagrus fulvidraco*. There are more than 20 species of principal economic fishes in the lower reaches of the Minjiang, such as *Clupanodon thrissa, Clupanodon punctatus, Coilia ectenes, Salangidae, Cyprinus carpio, Carassius auratus, Plagiognathops microleps, Hypophthalmichthys molitrix, Aristichthys nobilis, M. terminalis, Silurus asotus, Leiocassis* sp., *Clarias fuscus, Anguilla japonica, Cyprinus carpio, Lateolabrax japonicus,* and *Oxyeleotris*. A habitat description of the major freshwater lakes in the Yangtze River drainage basin is listed in Table 6.

Marine waters

The Yangtze River estuary

The estuary's habitat is complicated. The area contains 160 species of phytoplankton, of which 80% are diatoms. Additionally, there are some potentially harmful species of dinoflagellates, chrysophyta and blue-green algae. According to data from 1996-1997, about 90 species of phytoplankton have been identified in the western part of the estuary (121°50 ~122°30 E) (Xu et al. 1999).

The Yangtze River Estuary also contains 174 species of zooplankton of which the dominant species as measured by abundance is crustacean plankton. Others are jellyfish and arrow worms. The dominant zooplankton species are *Tortanus vermiculus, Schmackeria poplesia, Centropages dorsispinatus, Labidocera euchaeta, Acanthomysis longirostris, Monoculodes limnophilus, Calanus sinicus, Acartia pacifica, Sagitta nagae, Sagitta enflata*, and *Muggiaea atlantica*. The zooplankton species are those offshore species mainly tolerant of wide temperature ranges and low salinity, followed by warm water species that are widely distribued in the summer and autumn (Xu et al. 1999). According to historical data, there are 14 orders represented by 112 species of fishes

Table 6 Main freshwater lakes of the Yangtze River drainage basin.

Lake	Poyanghu	Dongtinghu	Taihu	Caohu	Dingshanhu	Xihu
Region	Jiangxi	Hunan	Jiangsu	Anhui	Shanghai	Zhejiang
Areas (km^2)	2 933	2 432	2 425	2 000	64	6
Storage (km^3)	14.96	15.54	5.14	2.07	0.16	0.01
Climate	Northern subtropical Monsoon	Monsoon humid	Monsoon	Northern subtropical Monsoon	Northern subtropical Monsoon	Northern subtropical Monsoon
Annual average temperature (°C)	16.5~17.8	16.6~17.0	16.0	16.1	15.5	16.1
Annual mean precipitation (mm)	1 570	1 305	905~1 965	996	1 037	1 473
Soil	Red and yellow brown	Red	Yellow and red brown	Yellow and brown	Rice field	Yellow and brown
Input water (km^3/year)	151.02	306.57	8.40	4.46	1.81	0.02
Output water (km^3/year)	151.02	302.10	8.14	4.46	1.76	0.02
pH	7.2~8.0	8.1	No data	7.5	8.0	8.5
COD (mg/l)	1.1~1.8	2.6	2.58	4.1	4.0	12.5
Pelagic algae (Number of genera)	154	32	134	71	91	59
Zooplankton (Number of species)	112	81	79	45	34	226
Zoobenthos (Number of species)	65	30	59	55	75	No data
Aquatic higher plant species (Number of species)	119	35	75	54	26	No data
Fishes (Number of species)	122	114	106	94	10	51
Birds (Number of species)	280	No data	No data	No data	No data	No data

(Source: Wang & Dou 1998)

in the Yangtze River estuary. These can be divided into 3 ecological communities: (1) freshwater; (2) brackish; and (3) marine. The estuary contains 17.4% freshwater fishes from the *Cyprinidae* and *Cobitidae* families, 21.6% brackish water fishes from the *Mugilidae* and *Gobiidae* families and 57.2% marine fishes from the *Clupeiformes, Beloniformes, Perciformes,* and *Pleuronectiformes* families. *Coilia mystus* and *Coilia ectenes* are the primary economic species, *Acipenser sinensis, Psephurus gladius,* and *Trachidermus fasciatus,* are the rare species, and the eel parr of *Anguilla japonica* is the main parr resource. *Exopalaemon annandalei, Exopalaemon carinicauda,* and species in the *Penaeinae* family are the main economic shrimp types in the estuary. *Eriocheir sinensis, Scylla serrata,* and *Portunus trituberculatus* are the main economic crabs.

Zhoushan Archipelago waters

There are 261 species of phytoplankton in this area (Zheng 2003). The predominant species are *Skeletonema costatum, Chaetoceros lauderi,* and *Nitzschia pungens.* Inshore warm temperature species are dominant. There are 223 species of zooplankton in this area, with abundant summer biomass. The main species are *Calanus sinicus, Labidocera euchaeta, Pseudeuphausia sinica, Acartia pacifica,* and *Sagitta enflata* etc. (Zheng 2003). There are 77 species of mollucs, 77 species of polychaetes, 95 species of crustaceans, and 136 species of protozon in the benthos. The Zhejiang coastal waters contain 203 species of nekton, and the main fish species are *Pseudosciaena polyatis, Pseudosciaena crocea,* largehead hairtail, *Ilisha elongata, Pampus argenteus, Harpodon nekereus, Miichthys miiuy, Muraenesox cinereus, Saurida* spp., *Acetes chinensis, Exopalaemon carinicauda, Portunus trituberculatus* Miers, and *Sepiella maindroni.*

Kuroshio Current

The Kuroshio Current is one of the largest currents adjacent to the continental shelf in the East China Sea. The flows and quantities of heat and water have an important influence on the shallow waters of the sea's continental shelf. According to cooperative research conducted by China and Japan from 1984 to 1990, the following species have been document in Kuroshio waters: 419 species of phytoplankton, 697 species of zooplankton, and 180 species of fish (Zheng 2003).

The characteristics of the main biotic community in the Kuroshio Current are as follows. The phytoplankton is composed of species tolerant of high temperatures and salinities, in addition to species that tolerate high temperatures and low salinities and low temperatures and high salinities, along with species with a wide range of tolerances. Zooplankton populations are represented by warm temperate species in the offshore zone and tropical species in the ocean. Because the Kuroshio waters are characterised by high temperature and salinity, phytoplankton indicator species, such as *Gossleriella tropica, Asterolampra marylandica, Cheatoceros dadayi, Ceratocorys bipes, Amphisolenia schauinslandi* can be found, along with about 20 zooplankton indicator species, including *Euchaeta concinna, Euchaeta marina, Pareuchaeta russelli, Sagitta enflata Grassi, Liriope tetraphylla, Pseudoconchoecia concentrica,* and *Euphausia tenera.*

Taiwan Strait

The upwelling in southern part of the Taiwan Shoal tends to be low temperature, high salinity and high density from east to west throughout the year. This is an area where bottom water travels up along the slope and forms an upwelling. According to investigations from 1987 to 1988, 102 phytoplankton species belonging to 22 families and 38 genera are found in the region (Hong et al. 1991). There were more zooplankton species than phytoplankton species, however, according to an investigation from 1984 to 1985, which recorded 491 species in total, with 118 species of copepods and 106 species of medusa (Cai et al. 1995). The economically important fish species are *Sardinella lemuru; Decapterus maruadsi; and Trachurus japonicus.*

Socio-economic characteristics

Population and economy

Population growth

Over the last few decades, the annual population growth in China has been 6.45 per million overall. Table 7 shows the natural growth rate in various parts of the East China Sea region. Shanghai has the lowest natural growth rate in the region. Shanghai has become an attractive area for China's young people and for foreigners both because of its unique geographic location and its rapid economic growth, but the local natural growth rate remains low. Zhejiang and Fujian Province have moderate population growth rates, but in relatively less developed provinces, such as Jiangxi, the population growth rate is higher.

Table 7 Annual population growth rate.

Country and region		Growth rate (per million)
China	China	6.45
	Shanghai	-0.54
	Jiangsu	2.18
	Zhejiang	3.79
	Fujian	5.78
	Anhui	6.03
	Jiangxi	8.72
Japan		2.00
Korea		8.00

(Source: NBSC-DPSSTS 2003)

Population structure

Table 8 shows the population structure of the region. The population of China is characterised by a young age structure, with about 21.29%

Figure 3 The changes of the skyline of Shanghai.
(Photo: Corbis)

under age 15, and 8.17% over age 65. This trend is more significant in less developed provinces such as Jiangxi. But Shanghai has 10.72% of its population under age 15, and 13.44% over age 65, which shows a trend toward an aging population. According to one report (SFSRG 2002), the population in the age bracket of age 50-64 will represent 46.67% of the population in 2015, suggesting the accelerating aging of Shanghai's population. Japan's population aged 65 and over amounts to 17.6%, suggesting a more serious aging problem than in China or Korea.

Table 8 Population structure in the East China Sea region.

Country and region		Population (million)	Age 0-14		Age 15-64		Age 65 and over	
			(million)	(%)	(million)	(%)	(million)	(%)
China	China	1 259	268.0	21.29	888.2	70.55	102.8	8.17
	Shanghai	16.01	1.716	10.72	12.14	75.83	2.152	13.44
	Jiangsu	72.97	13.72	18.80	52.04	71.32	7.215	9.89
	Zhejiang	45.77	7.520	16.43	33.14	72.41	5.104	11.15
	Anhui	62.78	15.19	24.19	42.42	67.57	5.171	8.24
	Fujian	34.13	7.198	21.09	24.34	71.32	2.594	7.60
	Jiangxi	41.52	10.19	24.54	28.27	68.09	3.058	7.37
	Taiwan	22.52	4.60	20.42	15.89	70.56	2.03	9.02
Japan		127.0	18.36	14.46	86.19	67.87	22.34	17.60
Korea		47.34	10.10	21.34	34.11	72.05	3.31	7.00

(Source: NBSC 2003a, NBSC 2003b)

Unemployment rate in urban areas

Of the three Asian countries of China, Japan and Korea, China has lowest unemployment rate, but the phenomena is changing because of political reform and the implementation of new economic policies. The unemployment rate is growing because of business reforms and lay-offs. This trend is more significant in the coastal area than in inland regions, particularly in Shanghai, which is considered to be the centre of the Chinese economy, which makes for more competition for jobs (NBSC 2003a, 2003b).

Economy

In the last several decades, the economies of China, Japan, and Korea have grown rapidly. Compared to 1990, China's 2001 GDP has grown by four-fold (Figure 4). Most coastal cities and provinces, including Shanghai, Zhejiang, Jiangsu, and Fujian, have shown rapid increases in GDP (NBSC 2003a). Inland provinces such as Anhui and Jiangxi have had correspondingly weak economic growth. Figure 5 shows the contribution of the three main industry sectors to the growth of the GDP. The contribution of primary industry to the GDP in China is 18-20%, which is higher than that of Japan and Korea. This indicates that agriculture is still an important economic factor in Chinese society.

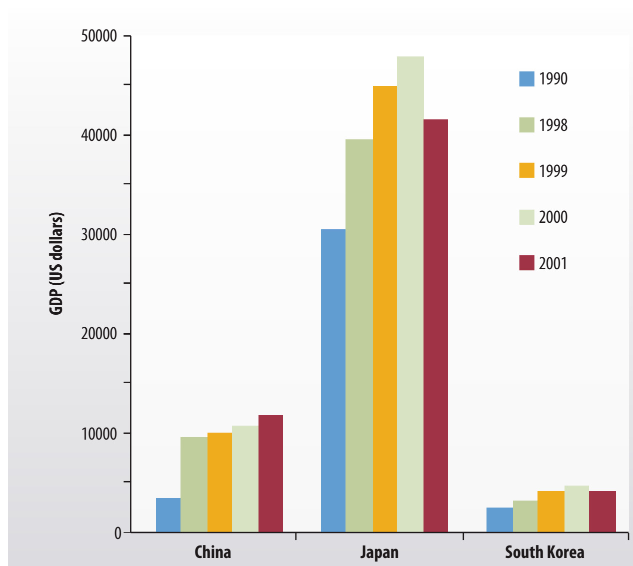

Figure 4 Gross domestic product in China, Japan and South Korea.
(NBSC 2003b)

Urbanisation

At present, Shanghai is the most urbanised area of China. The non-agricultural population of Shanghai was 10 million in 2001, which has increased by 15.6% as compared to 1990. The urbanisation level has reached 75.3%. In 2000, the immigrant population of Shanghai was 3.87 million people, which showed an increase of 2.81 million compared

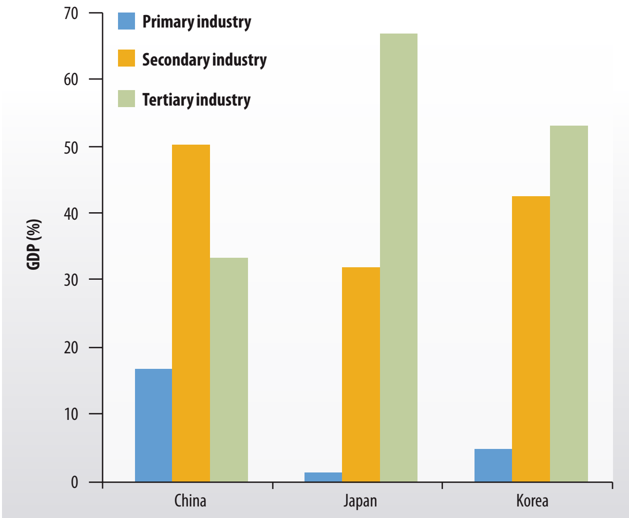

Figure 5 Contribution of primary, secondary, and tertiary industries to the growth of China's GDP.
(NBSC 2003b)

to 1988. There is an average of two migrants among nine now in Shanghai (Gu 2003). The Yangtze River Delta is the most developed and densely populated area. In 2000, the average urbanisation level was 49.61%, as compared to the national average of 36.22%. The urbanisation level in the provinces of Jiangsu and Zhejiang is 41.19% and 48.67%, respectively (Kong 2002). The urbanisation level of Fujian Province in 2000 was 37% (Huang 2004), equivalent to the national level. However, in the less developed provinces like Jiangxi and Anhui, the urbanisation level was only 27.67% in 2000 and 22.3% in 1998 respectively (Zhang & Lv 2003, Zhou & Wu 2000), both of which are lower than the national average. Figure 6 shows the urbanisation level of the region, which shows that the overall urbanisation level of China is much lower than the more developed countries of Japan and Korea.

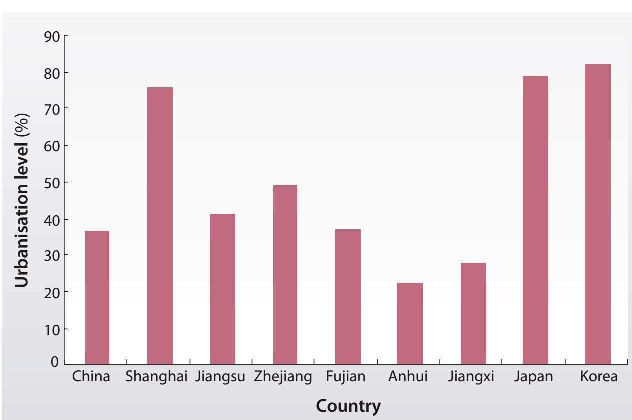

Figure 6 The urbanisation levels in China, Shanghai, Jiangsu, Zhejiang, Fujian, Anhui, Jiangxi, Japan and Korea.
(Gu 2003, Kong 2002, Huang 2004, Zhang & Lv 2003, Zhou & Wu 2000, NBSC 2003b)

Major socio-economic activities

Land use in the Yangtze River Basin

The forests of the Yangtze River Basin are mainly found in western Sichuan Province, northern Yunnan Province, southwestern Hunan Province, southern Anhui Province and northern Jiangxi Province. The total forest area in the Yangtze River Basin is 390 000 km², accounting for 29.7% of the country's forested area. The forests cover 21.9% of the Yangtze River Basin. Grasslands are mainly found in the headwater region, while farmlands are mainly found in the middle to lower reaches of the Yangtze River Basin (Figure 7). During the last ten years, as a result of high demographic and developmental pressures, land use in the upper reaches of the Yangtze River Basin has changed dramatically. Forests have been cut down and converted to agricultural land and human settlements or industrial zones. These changes have resulted in more pollutant loads and soil erosion into the Yangtze River (NIES 2004).

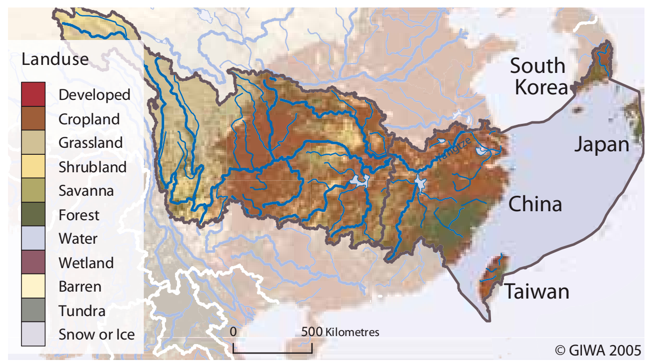

Figure 7 Land use map of the Yangtze River Basin.

Agriculture

The number of individuals working in agriculture represents 67.1% of the total population of China, which is above the average for the world as a whole (Zhang & Tian 2003). About 202.9 million people work in agriculture in the East China Sea region. The region's main crops are rice, wheat, corn, cotton, beans, and tubers. In the last fifteen years, the land use in the lower reaches of the Yangtze River has shifted from farmland to an urban landscape. The amount of farmland as a percentage of the total acreage has decreased from 47.3% in 1985 to 44.3% in 2000. In contrast, the proportion of urban land use increased from 9.73% in 1985 to 13.1% in 1996 (Zhen et al. 2003a). Water usage in agriculture varies according to the level of cultivation and extent of irrigation in each province. Jiangsu Province uses the largest amount of water for irrigation. Shanghai uses the least amount of water, which corresponds to the higher industrialisation and urbanisation of the city.

Fisheries

Fisheries contributes significantly to the economy of the coastal regions. The fisheries forms a major sector in economy, but is also critical in providing employment opportunities, income, and food security. In 2000, the fish catch in the East China Sea emounted 3.8 million tonnes (FAO 2003).

Tourism

Tourism is becoming increasingly important for the economy of China's coastal regions. In the twelve years from 1990 to 2001, the total number of people who travelled domestically in China increased from 280 million to 784 million. Incomes also increased from 0.2 billion to 4.25 billion USD (1.70 billion to 35.22 billion yuan) over the same period (Xu 2003). With the country's increasing income and national holidays, and changes in the Chinese concept of consumption, China's domestic tourism has developed rapidly (Xu 2003). East China, Suzhou, Hangzhou, Shanghai, Wuxi and Nanjin have become important tourist destinations. According to a report from regional governments, the income from tourism in Shanghai exceeded 25.4 million USD over the holidays of May 1-7, 2004 (Dragon TV of Shanghai 2004).

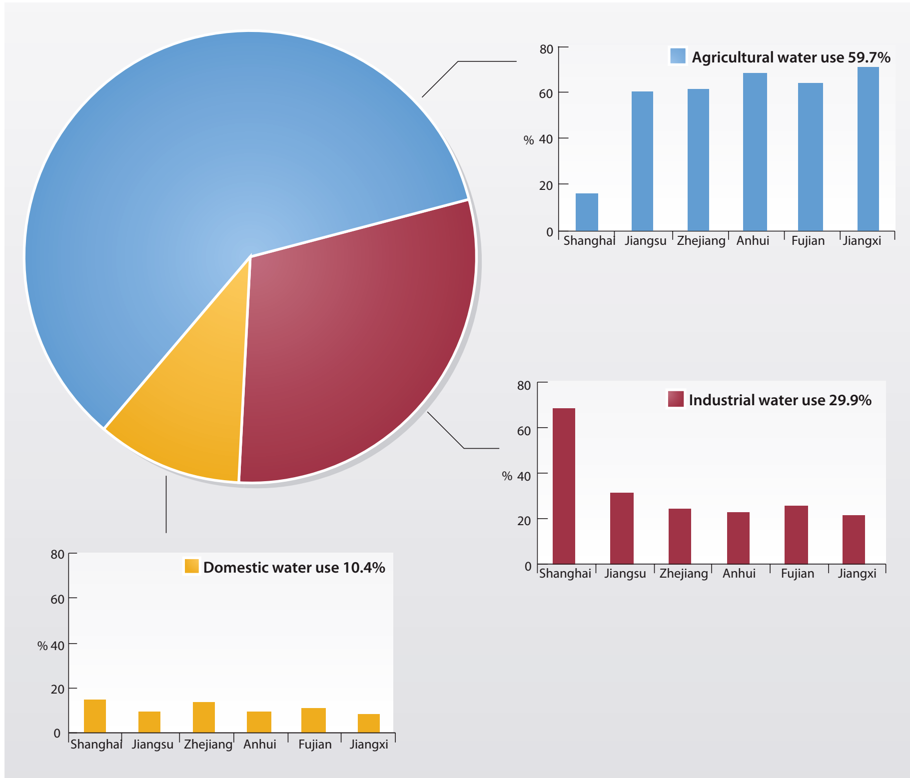

Figure 8 Water use by economic sector for Jiangsu, Shanghai, Zhejiang, Fujian, Jiangxi, and Anhui provinces.
(CNRD 2004, MWRC 1999a, MWRC,2001a)

Water-related issues

Figure 8 shows that agriculture consumes the greatest amount of water by sector. Agriculture water usage is 59.7% of the total amount of water use in China. Industry and domestic uses consume 29.9% and 10.4%, respectively. In China, the main use of agriculture water is for irrigation. With the development of the economy and industrialisation and urbanisation, non-agricultural water demands will increase dramatically. Domestic water consumption is lower than agriculture and industry, but with the increasing population in the region, this requirement will also increase.

Two representative engineering projects are the Three Gorges Project and China's South-North Water Transfer Project. The main purpose of Three Gorges Project is to prevent floods and produce electric power. The environmental problems caused by the project are controversial and include damaged ecosystems and increased soil erosion, which will bring socio-economic problems and negative effects on the coastal environment. The project to transfer water from China's south to the north is designed to solve freshwater shortage problems in northern China. Environmental problems that will result from this project, such as soil erosion and ecosystem changes, along with the issue of transporting the water itself remain under debate.

Legal and institutional frameworks

At present, China has 6 volumes of environmental protection laws, 9 volumes of resource management laws, many administrative procedures and rules of law pertaining to environment protection and resource management, as well as more than 400 different types of national environmental standards. These laws and rules together form the framework for the country's legal system. Annex III-VI show a list of laws and regulations existing in the region.

Assessment

Table 9 Scoring table for the East China Sea region.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter).
0 No known impact; 1 Slight impact; 2 Moderate impact; 3 Severe impact

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

East China Sea	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.7* ↗	1 →	0 →	0 ↗	1.0	4
Modification of stream flow	1					
Pollution of existing supplies	2					
Changes in the water table	2					
Pollution	1.7* →	1 →	1 →	2 ↘	1.5	2
Microbiological pollution	1					
Eutrophication	3					
Chemical	1					
Suspended solids	1					
Solid waste	1					
Thermal	1					
Radionuclide	0					
Spills	1					
Habitat and community modification	2.0* ↗	1 ↘	0 →	2 ↘	1.4	3
Loss of ecosystems	2					
Modification of ecosystems	2					
Unsustainable exploitation of fish	2.4* →	2 ↘	1 ↘	0 ↗	1.6	1
Overexploitation of fish	3					
Excessive by-catch and discards	0					
Destructive fishing practices	3					
Decreased viability of stock	2					
Impact on biological and genetic diversity	1					
Global change	0.5* ↗	0 →	0 →	1 →	0.5	5
Changes in hydrological cycle	1					
Sea level change	0					
Increased UV-B radiation	0					
Changes in ocean CO_2 source/sink function	0					

* This value represents an average weighted score of the environmental issues associated to the concern. 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 9.

Freshwater shortage

Environmental impacts

Modification of stream flow

In the past century, the expansion of irrigation, development of industry and population growth have been the major factors behind increased water demands.

The agricultural sector is China's largest consumer of water, representing 59.7% of total amount of water use, while industrial and domestic uses together represent only 29.9% and 10.4%, respectively (average values from 1997 to 2002), even though the industrialised sector in Shanghai consumes 69.0% of the area's water, with 16% and 15% consumed respectively by agricultural and domestic use. In most areas of China, industry and agriculture consume between 59.3-70.1% and 21.4-31.4% of all water, while domestic use is only 8.5-13.9%.

In the Yangtze River drainage basin, the main use of water in agriculture is irrigation. The effective irrigation area increased from 100 000 km^2 in 1978 to 115 500 km^2 in 1999 (Figure 9). Industry also consumes a great deal of water. This consumption is increasing with accelerated economic

Figure 9 Change in total irrigation area for Anhui, Jiangsu, Shanghai, Zhejiang, Jiangxi and Fujian provinces.
(NBSC-RERT 2004, BSA 2003, BSF 2003, BSJ 2003a, BSJ 2003b, BSZ 2003)

development. Industrial water use increased from 37.7 billion m^3 in 1997 to 42.7 billion m^3 in 2002, with a 2.5% average growth rate per year (Figure 10).

Domestic water use has also shown an increasing trend, from 12.8 billion m^3 in 1997 to 15.3 billion m^3 in 2002 (Figure 10), with a 3.6% average growth rate per year. Population growth is the main cause for this increase. This has resulted in a decrease in the available water resources per person per year to 1 763 m^3 in 2000.

The traditional approaches of dam construction, water transfer, dredging and canal dredging remain the main solutions for meeting this increasing water demand. In the late 1980s, 11 930 different-sized dams were constructed in the upstream reaches of the Yangtze River drainage. As of 2002, 650 large-scale (capacity: $>10^8$ m^3) and medium-sized (capacity: $\sim10^7$ m^3) reservoirs had been built in Jiangsu, Zhejiang, Anhui, Fujian and Jiangxi provinces. In the 1990s, there were 11 newly built large-scale reservoirs in the upstream reaches of the Yangtze River drainage basin with a capacity of 17.53 billion m^3, which effectively doubled the existing reservoir capacity. In 2000, the total capacity was at 27.28 billion m^3 (SCTGPCC 2002). Together with other projects such as the Three Gorges Dam Project, and the South-to-North Water Diversion Project, this new construction will presumably result in the reduction of river run-off, particularly in the dry season, affecting the health of freshwater ecosystems as well.

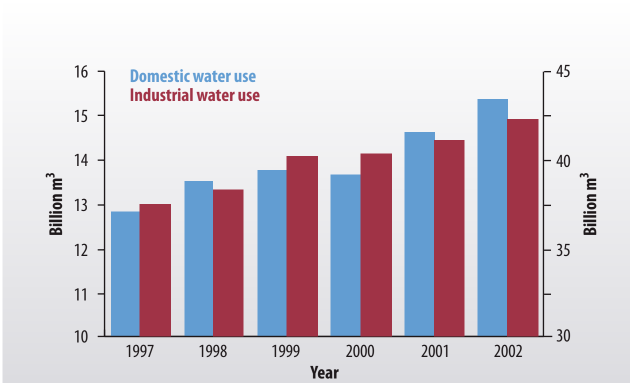

Figure 10 Total industrial water consumption and domestic water use for Anhui, Jiangsu, Shanghai, Zhejiang, Jiangxi and Fujian provinces.
(MWRC 1999a, MWRC,2001a, MWRC 2002a, CNRD 2004)

Pollution of existing supplies

Population growth, urbanisation and industrialisation have accelerated environmental pollution and water quality deterioration. The rivers in Shanghai have been seriously polluted, with more than 92.2% of the river sections monitored containing water that was not acceptable for domestic use. Pollution of the Yangtze River drainage basin is an important problem too, especially in the delta area. In the area adjacent to the Yangtze River Estuary, hypoxia is a problem (Figure 11). The estuary receives flows from various land-based pollution sources, which may alter the ecosystem.

Monitoring of sections of the Yangtze River system in 2001 and 2002 has shown that water quality has deteriorated. The key pollution indexes reported by the national environmental protection agency are petroleum hydrocarbons, ammonia, nitrogen and the potassium permanganate index. Pollution is fairly minimal in rivers of the Zhejiang and Fujian Provinces, but problems of water quality are a common topic of public discussion. The key pollution indicators are petroleum hydrocarbons and ammonia nitrogen. Among 20 monitoring sites in

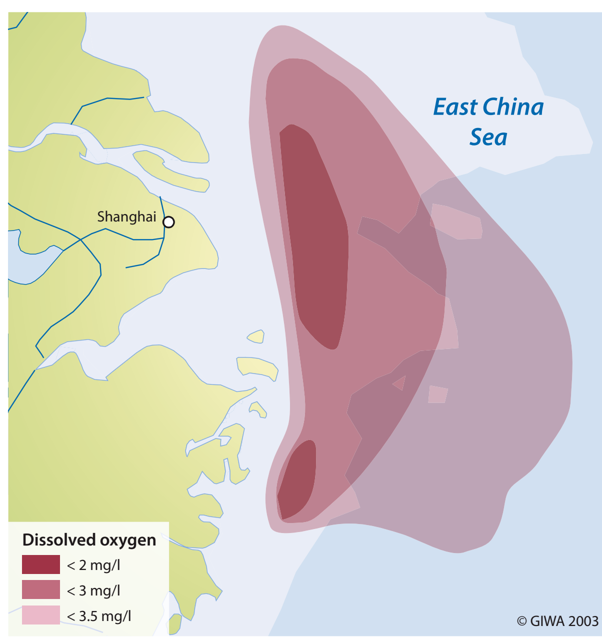

Figure 11 Hypoxy areas in the East China Sea.
(Source: Li & Zhang 2002)

Taihu Lake in 2002, the percentage that was of grade III, grade IV, grade V and worse than grade V was 5%, 35%, 5% and 55% respectively. The main pollutants are nitrogen and phosphorus, with the lake at a medium level of eutrophication. Water quality improved slightly compared relative to 2001 (SEPAC 2001, 2002).

In the past 30 years, the quality of surface water in China has decreased remarkably. Polluted agricultural run-off, and untreated industrial and domestic wastewater discharges are main sources of pollution. Rivers and lakes were reported to be polluted by bacteria, nutrients, organic compounds and other toxics carried in high-volume wastewater discharges. Fertilisers and pesticides have both been identified in agricultural run-off. Fertiliser use in agriculture (Figure 12), increase in cultivated area, and nutrient runoff can all lead to harmful algal blooms (Shen et al. 1999) in lake and coastal waters (Li & Daler 2004). An increase in domestic and industrial wastewater discharges is still the main source of pollution in urban areas in China (Figure 13). In 2000, the total discharge of domestic wastewater reached 5.44 billion tonnes,

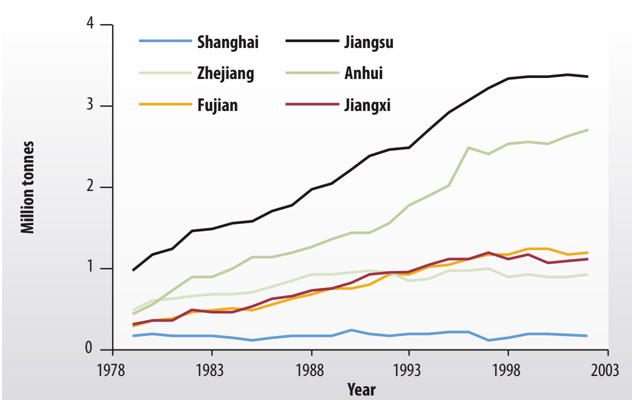

Figure 12 Consumption of chemical fertiliser by province.
(NBSC 2003a, NBSC-RERT 2004)

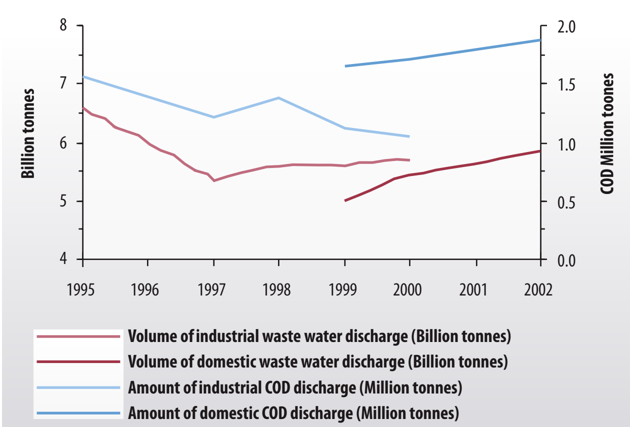

Figure 13 Industrial and domestic wastewater discharges in Anhui, Jiangsu, Shanghai, Zhejiang, Jiangxi and Fujian provinces.
(NBSC 2002, BSA 2003, BSF 2003, BSJ 2003a, BSJ 2003b, BSZ 2003, SCMC 2002)

COD reached 1.71 million tonnes, while the discharge of industrial wastewater was reduced, with the total amount at 5.74 billion tonnes, and a COD of 1.05 million tonnes. Industrial and domestic wastewater discharges to surface waters resulted in pollution, which results in water quality problems in meeting water requirements in urban areas.

Changes in the water table

Currently, groundwater in urban areas is used mainly in industry and for domestic use. Industry and agriculture once accounted for most water consumption, but economic development has led to increasing pollution of surface and groundwater sources and an associated increased demand for good quality groundwater. Domestic water use has also increased, particularly in Fuzhou in Fujian Province and in some cities of Zhejiang Province.

As the consumption of groundwater has always been higher than the supply, the water table is dropping. This is a worsening problem in Shanghai, Fuyang in Anhui Province, and Wuxi, Changzhou and Suzhou in Jiangsu Province. Overextraction of groundwater on the coast has resulted in seawater intrusion; this problem is particularly serious in Xiamen in Fujian Province.

Excessive extraction of groundwater in China has resulted in a problem called funneling, which results land subsidence, seawater intrusion, and other serious environmental problems. There are more than 13 places where the area affected by funneling is larger than 100 km^2. The worst case is in the region of Wuxi, Changzhou and Suzhou in Jiangsu Province in the lower reaches of Yangtze River, where the funnel effect covers a total area of over 5 000 km^2, which seriously threatens the social and economic growth of this region. Rapidly dropping water tables have resulted in ground subsidence, particularly in Shanghai, which is located in the region of Yangtze River Delta, where civil construction works face difficult challenges.

Socio-economic impacts

Freshwater shortages in the coastal area affect economic development. Water supply is a problem in some coastal areas and islands. In Shanghai and the mid- to southern region of Jiangsu Province, the average water volume is 245.85 m^3 and 457.55 m^3/person/year. It is worse in coastal areas, such as in the Zhoushang Islands. The 300 000 people who live on the island face water shortages and drinking water problems (Wang et al. 2003).

Conclusions and future outlook

Freshwater shortage has only a slight impact in the East China Sea region. The growth in water consumption for irrigation use and industrial development have caused a decrease in the availability of water for drinking and agricultural purposes, and a concomitant decrease in fish productivity in river basins. While the deterioration of water quality has had only moderate effects on human health, there has been an increase in the cost of water treatment and supply. In the future, it is anticipated that water withdrawal from rivers and other sources will increase as a consequence of population growth and expansion of industrialisation and urbanisation, and that the pollution of surface and groundwater resources due to excessive use of agrochemicals in the region is likely to increase. Freshwater shortage related issues might become an important environmental problem in the future, unless corrective measures are put in place.

Water supply shortages are increasing in the area and this trend will persist as a result of the increasing population, intensified urbanisation and the increase in water pollution. The area's urbanisation will make water shortages increasingly problematic.

Pollution

Environmental impacts

Microbiological pollution

In 2001, an investigation of the bacterial index of economic shellfish was conducted in the coastal areas of Shanghai, Zhejiang, and Fujian Provinces. The results show that hygienic indicators such as total bacterial counts and *Escherichia coli* in two types of economic shellfish (*Bullacta exarata,* and *Sinonovacula constricta*) in the coastal area of Shanghai meet national standards. Economic shellfish in most coastal areas of Zhejiang Province meet national standards, while in Shenjiamen, Wenzhou and Taizhou Bay, the amount of fecal *Escherichia coli* in economic shellfish is above national biological standards by a factor of 8.0, 8.0, and 1.5, respectively (ZOFA 2001). The standard value of fecal *Escherichia coli* in economic shellfish is 3 cell/g (fresh meat). In other areas of Zhejiang Province the amount of fecal *Escherichia coli* is 0.43- 2.4 cell/g (fresh meat), with the total count of heterotrophic bacteria at about 3 400-83 000 cell/g of fresh meat, and the count of Vibrio as high as 3 960 cell/g fresh meat (ZOFA 2001). In the coastal areas of Fujian Province, the total count of bacteria in economic shellfish is lower than the national aquatic product hygienic standards, and no harmful algal bloom toxins were detected in shellfish (Table 10).

On May 4th 2002, a harmful algal bloom covering about 30 km^2 was detected in the offshore area of Pufuning Bay in Fujian Province. The next day it grew to 500 km^2. The dominant harmful algal species are *Noctiluca scintillans* and *Prorocentrum triestinum,* followed by *Gymnodrium* sp. The event caused shellfish losses in a 133 400 km^2 cultivated area near the coast of Fuding (Zan et al. 2004).

Table 10 Bacterial indices and harmful algal bloom toxins in the coastal area of Fujian Province.

Shellfish	Total count of bacteria (cell/g)	Escherichia coli (cell/g)	Vibrio (cell/g)	Harmful algal bloom toxins (µg/g)
Oyster	2 136	>190	1 100	ND
Sinonovacula constricta	7 00	>240	3 200	ND
Venerupis variegate	3 000	24	700	ND

Note: ND = Not Detected.

(Source: FOFA 2001)

The main reason for bacterial pollution in economic shellfish is industrial and domestic wastewaters. In 1995, 41-77% of the total industrial wastewater discharges met national standards, and the wastewater treatment capacity in the coastal regions of the East China Sea was between 64 -86% of the total discharge (Figure 14). In 1999 the rate of wastewater treatment was considerably increased, but large amounts of untreated wastewater continue to be discharged directly to water bodies, in amounts that have recently increased. The treatment capacity for domestic sewage and household wastes is even lower than the rate of industrial wastewater treatment. In Shanghai, the treatment rate of domestic sewage is up to 60% and the rate of sanitary disposal of household refuse is between 70-90%, which has been found to be an important reason for bacterial water pollution. In some badly polluted near shore areas, the hepatitis virus, *Escherichia coli* and other infectious virus have been found in the water. In 1988, *Scapharca subcrenata* was contaminated by hepatitis virus in the Lvsi area, which resulted in a hepatitis A outbreak in Shanghai, which infected about 300 000 people.

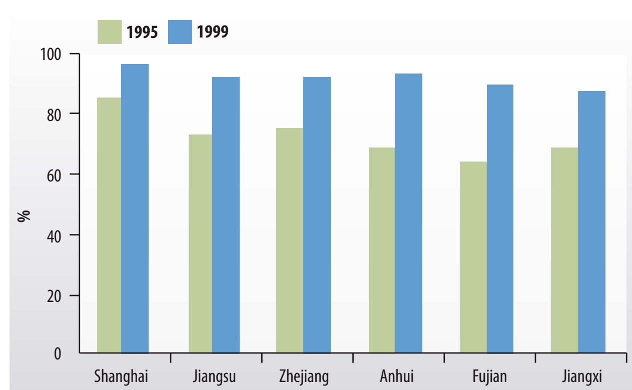

Figure 14 Industrial wastewater treatment capacity.
(CNRD 2004)

Eutrophication

Since the 1980s, the use of chemical fertiliser has greatly increased (Figure 12, 15 and 16), while aquaculture is also expanding. The loss of nutrients from these activities and the run-off of organic substances, nitrogen and phosphorus have caused eutrophication to be ubiquitous in rivers, lakes and the coastal sea. The main source of nitrogen is run-off from agriculture, while most phosphorus comes from domestic sewage and industrial wastewater discharges.

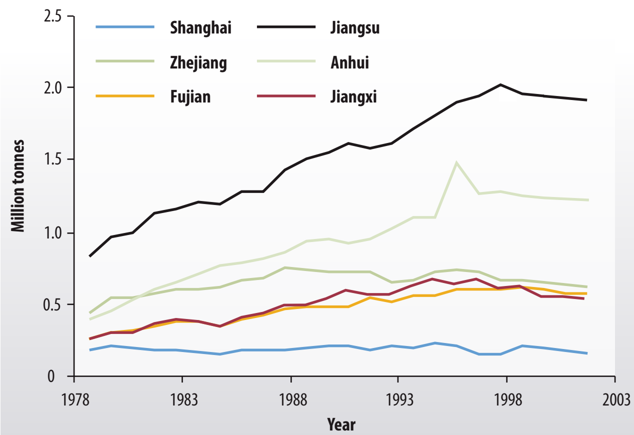

Figure 15 Consumption of nitrogenous fertiliser by region.
(NBSC 2003a)

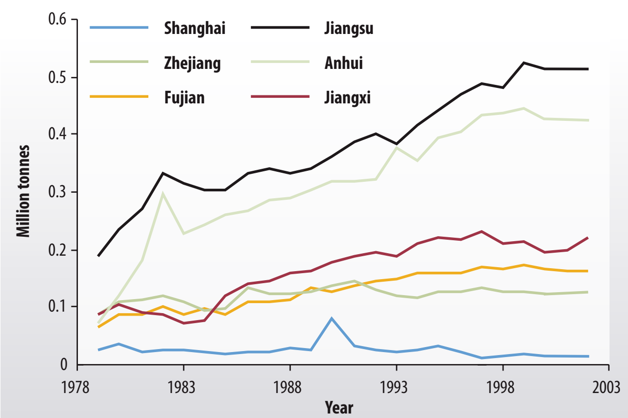

Figure 16 Consumption of phosphate fertiliser by region.
(NBSC 2003a)

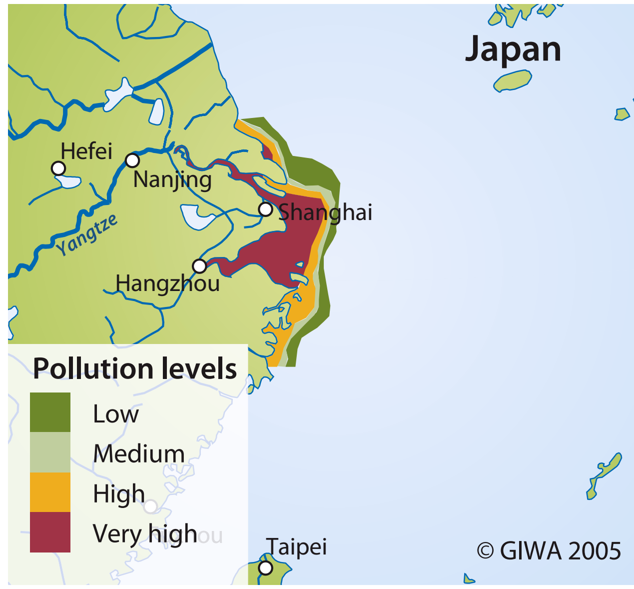

Figure 17 Distribution of pollution in the coastal area of the Yangtze River estuary.
(SOA 2003a)

The rate of pollution in the East China Sea is beginning to slow (Table 11). The main areas of pollution remain the Yangtze River estuary and Hangzhou Bay (Figure 17). The main pollutants are inorganic nitrogen and phosphorus, which have concentrations that are much higher than the national standard, particularly in the Yangtze River estuary and Hangzhou Bay, where the proportion of nutrients is affected by the freshwater inflow. The phytoplankton biomass has increased and the concentration of chlorophyll-a can be as high as 16 mg/m^3 in coastal areas, resulting in an increased frequency of harmful algal blooms in the East China Sea. In 2003, there were 86 harmful algal blooms with a total area of up to 12 990 km^2, 8.6 times and 58.4 times of that in 1993 respectively (Figure 18). These blooms had a measurable impact on fish stocks and other ecosystem services.

The main pollutants carried to the East China Sea by the Yangtze River, Mingjiang, and Jiulongjiang are COD, nutrients, petroleum hydrocarbons, and heavy metals, which have all been on the rise in

Table 11 Pollutants discharged to the East China Sea by major rivers.

Rivers	Year	COD (tonnes)	Phosphate (tonnes)	Inorganic nitrogen (tonnes)	Heavy metal (tonnes)	Arsenic (tonnes)	Petroleum hydrocarbons (tonnes)	Totals (tonnes)
Yangtze River	2002	2 480 000	31500	1 7800 000	15 100	1 550	49 600	4 350 000
	2003	2 7200 000	700 000	30 300	36 300	3 340	69 900	2 930 000
Minjiang	2002	900 000	1 590	10 500	1 780	43	2 810	107 000
	2003	1720 000	1 160	19 800	2 530	160	7 760	204 000
Jiulongjiang	2002	1240 000	1 060	2 650	8 410	30	614	136 000
	2003	2330 000	2 020	6 930	370	30	420	243 000

(Source: SOA 2002, SOA 2003a)

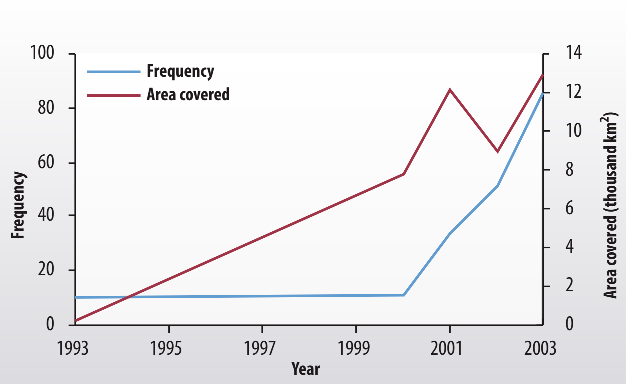

Figure 18 Trends in harmful algal blooms in the East China Sea.
(SOA 1999, SOA 2000, SOA 2001, SOA,2002, SOA 2003a, SOA 2003b)

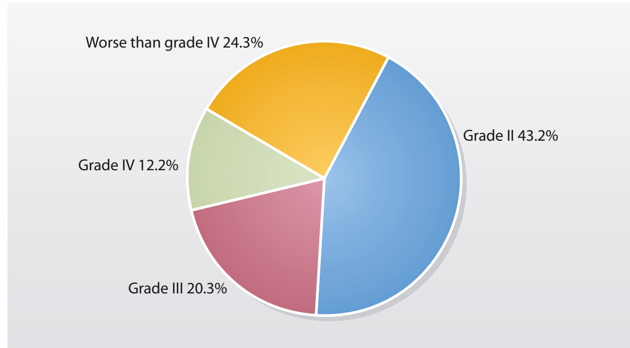

Figure 19 Water quality in the coastal area of the East China Sea.
(SEPAC 2001)

recent years (Table 11). Effluents from the lake contribute to pollution in the estuary and make it more difficult to control the pollution. The water quality in most estuaries does not meet the requirements of the proposed "national clean water strategy" for the East China Sea. Agrochemicals, including fertiliser and livestock manure, have become an additional source of pollution for the freshwater environment. High concentrations of nitrates in agricultural run-off have been the main reason for the eutrophication of aquatic systems throughout the drainage basin.

Eutrophication caused by nitrogen discharged to the ocean is of great concern. The available evidence indicates that toxic and harmful plankton species are on the increase in number and in geographic distribution; for example, a single algal bloom in Fujian Province in May 2003 caused damage equivalent to 3 million USD (25 million Yuan) (SOA 2004).

Chemical pollution

The coastal water quality in the East China Sea is primarily influenced by phosphorus and nitrogen from land sources. The pollutant load is dominated by COD, petroleum hydrocarbons and heavy metals (e.g. lead), with the majority of the waters of the coastal ocean belonging to grade II waters. Waters considered worse than grade IV represent 24.3% of the total (Figure 19). The main pollutants include nitrogen and phosphorus, followed by heavy metals (e.g. lead) and oil. Offshore of the Yangtze River estuary, the water quality is grade I and grade II, with the exception of inorganic nitrogen and inorganic phosphorus, which exceed national standards .The sediment quality in the coastal area off Shanghai is not seriously polluted as a whole (SEYEBS 2003). In the coastal area of the Shanghai, petroleum hydrocarbons in *Bullacta exarata* exceeds grade I for biological standards, and copper (Cu) exceeds the grade II standard. Heavy metals such as zinc (Zn), Cu, and

Table 12 Shellfish pollutants of the Shanghai coastal area.

Shellfish	Petroleum hydrocarbons (mg/kg wet wt.)	Zinc (Zn) (mg/kg wet wt.)	Copper (Cu) (mg/kg wet wt.)
Oyster	61.70	69.00	278.00
Bullacta exarata (Philippi, 1848)	20.70	13.10	33.60

(Source: SEYEBS 2003)

petroleum hydrocarbons, in the oyster area near Yangtze River estuary all exceed the standards, with petroleum hydrocarbons and DDT exceeding grade II, and Cu and Zn exceeding grade III (Table 12).

In 2001, pollutant residues like petroleum hydrocarbons were detected in shellfish *(Mytilus edulis, Sinonovacula constricta,* and *Venerupis variegate).* DDT and PCB were also detected, but at levels that are acceptable for human consumption (ZOFA 2001). Most of the coastal area of Fujian Province is clean except for the Minjiang estuary, where the content of Hg is 0.25 µg/l. The coastal area of Sishishuanglie Islands is lightly polluted with copper at levels of 0.015 µg/l. The heavy metal (Cu, Pb, Hg, As) content of surficial sediments in Fujian Province is within the range of natural variability. The average DDT content in surficial sediments is 6.68 µg/kg in Xiamen harbour where the DDT content in surface sediment has dropped 80% as compared to 10 years ago. The PCB content in surficial sediments is 1.52 µg/kg (FOFA 2002).

In 2001, 11 kinds of economic shellfish from the coastal area of Fujian Province, including oyster, *Sinonovacula constricta, Venerupis variegate, Mytilus edulis Linnaeus,* and *Tegillarca granosa* were reported to meet national standards, but petroleum hydrocarbons in *Sinonovacula constricta* of Mingjiang estuary were found at too high concentrations (Table 13).

The concentration of organochlorine compounds such as hexachlorocyclohexane (HCHs), dichloro-diphenyl-trichloroethane

Table 13 Pollutants in shellfish in nearshore waters in Fujian.

Pollutant	Concentration (mg/kg (wet weight))					
	Sinonovacula constricta	*Venerupis variegate*	*Mytilus edulis*	*Tegillarca granosa*	*Paphia undulata*	Average
Petroleum hydrocarbons	82.3	11.7	ND	ND	ND	ND
Mercury (Hg)	0.012	0.014	0.029	0.007	0.004	0.014
Copper (Cu)	3.0	4.3	2.3	1.6	1.7	13.1
Lead (Pb)	0.15	0.12	0.11	0.10	0.006	0.11
Cadmium (Cd)	0.06	0.13	0.06	2.02	0.19	0.33
Zinc (Zn)	16.0	22.6	10.3	14.1	8.4	67.0
Arsenic (As)	0.368	0.077	ND	ND	ND	0.204
DDT	0.0145	0.0084	ND	ND	ND	0.0206
PCB	0.0021	0.0059	ND	ND	ND	0.0069

(Source: FOFA 2002)

(DDTs) and polychlorinated biphenyls (PCBs) has been investigated in sediments from Chinese river and estuarine systems. The results show that the large Chinese rivers and estuarine systems are not significantly polluted by the organochlorine compounds measured (Wu et al. 1999).

The main coastal contamination comes from industrial sewage, municipal sewage, and agricultural run-off discharged to the coastal area, along with nearshore engineering construction traffic and wastes discharged from oil platforms, oil spills, ocean mining and aquaculture. For example, in 2003, the total amount of waste carried by the Yangtze River, Qiantangjiang, Mingjiang and Jiulongjiang was 2 929 000, 204 000 and 243 000 tonnes respectively; with all these values showing an increase compared to 2002. The main pollutants entering the sea are inorganic nitrogen, inorganic phosphorus, COD, petroleum hydrocarbon, and heavy metals (Table 14). In 1999, the total discharge of wastewater from the Shanghai, Zhejiang, and Fujian Provinces was 5 billion tonnes, of which 2.8 billion tonnes was directly poured into the East China Sea. In addition, there are about 33-37 million m^3 of dredged materials dumped into the East China Sea. Accidental oil spills and marine transportation, especially ballast water from oil ships, are other important sources of pollution in the coastal and marine areas. The amount of cargo handled in the coastal area of the East China Sea has been on a constant increase, with the Shanghai and Fujian seaports handling 83.6 million tonnes in 1978 to 365.8 million tonnes in 2002 (SCMC 2002, BSF 2003,2004, BSS 1991, 2004, BSZ 1997, 2003, 2004).

In 2001, the total number of powerboats exceeded 50 000 in Fujian Province. These boats produce oily wastewater and gas pollution, as well as domestic refuse and sewage. The cultivated area in the inshore region of the East China Sea increased from

Table 14 Annual sediment load and suspended solids in Yangtze, Qiantangjiang and Mingjiang rivers.

River	Hydrology station	Year	Annual sediment load (million tonnes)	Suspended solid (kg/m³)
Yangtze River	Datong	2002	275000	0.277
		2001	276000	0.336
		2000	339000	0.365
		1950-2000	433000	0.486
Qiantangjiang	Lanxi	2002	237	0.099
		2001	76.2	0.059
		1950-2000	216	0.127
Mingjiang	Zhuqi	2002	272	0.044
		2001	96.7	0.015
		1950-2000	637	0.12

(Source: MWRC 2000b, 2002b)

296 km^2 in 1980 to 2 478 km^2 in 2001, which made aquaculture one of the primary sources of pollution in the local coastal area. Population increases and the expansion of industrialisation, urbanisation and the tourist industry increase pressures on the environment of the coastal zone.

Suspended solids

The main sources of suspended solids in the Yangtze River, Qiantangjiang, and Minjiang rivers and the East China Sea coastal waters are soil erosion, together with deforestation and intensive cultivation. Reduced coverage of vegetation causes more serious soil erosion. The area of soil erosion in the Yangtze River Basin increased from 304 200 km^2 in 1987 to 572 400 km^2 in 1992 (CNRD 2004). The rate of water loss and soil erosion reached 25% in Jiangxi and Zhejiang Provinces. These serious losses increased the concentration of river sediments, which gradually increases the deposits of silt in lakes, reservoirs and river courses. Waterway dredging, bridge and dam construction, mining sands from riverbeds and reclamation all change the concentration of suspended solids (Table 14). For example, the concentration of suspended solids in the Yangtze River estuary and Hangzhou Bay is higher in the flood period of July to August than in other seasons (Figure 20).

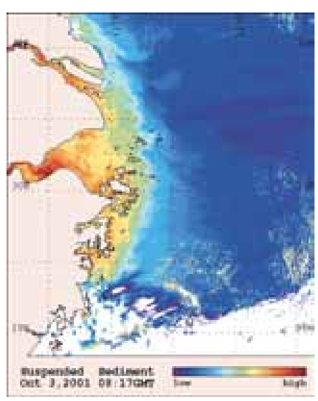

Figure 20 Suspended solids in the coastal area of East China Sea
(Source: CCAR/HKUST 2005)

Solid wastes

In 1980s, the Chinese government enacted a policy of encouraging the comprehensive use of solid wastes and reducing the production of refuse.

With rapid economic development at the end of 1990s, however, the problem of dumping wastes in the suburbs and rural areas emerged. The waste accumulated around the cities, smelly rubbish was dumped along rivers, streets or public areas. Many suburban areas were covered by urban rubbish. Toxic chemicals from industrial solid wastes infiltrated directly into surface and groundwater.

As the living standards of urban areas have improved, domestic wastes have increased quickly. In 1999, the total domestic waste load in Shanghai reached 5 million tonnes, equal to 1 kg rubbish produced per person per day. Roughly 85% of this trash was disposed of in sanitary landfills. Rapid industrial development, especially village- and town-owned enterprises and private companies, which have not been under the strict control of national regulations, resulted in a rapid increase in amount of industrial solid wastes. In 2000, the amount of solid wastes reached 156 million tonnes, with an average rate of comprehensive use at 65%. However, this rate of use is more than 90% in Shanghai and Jiangsu but is less than 20% in Jiangxi Province. The total discharges of industrial solid wastes increased from 101 million tonnes in 1987 to 156 million tonnes in 2000, with some uncontrolled dumping, which leads to the pollution of land and surface and groundwater.

Thermal pollution

Thermal pollution was considered to have little impact in the region. Effluent discharges of cooling water from power plants, including nuclear stations, were observed, but without large-scale environmental effects beyond the mixing zones and no significant interference with biological communities. The region has strict regulations penalising effluent discharges that cause water temperature change exceeding 4°C.

Spills

The effect of oil spills in the coastal waters of the East China Sea is episodic. Oil pollution may lead to the death of the halobios and contamination in the coastal area as well. Spilled oil and oil products generated by shipping and from offshore oil gas fields are important sources of pollution. The most seriously oil-contaminated areas are estuaries, canals and oil fields. In 2002 and 2003, the total amount of oil pollutants discharged into the East China Sea by the Yangtze River, Mingjiang, and Jiulongjiang was 119 500, 10 600 and 1 000 tonnes respectively (Table 11). During 1999 to 2002, the Pinghu Oil Gas Field in the East China Sea discharged 9.94 million tonnes of wastewater containing 34.8 tonnes of oil (SOA 1999, 2000, 2001, 2002). During transportation of oil and other chemical products, oil tanker collisions with other vessels or rocks may cause unexpected accidents, leading to oil spills that affect inhabitants, biota and regional economies in the coastal zone. The following are some examples:

On June 6, 2000, the cargo ship "Minyou No.1" hit "East Ocean", and approximately 100 tonnes diesel oil leaked, contaminating the coastal area of 4 villages and towns in Fujian Province. On October 15, 2000, a natural gas pipeline on the floor of the East China Sea was broken at 2.5 km from Daishan Island, leaking 300 m^3 of crude oil (SOA 2000).

On April 17, 2001, the Korea bulk cargo vessel "Da Yong" collided with the Hong Kong vessel "Da Wang" in the coastal area outside of the Yangtze River estuary, leaking 701 tonnes styrene (Shanghai Ocean Administration 2001).

On January 27, 2001, the "Longbo No. 6" oil tanker, owned by the Nanjing Hongyou Transportation Co., loaded with 5 360 tonnes of diesel oil, sank after striking a rock near Dongyang Island of Pingtan County. Only 1 800 tonnes of diesel were recovered; the spilled oil damaged the coastal environment, the fisheries and nearby aquaculture facilities.

On September 30, 2001, the "Jin Hai Sun" oil tanker, owned by Zhonghai Haisheng (South Ocean) Shared Co. Ltd, loaded with 4 439 tonnes of diesel oil, sank after striking a rock near Xiyang Island of Xiapu County. Diesel from the accident damaged the nearby marine environment and the fisheries (FOFA 2001).

Socio-economic impacts

The number of small-scale industries is growing with the economic restructuring that has taken place in the Yangtze River watershed. However, it has proven difficult to manage pollution from these industries. This pollution source was cited as an important reason behind the problems in developing sustainable recreational and fisheries activities.

The incidence rate of liver diseases and mortality in residents near the discharge area of a chemical factory in the Zhoushan Islands is higher than elsewhere. Many small rivers, streams and canals are not swimmable due to pollution. Problems related to pollution include coastal eutrophication and hypoxia, reduced efficiency of water treatment, an increase in suspended solids, and flooding by poisonous pollutants such as heavy metals and persistent organic pollutants.

The accumulation of poisonous pollutants in fish affects human health, which reduces the economic quality of the resources and causes infectious diseases.

Conclusions and future outlook

At present, the most important sources of pollution in the East China Sea region are chemical fertilisers, sewage and other nutrients that can cause coastal eutrophication. These pollutants originate primarily

Figure 21 Solid wastes littering the riverside in the Yangtze River drainage basin.
(Photo: Corbis)

from urban centres, and agricultural run-off and aquaculture-related activities, from which they are transported by rivers and discharged into the East China Sea. The socio-economic and health impacts caused by pollution problems are more serious in urban centres than suburban areas, with important consequences for the communities themselves, as well as human health. The various forms of pollution lead to increased risks of harming human health, with attendant increases in the costs of ecosystem protection, medical care, water treatment and clean-up. The impact is primarily a consequence of industrialisation and urbanisation in the Yangtze River catchment area, particularly as a result of the use of agrochemicals and change in land use, such as an increase in aquaculture. Moreover, the impact of pollution is likely to increase in the future because of industrial development and population growth. In addition, the progress of industrialisation and urbanisation is likely to cause considerable increases in the quantity of wastewater discharge to rivers and coastal areas. Eutrophication caused by agrochemicals, aquaculture and sewage discharge has become one of the primary issues in the East China Sea region. Currently, pollution problems exist primarily at a local scale and are not yet a major concern for the whole East China Sea region.

As agriculture is still one of China's important economic sectors, non-point pollution is extensive and difficult to manage. The lack of appropriate investments to treat pollution before it is discharged makes the situation even worse. The main area affected by pollution is currently restricted to the coastal Yangtze River estuary and Hangzhou Bay and coastal areas, resulting in frequent harmful algal blooms in the East China Sea. Although pollution in some regions has decreased, the situation does not offer reason for optimism. One possible solution is to encourage investments in the treatment of non-point pollutants with approaches such as protective zones and artificial wetlands.

Habitat and community modification

Environmental impacts

Loss of ecosystems or ecotones

The main wetland types in the littoral zones of the East China Sea are estuarine wetlands, such as salt marshes and swamp marshes, which are chiefly composed of saline marshlands and beach. The wetland usually is covered with herbaceous plants in the high- and middle-tide zone. These wetlands provide habitats for many kinds of birds, thus forming a marsh - meadow - bird ecosystem. In the littoral zones of the East China Sea, the wetlands can be found on Chongming Island in the Yangtze River estuary, in the Nanhui district in Shanghai, on the beach in Hangzhou Bay, on the beach of Yongjiang and Oujiang, and in the coastal zones in Fujian Province. These wetlands can be classified into two categories: one is the mangrove swamps in Fujian Province; the other is the coastal argillaceous beach (salt marsh). With the exception of the Chongming East Beach of the Yangtze River estuary, the primary status of these wetlands is seriously degraded. The Chongming East Beach is a good representative of the coastal argillaceous beaches.

Yangtze River estuary wetland

The Yangtze River estuary wetlands are broad and vast, composed of silt and beach deposits. The wetland is an important breeding and spawning ground for birds, animals and fish. It provides a passageway for migratory fish to enter the sea or travel to inland waters for spawning, as well as a nursery area whereyoung fish can forage and grow. Secondly, the wetland provides an ideal stopping place for migratory birds in the Asia-Pacific area and a hibernacle for birds such as wild geese and ducks. Thirdly, the soft substratum is favourable for the growth of wetland plants and provides habitat for benthic fauna. In addition, run-off into the Yangtze River estuary carries nutrients and organic substances, which are required for the reproduction of both phytoplankton and zooplankton that furnish resident fauna with food resources. This results in a productive fishing ground where both salt- and freshwater fishes can live, spawn and forage.

The main vegetation communities in the estuarine tidal zones and littoral zones are *Phragmites australis* and *Scripus mariqueter* communities. The former is found in the higher tidal zone where it is comparatively dry or seldom flooded, while the latter is mostly in the lower flats. Other communities can also be found, such as the *Scripus triqueter* community, the *Carex scabrifolia* community and the *Ischaemum aristatum* var.*glaucum* community.

The wetlands in Yangtze River are one of the most important stopovers in a well-known bird migration route, and are also an overwintering area for water birds. There are nearly 274 kinds of transients inhabiting the East Beach of Chongming Island, totalling 2 to 3 million birds, representing about 10% of all species in China, and 25% of Shanghai's total. The dominant bird families are *Charadriiformes, Anatidae, Gruidae* and *Laridae*.

The benthic community is dominated by tidal flat crustaceans, such as *Metaplax longipes*. Members of the *Bradybaenidae* and *Assiminea* are well-represented. There are different molluscs such as *Stenothyra glabra, Mactra veneriformis, Mactra sulcataria* and several kinds of crabs found in the high tidal flats, while other crabs, such as *Moerella iridescens* and *Bullacta exarata* live in the low tidal flats. The waters near the beaches are inhabited by *Boleoophthalmus pectinirostris, Tetraodontoi dei,* Grey mullet, Hilsa herring, and Chinese sturgeon. The Hilsa herring and Chinese sturgeon are protected species.

Based on a survey of the Yangtze River estuary, 14 orders and 112 species live in the estuary, of which *Elasmobranch* has 7 families and 9 species. *Teleostean* has 103 species, about 91.96% of all fish in the area. Of these, *Perciformes* represent 41 species, or about 36.61% of the order; most of these are marine fish. *Clupeiforms* is represented by 17 species, or about 15.18% of the total. *Cypriniformes* is represented by 15 species, or about 13.39%. These are all freshwater fish species. *Pleuronectifornes* has 8 species and *Anguilliformes* has 5 species, about 4.46%. The numbers of other fish such as *Mugiliformes, Scopeliformes,* and *Acipenseriformes* are quite limited. In these families, *Coilia nasus* and *Coilia ectenes* Jordan and Seale are the main fisheries species. Chinese sturgeon *(Acipenser sinensis)* and the mountain witch *(Trachidermus fasciatu)* are rare fishes. The spawning stock of Japanese eel is a very important fry resource. The ridgetail white prawn is the primary economic shrimp. *Eriocheir sinensis, Scyna serrata,* and *Portunus trituberculatus* are the primary economic crabs.

Mangroves and wetlands in Fujian Province

The Fujian mangrove wetland is found in the estuaries of the Xiahe in Zhaoan County to the Bayou in Fuding County. They are often found in the area between the Zhangjiang estuary and the Jiulongjiang estuary. The Fujian mangrove contains 10 species representing 8 families and 9 genera. These species are: *Acrostichum aureum, Bruguiera gymnorrioza, Kandelia candel, Hibiscas tiliaceus, Excoecaria agalocha, Derris trifoliate,* *Aegicerae comiculatum, Acanthus ebractealus, Acanthus lilcifolius* and *Avicennia marina*.

The number of species found in the mangroves declines gradually as the latitude increases. For instance, the number of mangrove species in the Zhangjiang estuary is the highest along the coast of the East China Sea, with all species represented. The Jiulongjiang estuary contains six mangrove species: *Kandelia candel, Excoecaria agallocha, Aegicerae comiculatum, Acanthus ebractealus, Acanthus lilcifolius,* and *Avicennia marina.* Quanzhou Bay has four species, *Kandelia candel, Excoecaria agallocha, Aegicerae comiculatum* and *Avicennia marina*. Only one species, *Kandelia candel,* has been found in the north at Sanjian. Mangroves are important wetland ecosystems in the southeastern coastal area of China and play an important role in the protection of the environment and biodiversity. But in recent years, due to intensive development, the area of mangroves has continuously declined and plant and animal habitats in the mangrove ecosystems have been greatly changed. According to statistics from Fujian Province, about two-thirds of mangroves have disappeared (Huang 2000).

Loss of wetlands

Areas of wetlands along the East China Sea have decreased dramatically in the last two decades, which has increased damage from floods in the rainy season. China's rapid population growth and growing economy in the littoral region of the East China Sea are resulting in serious losses and degradation of the habitats of coastal wetlands. China has planned to reclaim a further 45% of its current mudflats. The largest river flowing into the East China Sea, the Yangtze River, is undergoing significant changes that will greatly reduce the amount of sediment input, so that future losses of intertidal areas are predicted to occur at an increasing rate due to the combined effects of reclamation and reduced sediment input. The loss of wetlands will destroy animal habitats and lead to the loss of biodiversity.

Reclamation of wetlands of estuary

A sediment load totalling 48.6 million tonnes is deposited in the Yangtze River estuary every year, which creates an environment for continually expanding wetlands. In the meantime, however, wetlands are being continually reclaimed. Since 1949, 840 km^2 of coastal wetlands have been reclaimed in Shanghai, so that the land area of Shanghai has been increased by 14%.

In the past twenty years, 293 km^2 of coastal wetlands have been reclaimed in this region. From 1995 to 2000, 120 km^2 of coastal wetlands have been converted to other uses in Shanghai (Jin 2004).

Chongming Island, located in Yangtze River estuary, is the third largest island in China. Since 1950, Chongming Island has had five major reclamation efforts, and more than 40 km^2 of fertile farmland has been added to the island (Least 2004). At present, the total area of Chongming Island has been doubled from less than 600 km^2 in the 1950s to more than 1 200 km^2 in 2003 (SouFun 2004).

Reclamation effects on lakes

In the past 50 years in the Yangtze River Basin, about 1 000 small lakes have disappeared and the area of 22 big lakes had decreased to about 40% of their previous size. For example, the area of Dongtinghu has decreased to less than half of its maximum size, and the number of lakes on the Jianghan plains has decreased from more than 1 000 to just 309 (Jin 1998). Because of reclamation and overfishing, the fisheries in Dongtinghu have been on a continual decline.

Reclamation has resulted in a reduction of the surface area of the Taihu by 160 km^2 over the last 50 years, which represents roughly 5-10 % of the total surface area. The eastern part of the Taihu lost 68 km^2 and the lake's water volumehas been decreased by 320 million m^3, but the average water level was increased by 9 to 14 cm because of the decrease in surface area Qin et al. 2002).

Soil erosion

According to historical records, the total area lost to soil erosion in the Yangtze River drainage basin in the 1950s was 363 000 km^2, which accounted for more than one-sixth of the total area. In the 1990s, the area lost to soil erosion amounted to 613 000 km^2 (Chen 1998, WWF 2003). In the 1950s, the amount of water and soil erosion of the whole drainage basin was about 160 million tonnes and in the 1990s the losses in that of the upper reaches were equal to this earlier amount. Since 1958, water run-off in the Minjiang drainage basin has increased because of the forest cover has been cut down. Soil erosion has become quite serious and totals 2.5 million tonnes per year (MWRC-TBA 2004a). In the 1950s, the area of the water and soil lost represented 4% of the total area in Jiangxi Province. In the 1970s, it increased to 13% (CIGEM 2004).

Rocky coast

Port development, tourism and an expanding industrial base have all damaged the region's rocky coasts, particularly in Zhejiang Province.

Barrage of waterway between lake and river

The Baiji or Yangtze River dolphin *(Lipotes vexillifer)* is the world's most endangered cetacean species. The Baiji shares its habitat with another small cetacean in the middle and lower reaches of the Yangtze River, Dongtinghu and Poyanghu. The population in the Yangtze River is a unique freshwater sub-species. The population has been in decline in recent years because of the construction of dams between rivers and lakes on the waterways (Chen & Hua 1989).

Hundreds of dams were built in the Yangtze River drainage basin over the last forty years. As migrating fishes are prevented from moving upstream by the dams, they can no longer enter lakes from the river. This has led to sharp population declines in both the lake and the river. The biodiversity of fish species has declined sharply for this reason as well. For instance, Honghu Lake once had more than 90 species. In 1958, a sluice was constructed in the canal linking the lake with the river, thus severing the connection between the river and the lake. A survey in 1964 showed 74 species, while in 1981-1982 just 54 species were left, of which only 33 species were found in the lake, while the other remaining 21 species were river fishes carried into the lake by the channeling of the Yangtze River for the purpose of irrigation.

Modification of ecosystems or ecotones

Harmful algal blooms in the East China Sea

According to statistics from the State Oceanic Administration (SOA), there have been 107 harmful algal blooms from 1986 to 2000, with these blooms typically occurring in late April to November. Harmful algal blooms occur most frequently from May to August, with an average of 60 days per year affected by harmful algal blooms. The blooms usually last from 4-6 days, with a minimum of 2 to 3 days to a maximum 20 or more. Most of the harmful algal blooms in the East China Sea occur near the waters off of the Yangtze River estuary, the West Harbour of the Xiamen, Xiangshan Bay, the Sanmen Bay and some aquatic zones. Of these, the Yangtze River estuary showed the highest frequency, accounting for 70% of the total occurrences. About 70% of all blooms cover an area between 100-1 000 km^2, but the biggest bloom recorded took place in the coastal waters in Zhejiang Province in May of 1990 and covered an area of 7 000 km^2.

In 2001, the coastal area of Zhejiang Province had 26 harmful algal bloom covering 1 400 km^2, the waters of Shanghai experienced 2 harmful algal blooms covering an area of 1 400 km^2, and the coastal waters of Jiangsu had 4 harmful algal blooms covering more than 1 200 km^2. In total, the coastal waters of East China Sea experienced 51 blooms in 2002 covering a total area of 9 000 km^2. In 2003, 86 harmful algal blooms were reported in the East China Sea, with the coastal waters of the Zhejiang Province reporting 49 events, and Fujian reporting 29 events. The area affected by these blooms totalled 12 990 km^2.

More than 100 plankton species cause algal blooms in the East China Sea. *Noctiluca scintillans* is the most important species among all algal bloom organisms because it accounts for 55% of all bloom events. The primary species of algal blooms in the Yangtze River estuary and the coastal waters of Zhejiang before late June are *Prorocentrum triestinum,* a dinoflagellate, and *Skeletonema costatum,* of the *Bacillariophyta.* Harmful algal blooms in the coastal waters of Fujian are dispersed over a small area, but there are numerous harmful algae, including *Alexandrium* sp., *Karenia mikimotoi, Dinophysis fortii, Chattonella marina, Heterosigma akashiwo,* and *Phaeocystis globosa.*

Harmful algal blooms result in tremendous economic losses. The harmful algal bloom that occurred in May, 2000, in the Yangtze River estuary and the coastal waters of the Zhejiang covered more than 7 000 km^2, and seriously endangered the region's seawater aquaculture. The Zhoushan Islands experienced direct economic losses of 3.6 million USD (30 million Yuan).

Freshwater environments

Lakes across China have lost both surface area and volume, as a result of a continuous supply of mud from river water and from extensive reclamation of wetlands. This is a serious problem throughout the country. Over the past decade, farming and the lumber trade have resulted in deforestation that has led to shrinkage in lake sizes in the western part of China. Lake losses in the eastern region are mainly caused by precipitation of mud from river water, and by reclamation of land for farmland. For example, the total surface area of Dongtinghu Lake was 4 350 km^2 in 1949, but declined to 2 623 km^2 in 1995, due to continuous precipitation of mud from river water and extensive reclamation of farmland from the lake (Table 15). Lakes and their wetlands usually are ideal homes for many birds. The rich fish and plant resources in lakes attract hundreds of thousands of migrant birds each year. With the reclamation of farmland the lake is now gradually losing many of its wetland functions.

Table 15 Area of the Dongtinghu Lake.

Year	Area (km^2)
1825	6 000
1896	5 400
1932	4 700
1949	4 350
1954	3 915
1958	3 141
1971	2 820
1978	2 691
1995	2 623

Note: The area is measured when the water level at Chenglinji station is 31.5m.

(Source: Fang & Zhong 2001)

The catch of fish from all lakes has been on a continuous decrease, so that the current catch is less than half of the historic average. The lakes' isolation means that they are characterised by rare species that live in the middle reaches of the Yangtze River. *Acipenser linnaeus* and

Macrura reevesii have almost disappeared in these isolated lakes and *Luciobrama macrocephalus* and *Ochetobius elongatus* numbers have decreased sharply. At the same time, the proportion of fishes that trace to the source in some rivers and lakes has decreased sharply, in some cases from 50% in the past twenty years to less than 20% currently (Xie & Chen 1995).

Human activities have resulted in deterioration of the water quality and biodiversity of the Yangtze River ecosystem. *Macrura reevesii* is a good example of this problem: since 1975, the output of this fishery has decreased from year to year because of intensive fishing pressure. The population has never fully recovered from the fishing pressures. The area where the species spawns has greatly decreased (Qiu et al. 1998).

Pelochelys bibroni and A*ndrias davidianus* are a native rare turtle and salamander, respectively, that live in the Oujiang. At present, these two species have almost disappeared in the upper reaches and tributaries because they have been heavily hunted and their natural egg-laying areas have been destroyed. The remaining habitats are limited to the deep water of the river's mid to lower reaches. It has been estimated that there are less than 200 *Pelochelys bibroni* (MWRC-TBA 2004b).

More than ten thousand tonnes of sands are dredged from the lower reaches of the Mingjiang each day. Channel dredging has resulted in saltwater intrusion and influenced the original freshwater and wetlands fauna, so some organisms that can only live in freshwater have died because of saltwater intrusion.

Farmland

The abuse of chemical fertilisers and pesticides in the Yangtze River Basin has seriously threatened the health of farmland ecosystems and has resulted in the pollution of rivers and lakes. The farmlands around Taihu of south Jiangsu Province consume twice as much nitrogenous fertiliser as other regions in the past several years.

In the Shanghai countryside, only 30-50% of the total nitrogenous fertiliser applied to farmlands can be used by crops, while the remainder runs off into streams, rivers or lakes. At present, 72-75% of the total nitrogen in the Taihu comes from fertiliser applied to farmlands around the Taihu; this has resulted in lake eutrophication. In China, urbanisation has greatly decreased the area of arable lands in some provinces. The area of paddy field in the south of Jiangsu Province has declined from 330 km^2 in 1999 to 120 km^2 in 2003 (NFC 2003). The change in farmland area in the past 50 years in Jiangsu Province, shows that paddy fields have increased, but the area of dry land is decreasing sharply and the total farmland area is decreasing (BSJ 2003a).

Forests

According to a survey in 1957, forests covered 22% of the Yangtze River drainage basin. By 1986, the coverage dropped to 10%. Over the past 30 years, deforestation has decreased forest coverage by half (Figure 22). In some of the upper reaches of the Yangtze River, local people still use primitive methods of burning natural vegetation to create new farmland. In the middle to lower reaches of the Yangtze River, the forest coverage in Jiangsu and Anhui Provinces has decreased by half from the 1950s to 1980s (Jin 1998). But local governments have been making great efforts in reforestation in six provinces (Figure 23) and the public has come to realise the importance of forests in reducing soil erosion and regulating the climate.

Socio-economic impacts

Habitat modification and destruction contributes overfishing and pollution, along with declines in fish landings, raw materials for pharmaceutical production and other economic outputs of the ecosystem. There is limited impact in terms of employment opportunity reductions associated with habitat alteration, such as might result from harmful algal blooms and the poisoning of seafood. Moderate social and economic impacts have resulted from the loss of spawning habitat due to changes in waterways, land reclamation and infrastructure developments, such as dams.

Conclusions and future outlook

The increasing population, and the development of both industry and agriculture in the region will increase pressures on wetland, river and lake ecosystems and thus will lead to increased losses and modifications of habitats and communities.

In the last two decades, the coastal environment of the East China Sea has undergone rapid industrialisation and economic and social development. With economic development after the early 1980s, coastal waters have become a central issue with respect to pollution resulting from increased economic activities. The heavy reliance on marine resources in the East China Sea countries requires continued vigilance to ensure environmental sustainability of the littoral area and to protect the resource for the welfare of future generations.

The unprecedented rapid industrial development and population growth over the last decade, which has proceeded with little regard for the environment, has been accompanied by the overexploitation of resources, causing marine and coastal ecosystems to lose their productive capacity. Some of problems that have occurred are due to poor management, inadequate monitoring and lack of information and resources, poor communication between scientists and managers,

Figure 22 Deforestation in China.
(Photo: Corbis)

a sectoral approach to terrestrial and marine management, ignorance of the costs and economic and social practicalities of implementing solutions, and the lack of will on the part of policymakers in local government. The results can be summarised as follows:

- Pollutants transported and dumped in the East China Sea from land-based sources have a potential link to the harmful algal blooms that have been damaging to the fishery, aquaculture and people's health.
- Deforestation in the watersheds, vegetation loss and unsustainable agriculture has caused siltation in rivers.
- A combination of factors including population growth, a demand for cultivatable land for agriculture, urbanisation, and demand for timber for domestic and foreign markets has resulted in massive losses of forest cover in many parts of the upper reaches of the region.
- Construction of dams or other irrigation engineering structures results in the destruction of the lake-river ecosystem by severing lake connections in the Yangtze River watershed.
- Coastal development, including land reclamation, dredging and conversion of coastal land for industry and housing, aquaculture and agriculture activities, tourist resorts and sand mining, are major factors in overall habitat deterioration and loss. These developments result in severe coastal erosion and loss of beach habitats, and cause overall water quality deterioration.

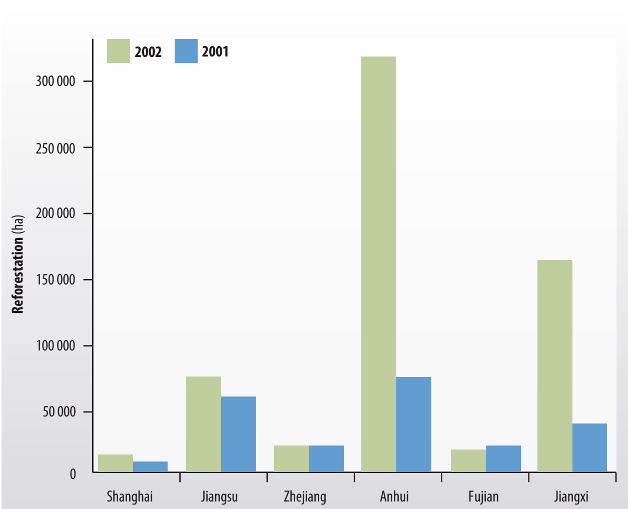

Figure 23 Reforestation areas by region.
(CFM 2003)

Solving these problems requires addressing basic problems of poverty, political stability, social order and good governance. The dilemma of economic development and sustainable environmental management is likely to command the attention of policymakers, given the desire to achieve economic growth. It will require strong and unwavering political will based on a clear understanding of the value of the sustainable development of marine and coastal resources so as to meet long-term national demands and aspirations.

Land use change and degradation, human activity and deforestation problems are becoming increasingly important throughout the whole of the Yangtze River catchment area, from its upper reaches to its estuary. Although the present impact of these activities on the environment of the Yangtze River Basin is moderate, if the current trends persist there will be severe impacts by the year 2020. High demands for fish products cannot be met by aquaculture. The river itself must to be protected from further water quality degradation to meet the requirements of the increasing human population. The fishery must be able to coexist with other activities in the area, such as transportation, tourism, and agriculture. There is also a need to measure the spatial extent of the land degradation under different land-use scenarios and to assess the effect of human activity on vegetation community structure over the last several decades, in order to understand how the landscape can be better managed to reverse negative trends and mitigate losses.

Unsustainable exploitation of fish and other living resources

About 730 fish species have been identified on the East China Sea shelf, along with 91 species of shrimps and crabs and 64 species of cephalopods. The traditional catch in the East China Sea includes the Yellow croaker, ribbonfish, Mackerel, and Herring. All of these species have suffered from overfishing since the 1960s. The catch of some economically important species, such as Yellow croaker and Mackerel, has decreased dramatically since the 1970s (Tang & Su 2000).

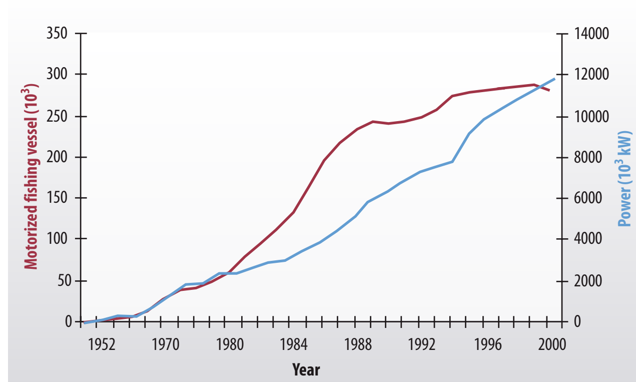

Figure 24 Fleet strength and numbers of Chinese-owned marine motorised fishing vessels.
(COYEC 1997-2002, FBAM 2001-2003)

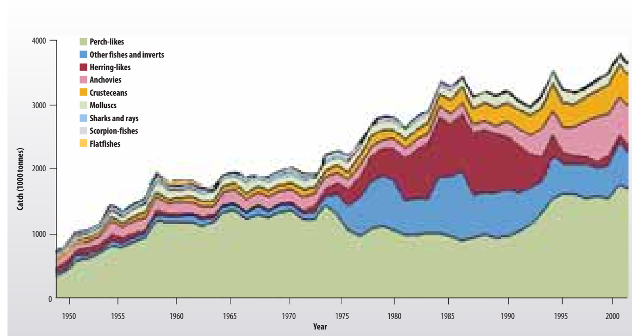

Figure 25 Catches in the East China Sea.
(FAO 2003)

Table 16 Area of main fishing ground in the East China Sea.

Fishing ground	Area (km^2)	Fishing ground	Area (km^2)	Fishing ground	Area (km^2)
Yangtze River Estuary	9 990	Yuwai	13 880	Minzhong	10 580
Jiangwai	9 220	Wentai	6 380	Taibei	13 840
Zhoushan	14 350	Wenwai	16 610	Minnan	13 840
Zhouwai	14 010	Mindong	4 830	Taidong	11 820
Yushan	15 620	Minwai	9 370	No data	No data

(Source: NMDIS 2004a)

Figure 24 shows only the Chinese fishing effort off the Chinese coast. The fishing effort in the East China Sea has increased dramatically since 1952, resulting in great pressure on the fisheries resources in the East China Sea, and which may be the main reason why the fisheries resources in the East China Sea have decreased. Table 16 shows the distribution of marine fishing areas in the East China Sea, with respect to different counties and regions. The annual catch in the East China Sea has not increased proportionately with the increase of fishing effort there. Fish catches for different species and groups over the last 50 years are described in Figure 25. Perch-like fish form the most important group of economically valuable fishes in the East China Sea. This group is characterised by a steady catch and high economic value. Herring-like fish and anchovies belong to the pelagic species group, which has a fluctuating annual catch. Herring-like fish had great yields in the 1980s, but this group is currently in poor condition. The anchovy catch has been increasing lately. Table 17 shows the seasonal species composition of the East China Sea. The maximum number of species (383) is found in the autumn, followed by the spring and summer, and winter (365, 350 and 305 respectively). Squid are least abundant in all seasons.

The maximum number of species is found in the northern part of the East China Sea and the minimum is found in Taiwan Strait (Zhen et

Table 17 Seasonal changes in the number of species in the East China Sea.

Seasons	Fish	Crustaceans	Squid	Total
Spring	235	102	28	365
Summer	224	91	35	350
Autumn	264	87	32	383
Winter	201	83	18	302

(Source: Zhen et al. 2003b)

al. 2003b). The number of species is higher in the pelagic area than offshore. The distribution of fish density in a total year is larger in the north than in the south. Fish densities decrease in the following order: from the offshore region to the north of the East China Sea, to the pelagic sea in the north of the East China Sea to the pelagic sea in the south of the East China Sea to the offshore in the south of the East China Sea and Taiwan Strait. The seasonal fish resource density is distributed as follows: in the spring the greatest density is in the pelagic sea to the north of the East China Sea, in the summer the greatest density is found offshore in the north of the East China Sea, and in the autumn the greatest density is in the pelagic sea in the north of the East China Sea. The least densities are found in the Taiwan Strait in the summer, the autumn and the spring. In winter the highest density is in the south of the East China Sea and the lowest density is in the pelagic sea to the north of the East China Sea. The maximum distributions of fish resource weight densities as compared to water depths in the East China Sea decrease in the following order: the most fish are found at 60 m or less, then in 60-100 m of water, then at depths of >150 m and finally at depths of 100-150 m. Fish stock weight density varies seasonally in the following manner: the maximum weight density is at water depths of 60 m in the spring and autumn; in the summer it is found at depths between 60 m and 100 m; and in the winter it is at depths of >150 m. Daytime resource weight density and resource number density are 1.49 times and 1.33 times more than nighttime densities respectively at the end of the twentieth century (Zhen et al. 2003b).

The catch from the East China Sea is historically about 50% of the national catch; at present it is 42%. Production of some economically important fish species from the East China Sea, such as *Larimichthys crocea,* and *Larimichthys polyactis,* had begun to decline even before 1970. Although total production had partly increased, the catch per unit effort (CPUE) gradually decreased, and the individuals caught decreased in size (Tang & Su 2000). The catch of high quality fish also decreased. For example, catches of *Larimichthys polyactis* decreased from 163 000 tonnes in 1957 to 23 000 tonnes in 1990. The catches of *Larimichthys crocea* decreased from 178 000 tonnes in 1957 to 25 000 tonnes in 1990, while the yields of *Trichiutus lepturus* Linnaeus decreased from 577 000 tonnes in 1974

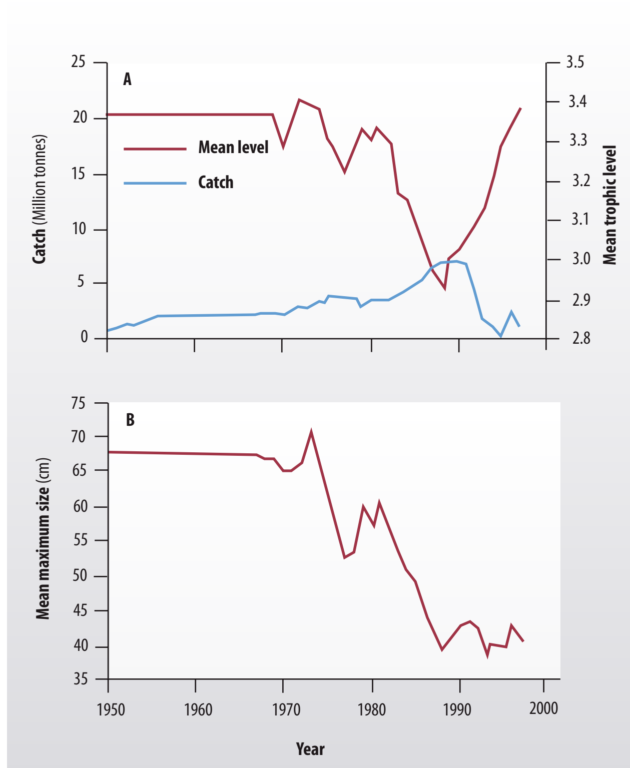

Figure 26 Ecosystem status indicators for Chinese marine waters.
A: Nominal catch and mean trophic level of catch.
B: Mean maximum length of species in the catch.
(Pang & Pauly 2001)

to 498 000 tonnes in 1990, the latter owing most likely to an increase in fishing effort. The trends in the major inshore fisheries are that the catch tends to be small in size, of low value, young, and of earlier maturation, like *Trichiutus lepturus* (Figure 26).

Environmental impacts

Overexploitation of living resources

Largehead hairtail (*Trichiurus lepturus)* is distributed throughout the tropical and temperate waters of the world, including the offshore waters of China. The Shengshang fishing ground in Zhejiang Province is the largest fishing area for *T. lepturus* in the East China Sea (Figure 27). The Small yellow croaker lives in the Yellow Sea, the East China Sea and the Bohai Sea, mainly in near shore areas off Jiangsu, Zhejiang, Fujian, Duangdong and Shanghai (Figure 28). It lives in the sublittoral zone in sandy mud bottoms. Fish of the species Chinese sturgeon *(Acipenser sinensis)* migrate to the upper reaches of the Yangtze River to spawn. Population numbers have dropped so rapidly in recent years that the species has been designated as a national threatened and state endangered species. Fry are found in slow-moving water, adults in deep water.

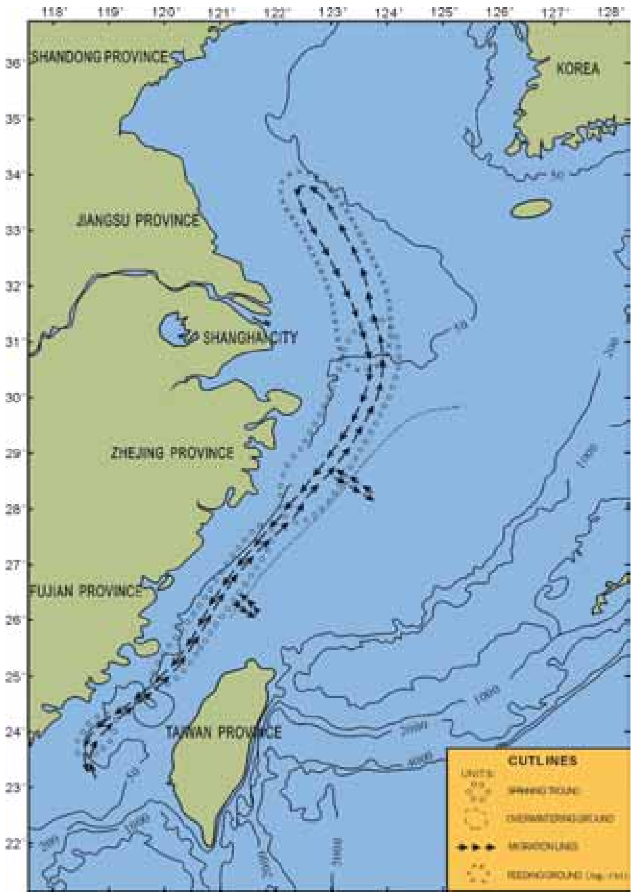

Figure 27 Distribution of *Trichiurus lepturus* and its migration routes.
(Zhen et al. 2003b)

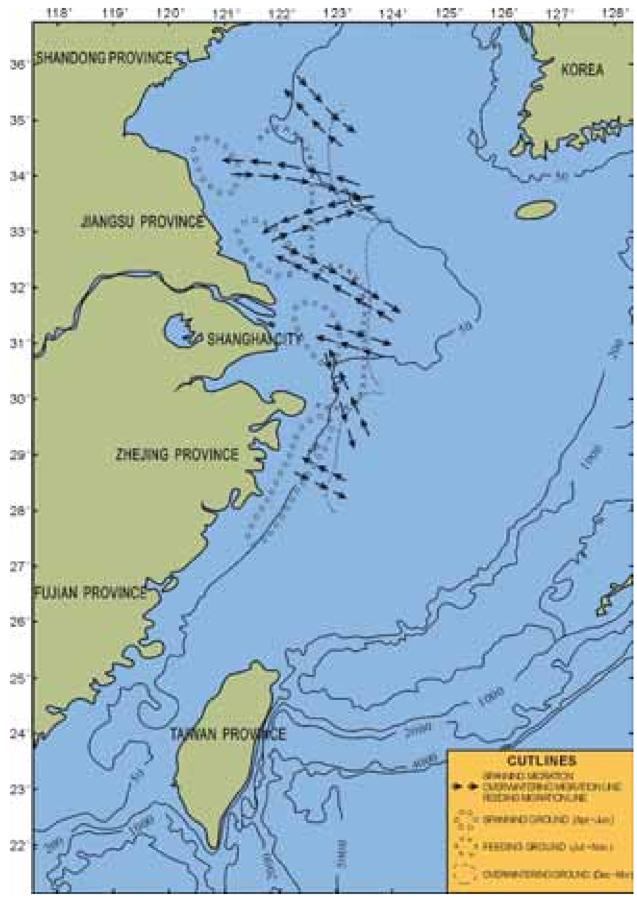

Figure 28 Distribution of *Larimichthys polyacti* and its migration routes.
(Zhen et al. 2003b)

As a pelagic species, the Chub mackerel (*Scomber japonicus*) lives to in a lesser extent in epipelagic waters. It stays near the bottom during the day and rises to the surface at night where it feeds on copepods and other crustaceans, fishes and squids. In Asian marine waters, it is said to move to deeper water and remain inactive during the winter season. The catch of *Trichiutus lepturus* in the East China Sea has increased in recent years as a result of fishing restrictions. Strong recruitment of *Trichiutus lepturus* has also contributed to the trend. In the early 1990s, *Trichiutus lepturus* resources declined radically; fishing for the species was restricted in the summer of 1995. After that time its yields increased quickly as a result of conservation efforts. *Trichiutus lepturus* is characterised by broad distribution, long-distance migration, a long spawning period and an expansive spawning area. Now the primary catch is composed of year-old individuals, which effectively results in miniaturisation of the catch. The catches average anal length of fish caught in the summer in the 1990s was 194.9 mm, 32 mm shorter than in the 1980s. The average anal length in the winter of the 1990s was 188.5 mm, 38 mm shorter than in the 1980s. The average anal length now is 176.34 mm, 15 mm shorter than 1990s. The fishing period in winter season was once about 4-5 months, but it has now been reduced to about 3 months. In the past, the Shengshan Fishing Ground was the main fishing area in the winter fishing season, but this area hasn't been opened to fishing in recent years.

Larimichthys polyactis has been in decline over the past few decades, in part because of poor fishing practices such as boat-knocking, a traditional Chinese fishing technique in which the side of the fishing boat is struck to make sounds to damage the fish's ear. By the mid-1970s, yields had dropped dramatically. *Larimichthys polyactis* catches have increased in recent years because of the 1995 closure of the fishing season and a ban on fishing in the Lusi Fishing Ground. As is true with *Trichiutus lepturus* , the catch increase exceeds recruitment. The average age of catch for this fish dropped from 3 years in the 1960s to 1.02-1.33 years by the late 1990s. Catch miniaturisation became quite serious in the late 1990s as compared to the 1950s-1960s, when the average age was 4-6 years. Therefore *Larimichthys polyactis* can also be considered to be overexploited (Tang & Su 2000).

Poor fishing techniques have also contributed to the dramatic decline of the Large yellow croaker. This species is now rarely can caught in traditional fishing grounds such as Lvsi (north of the Yangtze River estuary) and Daiquyang (Zhoushan Islands). The species also cannot be found in traditional wintering grounds and the population is still declining.The age composition of the Large yellow croaker population is very complex; with a low fecundity and long lives (the oldest specimen was found to be 29 years old), the fish do not lend themselves to rapid recovery once the population is destroyed. Therefore, although efforts have been made over the last 20 years to implement a seasonal fishing ban on the main fishing grounds, there is no sign of recovery.

Destructive fishing practices

Beginning in the 1950s, in an effort to increase the catch, the idea of "more fisherman and more nets, more fishing and bigger catches" was embraced by policymakers, while resource conservation was ignored. To improve fishing capacity, trawling and trap nets were adopted whereas the traditional fishing methods like drift nets, which are relatively benign for the fisheries resource were abandoned. Fishermen were equipped with large horsepower boats and nets with small mesh. Fishing shifted from being a seasonal operation to all-year work, so that the spawning and wintering stockes were fished equally aggressively, and the resource was terribly destroyed. Illegal fishing techniques, such as electrofishing, poisoning and fishing with explosives were also reportedly used. Poor fishing methods intensified resource decline. Before the 1970s, popular fishing techniques such as boat-knocking resulted in reductions of large yellow croaker and little yellow croaker populations, leading to the extinction of the Small yellow croaker in the mid 1970s and Large yellow croaker in the mid 1980s.

Decreased viability of stock through pollution and disease

Serious pollution leads to eutrophication of coastal waters and results in harmful algal blooms (HAB). In the 1980s, there were more than 220 harmful algal blooms in coastal areas of the East China Sea, with 127 species of algae capable of producing harmful blooms. Blooms damage the nearshore fishery, as well as oyster and shrimp farms. The tidal flats in the littoral zone are polluted, which has occasionally led to extinctions. For example, pollution in the Yangtze River delta region led to the extinction of *Hemisalanx prognathus* in the 1990s.

Hemisalanx prognathus is an economically valuable fish that inhabits near shore areas. Around February every year, a spawning population migrates from the East China Sea to rivers to breed. They swim into the Yangtze River in March, moving along the south bank of the Yangtze River estuary during their anadromous migration. From late February to the middle of March, the temperature of the water in Yangtze River is about 8.5°C, and adult fish begin to spawn. *Hemisalanx prognathus'* lifecycle lasts only one year. The larva move down the estuary and stay in the bayous of the Yangtze River, Tongsha, and Niupijiao, where the larva feed and overwinter. Based on statistical data from 1959 to 1987, the maximum production of *Hemisalanx prognathus* per year was about 560 tonnes while the minimum was 21 tonnes. Pollutant discharges into the Yangtze River bayou destroyed spawning areas for *Hemisalanx prognathus,* while overfishing reduced adult fish biomass. Resources of *Hemisalanx prognathus* were exhausted by the 1990s. Since the 1990s the species has disappeared from the Yangtze River estuary.

Maricultural enterprises in the coastal areas of the East China Sea have developed to the point where in the 1980s they had grown to be an important source of income relative to the traditional fishery (Figure 29). Large-scale aquaculture led to an increase in organic pollution in the coastal waters, which in turn affected or even destroyed the aquaculture economy (Ye et al. 2004). Shrimp disease is prevalent in aquaculture farms, with many diseases related to environmental pollution from the industry, such as *Penaeus chinensis* red-leg disease and *Zoothamnium* disease. In the early 1990s, the fatal *Penaeus chinensis* red-leg disease became so widespread that the prawn-culture industry suffered great losses.

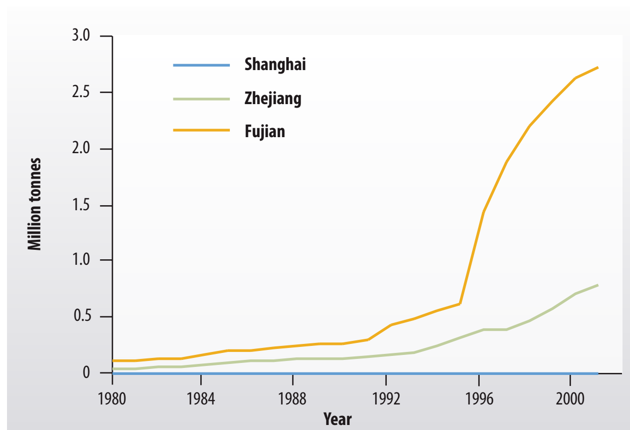

Figure 29 Mariculture production in East China Sea coastal provinces.
(NMDIS 2004b)

Red-leg disease makes a prawn's thoracic limb and abdominal appendage appear red. Abnormal behaviour affects the shrimp's ability to swim, search for food and moult. In the end, the shrimp move slowly, cannot control their direction, swim around the side of pool, and fall down to the bottom of the farming pool and die. This fatal disease attacked the Chinese shrimp culture industry so seriously that it destroyed most of national cultured shrimp harvest. Organic pollutants, increased water temperatures and poor water quality were identified as contributing reasons for the disease (Ye et al. 2004).

Impact on biological and genetic diversity

In 1960s, reclamation in the tidal flats of littoral zones of the East China Sea destroyed these areas' biological diversity. Fujiang Province, for example, has a total beach area of about 2 800 km^2, but one-third of this area was reclaimed for either farmland (746 km^2) or salt production (170 km^2). Therefore, most of the reclaimed areas have lost their benthic fauna (such as shellfish), and a significant amount of *Amphioxus belcheri* has been lost in recent years. Reclamation on a large scale in the coastal zone has led to the shrinkage of benthic fauna habitat, and increased the likelihood of soil erosion, which in turn has led to turbidity in nearshore waters.

In Zhejiang Province, inclosures on the tidal flats in littoral zones began in the 1950s. Up until the end of 1996, about 1 550 km^2 of tidal flat area had been reclaimed, or about one-fifth of the total area of reclaimed farmland in China. Although reclamation has helped develop the local economy, environmental issues were largely ignored. For example, the Zhoushan Fishing Ground is one of the largest fishing grounds in the East China Sea, however, the fisheries resources there have declined sharply over the last four decades, and deterioration of the marine environment (as a result of reclamation) is one of the main reasons. On the Zhoushan Fishing Ground, rock reefs and beaches are important habitats. Once landforms and the undersea topography had been modified, fish habitats and migratory routes were modified or destroyed as well. Building farmland on the coast at a large scale is, for migrating fish species, the same as changing the magnetic field for a homing pigeon; the change makes it impossible for them to return to their habitat. In the last 40 years, the total area of reclaimed farmland in the East China Sea region has added up to 10 000 km^2. In the last 20 years, nearly 300 km^2 of wetland area has been reclaimed along the coast of Shanghai. Marine construction, such as building harbours, has destroyed habitats, particularly wetland ecosystems, which has prevented many birds and migratory fishes from returning to their nesting and spawning grounds, resulting in biological losses.

Introduced, non-native species now found in the East China Sea have occupied the habitats of local species and pushed them out. For example, various *Balanus* sp. , *Mytilopsis sallei* and *Spartina angelicahave* outcompeted native species. Competition between introduced species and native species, has threatened the survival of *Scirpus mariqueter*, for example, by *Spartina alterniflora* on the East Beach of Shanghai's Chongming Island (Ding & Xie 1996).

Socio-economic impacts

The catch per unit of effort has been reduced by more than 40 times in last five decades , while wild fish stocks have decreased (Jin 2000). Over the last decade, there have been a few reports of human disease outbreaks resulting from tainted fish or other marine products. Despite overfishing and depletion of wild fish stocks, the total income from the region's fisheries and from other marine products has increased due to significant increases in aquaculture production. From 1956-1988, the total landings of fish in China increased by a factor of eight, but there was a shift in the composition of species, from high economic value (e.g. Small yellow croakers) to less economically valuable ones (e.g. sardines)

Conclusions and future outlook

The marine waters of the East China Sea are one of the most productive areas in the NW Pacific Ocean and are heavily exploited for fish and other living resources. An important contribution to the world's fishery production comes from waters in this region, which provides high quality protein to a large percentage of the region's population. The East China Sea supports a rich diversity of marine fauna and flora. The increasing population of countries in the coastal areas is partly dependent on marine and coastal resources as their main source of food.

The fisheries resources are the basis of fisheries development, and the quality of the marine environment is the foundation for the fisheries resource and activities. The tradition for many years in the countries in this region has been to rely primarily on natural stocks, but heavy exploitation has resulted in the depletion of the fisheries resource at the end of the twentieth century, which has retarded the development of the region's fisheries-related economy.

The average fish size in today's catch has shrunk because the stocks are fully or overexploited, leaving the fishery dependent on small pelagic fish and young or immature fish with lower economic value. Miniaturisation and earlier maturation of fish resources are signs that stocks have been seriously depleted (Tang & Su 2000).

Today, the fishing effort and intensity in the East China Sea are expected to continue to increase. Although protective measures have been enacted, serious problems, such as an increase in the number of fishing boats, still remain. In addition, some illegal fishing methods, such as trawling with nets with small-sized mesh, and electroshock fishing, have accelerated the decline of the fisheries resource. Moreover, some coastal waters have been so seriously polluted that spawning and hatchery grounds have been affecting, which in turn affects recruitment.

Compared with other regions of the world, the current fisheries management in the East China Sea is not well developed. Implementation of approaches such as Ecosystem Based Management (EBM) will require a huge effort in order to develop sustainable fisheries for the region.

Global change

Global change is considered a concern of moderate to high importance in the East China Sea region, given the rapid economic growth, dense population and lowland character of the countries bounding the sea. At interannual time-scales, the spectra of sea surface temperature anomaly (SSTA) in the East China Sea show strong signals at the periods of 2.0, 3.7 and 7-8 years, and significant coherence with the Kuroshio at periods longer than 5 years, which was comparable to the characteristics of the El Niño 3.4 sea-surface temperature (SST) of Equatorial Pacific Ocean (Park & Oh 2000). It is known that the influence of El Niño causes changes in the amount of precipitation received by the drainage basins and the water flow of rivers in this region; however, how anthropogenic activities have affected the frequency and magnitude of this natural phenomenon remains poorly documented.

Environmental impacts

Change in the hydrological cycle

Variations in the hydrological cycle are mainly related to human activities and climate change, which can be identified in the fluctuation between high and low water stages in the river, and the dynamics of the surface level variation of water bodies. Hydrographic observations in the land area bounding the East China Sea can be traced back to the late nineteenth and early twentieth centuries, in the watersheds of the Yangtze River. The hydrographic data from the lower reaches of the Yangtze River show that the annual water discharge varies from 15 000-20 000 m^3/s to 40 000-45 000 m^3/s in 1920-2000, with an average of ca. 30 000 m^3/s. Although the long-term annual water discharge does not show any increasing or decreasing trends, statistical analysis shows a signal of interannual changes in water discharge, in synchronisation with the El Niño Southern Oscillation (ENSO). At interannual time scales, the water flow has periods of 7, 9 and 17 years (Shen et al. 2003). The annual average water flow in the period of 1960-1980 was 20-30% lower compared to that for 1930-1950.

Sea level change

Sea level change is of major concern in this region, especially with respect to the economic development of countries bordering the East China Sea. For example, the most economically developed areas of China are located in the lowland fluvial plains to the west of the East China Sea, at elevations of <10-50 m above sea level. Similarly, the coastal area of Korea and Japan and some of the islands in the East China Sea will also be affected by sea level increases. Based on information from a national monitoring network, the sea level as measured along China's coastline had increased at rate of 1.0-3.0 mm/year over the last 50 years. In 2000, the sea level increased at a rate of 2.8 mm/year for the East China Sea, 45 mm higher than for 1975-1986 (State Oceanic Administration 2004a). In 2003, the sea level rose by 3.1 mm/year, and the sea level was 66 mm above that for the average of period of 1975-1986 (State Oceanic Administration 2004b). On the East China Sea coast, the sea level change rate varies considerably from north to south, i.e. 2.5-3.5 mm/year in 2003.

It was predicted that by 2006, the average sea levels for the coast of the East China Sea will be increased by 6-28 mm relative to 2000; while in 2013, sea levels will be 26-55 mm higher than in 2000.

Socio-economic impacts

It is difficult at present to identify any regional economic stagnation in relation to global change. There is no significant evidence suggesting there will be regional human health problems as a result of global change. Human health concerns are considered to be more important than the economic impacts under consideration. There is no discernable pattern linking social conflicts relating to resource use, and environmental damage liability and compensation increases over last 4-5 decades with global changes. Sea level change may affect human settlements and the stability of social and economic frameworks in the region, in terms of sustainable development.

Conclusions and future outlook

Global change is a complex process. Although global change affects the economy of the East China Sea, the detailed effects remain unclear. In the future, research will be required to determine and address regional manifestations of global change.

Priority concerns

GIWA concerns were assessed as slight or moderate in the East China Sea region. The priorities were assigned based on consensus decisionmaking using available information and future trends discussed during the workshop. The assessment considered overexploitation of fish, pollution and habitat modification.

The GIWA concerns were prioritised as follows:

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

The most severe problem for the region at present is the unsustainable exploitation of fish and other living resources, particularly overexploitation of fish stocks. The fishing effort in the East China Sea has increased hundreds of times since 1952, which results in great pressure on the fisheries resources. The annual catch in the East China Sea has not increased proportionately with the increase of fishing effort there. Currently the fishing effort and intensity in the East China Sea are expected to continue to increase. The analysis carried out for the region predicts that its resources will continue to be overfished despite regulation and control mechanisms. This problem will persist in coming years.

Pollution threatens the environmental sustainability of aquatic ecosystem in the region. Pollution has affected marine species and modified habitats, with severe consequences for biological diversity and abundance. Furthermore, these impacts are affecting economic activities. In the past 30 years, China's surface water quality has declined remarkably. Polluted agricultural run-off along with untreated industrial and domestic wastewater discharges are the main sources of pollution. Land-based pollution leads to estuarine pollution and makes it more difficult to control pollution sources efficiently. Moreover, the impact of pollution is likely to increase in the near future because of industrial development and population growth. In addition, growth in industrialisation and urbanisation is likely to cause considerable increases in the quantity of wastewater discharged to the rivers and coastal areas, unless proper measures are taken at both regional and national levels. Eutrophication caused by agrochemicals, aquaculture and sewage discharges has become one of the primary issues in the East China Sea coastal region. Cooperation and coordination between countries in the East China Sea will be required to improve the water quality in the sea, particularly taking into account land-based human activities, with the outlook of regional ecosystem health and sustainable development.

Habitat modification is expected to increase in the future. Mangroves are important wetland ecosystems in the southeastern coastal area of China and play an important role in the protection of environment and biodiversity. But in recent years, due to high intensity development, the area of mangroves has declined dramatically. Habitats of plants and animals in mangrove ecosystems have been greatly changed. Areas of wetlands along the East China Sea have decreased dramatically over two decades, which has increased damage from floods during the rainy season. Land-use changes and degradation, human activity and deforestation problems are becoming increasingly important throughout the whole of the Yangtze River catchment area, from its headwaters to its estuary. Although the present environmental impacts in the Yangtze River Basin are moderate, severe impacts can be expected by 2020.

The linkages between the GIWA concerns are illustrated in Figure 30.

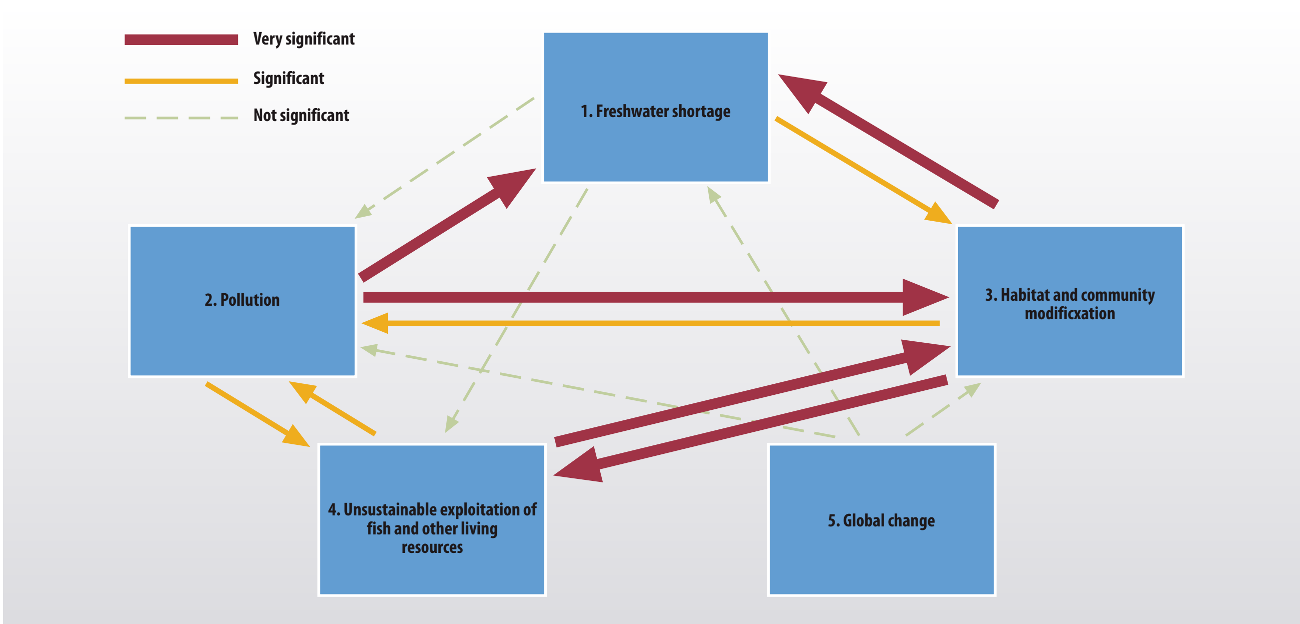

Figure 30 Linkages between the GIWA concerns in the East China Sea.

Causal chain analysis

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

Overexploitation of living resources in the East China Sea

The last four decades of fisheries exploitation in the East China Sea clearly show the impact of human activities. Rapid development occurred in the 1950s after the recovery from the civil war, followed in the 1960s by overexploitation and fluctuations in fish stocks. In the 1970s overexploitation was a serious problem, and development of the fisheries slowed in spite of an increase in fishing effort. Although production still increased by 4% each year, there were serious collapses of prime stocks such as Large and Small yellow croaker. Since the 1980s, the major economic species have shifted to pelagic species, particularly the small pelagic fish such as scad, young chub, mackerel and anchovies. The development of capacity to harvest fish has grown the most during the last decade.

Nearshore species are migratory fishes that travel south and north along short distances of the coast, consisting mainly of warm-temperate species. Offshore species mainly consist of warm water species due to the influence of Kuroshio warm current. The traditional major fishery species include: Largehead hairtail, Large yellow croaker, Small yellow croaker, Chinese herring, pomfret, Filefish *(Navodon septentrionalis),* Scad *(Ecapterus maruadsi),* Spanish mackerel, Chub mackerel, Daggertooth pike-conger *(Muraenesox cinereus),* White croaker *(Argyrosomus argentatus),* Cuttlefish *(Sepiella maindroni),* and Blue crab. At present, the most important fishery for largehead hairtail is highly dependent on recruitment and is fully or overexploited. Most of the species that have been mainstays of the traditional fishery are much like the Largehead hairtail, fully or overexploited. Large yellow croaker and Filefish have been fully depleted.

An analysis of the causal chain from immediate causes of overexploitation of fish to root causes are illustrated in Figure 31.

Immediate causes

Increased fishing effort

Although landings for marine fisheries have increased in the last five decades, the catch per unit effort (CPUE) has decreased almost linearly after the mid-1950s, from 37.9 tonnes/horsepower in 1953 to 3.3 tonnes/ horsepower in 1962, to 2.1 tonnes/horsepower in 1972, 0.8 tonnes/horsepower in 1982, and below 1 tonnes/horsepower thereafter (Figure 32). Overfishing in the East China Sea is also the result of the growth of the region's fishing fleets. China has 12 633 steel fishing vessels, of which 890 have more than 600 HP; there are another 80 000 smaller wooden fishing vessels in China, with more than half of

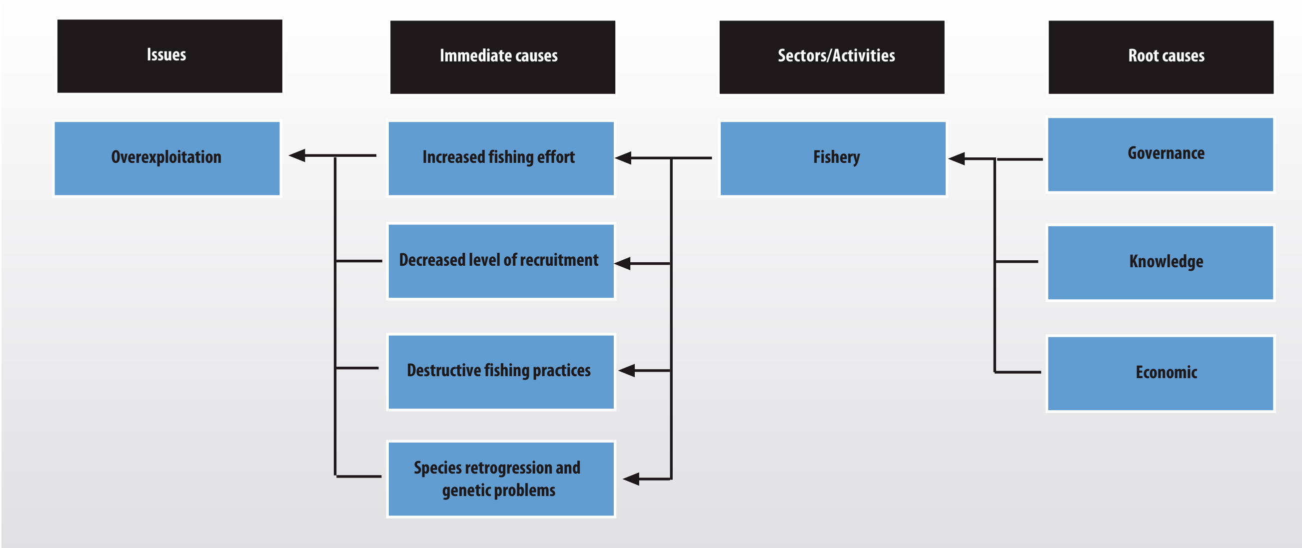

Figure 31 Causal chain diagram illustrating the causal links resulting in overexploitation of resources in the East China Sea.

them with motors less than 15 HP. There are also 13 854 non-motorised fishing vessels fishing the coast of the East China Sea. The size of the fishing fleet has greatly increased over the last few years. The number of steel vessels with more than 600 HP engines has shown a 77% increase since 1997, the greatest increase to date.

With the expansion of the fishing effort in the East China Sea, overfishing has threatened more and more marine biological resources. Overexploitation can reduce species biomass to the brink of extinction. Individual species are often targeted because of their value as a commodity, which results in a shift from big to small individuals (Jin 2000). In 2000, 40% of the total marine catch of China came from the East China Sea. Even though it is less important now than previously, the East China Sea is still the most important fishing area for the countries in the region, especially the coastal waters of Zhejiang, Fujian Provinces and Shanghai. Most fishing grounds are at depths between 100 and 200 m.

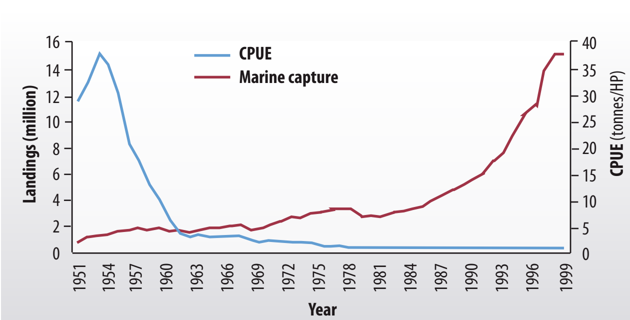

Figure 32 Marine capture and CPUE in China.

The Yellow Sea and East China Sea represent 60-80 % of the total.

(Source: Jin 2000)

Decreased level of recruitment

There has been a continually decreasing level of recruitment in the fisheries resource in the East China Sea, especially in squid and crabs which have a short lifespan and rapid growth, and with reproduction highly dependent on the level of supplemental recruitment. The increased effort in marine fishing has become a problem in recent years as this has led to reduced marine resources recruitment. The spawning ground of the common Chinese cuttlefish (*Sepiella maindroni*), one of the most well-know marine species of economic importance, is situated near Zhoushan Island and Ningbo. Under increasing fishing pressure, typified by an increasing number of fishing boats using improved and new techniques, the overfishing of Chinese cuttlefish has reached a level that gives stocks no time to recover and reproduce. Now fishing of Chinese cuttlefish at its spawning and hatchery grounds has dropped to a very low level. Similar serious problems have happened with recruitment of Yellow croaker (*Larimichthys polyactis*), Large yellow croaker (*Pseudosciaena crocea*), Large shrimp (*Penaeus orientalis*) and the crab *Portumus trituberculatus*.

Destructive fishing practices

These practices include fishing with explosives, trawling with nets and chains, and using cyanide to stun fish so that they can be caught alive, and other practices that damage or degrade important fish habitats such as reefs and mangroves. Illegal fishing methods have accelerated resource declines. Before the 1970s, the popular fishing technique called boat-knocking destroyed populations of the large yellow croaker and the Small yellow croaker, finally leading to the extinction of the Small yellow croaker in the middle 1970s and the Large yellow croaker in the middle 1980s. Trawl fisheries, mainly bottom trawl, have had the highest yield of all fishing fleets, between 40-61% of the total catch. This fleet accounts for 47% of the total catch which slightly decreased. The other major fishing methods are purse seining, driftnetting, and fixed netting.

Species retrogression and genetic problems

Because of species retrogression and genetic problems due to successive inbreeding aquaculture stocks have shown some genetic problems such as declines in growth and age at maturity, smaller adult fish, and an increase in the incidence of diseases (Ye et al. 2004). In natural populations of silver carp, the female age of maturity is 3-4 years with an average body weight of 4.85 kg, and the male age of maturity is 3 years with an average body weight of 3.81 kg. After inbreeding for five generations, the female age of maturity declined to 2 years with a body weight of only 1.25 kg and the male age of maturity declined to one year with a body weight of only 0.69 kg. Severance of the links between lakes and rivers by hydroelectric and irrigation projects has changed or disrupted dispersal and migration of species. These environmental changes accelerate the extinction of remnant species, and consequently decrease biodiversity abundance.

Root causes

Knowledge

Insufficient knowledge about the maximum sustainable yield (MSY) of the fisheries resource and a lack of both systematic monitoring and surveys of fish stocks are the main problems in fishery management. The dynamics of fish resources and the maximum sustainable catch are not well understood, thus marine fisheries have been managed without any concern for sustainable yields. Many fishers and marine fishing businesses continue to believe that the marine fishery is unlimited, and that the more fishing vessels that are deployed, the more fish will be caught.

Trawlers have seriously damaged the juvenile fish populations of major economic species. Moreover, ground trawls damage not only the fisheries resource but also the habitat and environment of the inshore and offshore areas. The fishing grounds for static nets are all located in inshore waters or estuaries, and intercept the migration of fish, which causes severe damage to the fisheries resource, especially juvenile fish. Gill net operations have been greatly increased owing to the shift in target species to small-size species in recent years. Gill nets with small-size mesh catch a large amount of the juveniles of large-size fish species while also catching the small-sized, target fish species. In addition, all the gill net operations are conducted in inshore areas that are also the spawning and nursery grounds for fish, thus gill net fishing also damages the coastal fishery.

Governance

There are too many trawlers and static nets in operation, and gill net mesh sizes are smaller than are allowed by national regulations. At present, although China has taken measures such as imposing (1) closed fishing seasons and areas, (2) limits on fishing capacity, (3) controlling the licensing of access to fishing, and (4) restrictions on the construction of fishing vessels, these measures have not fundamentally reversed the overfishing situation, owing to a lack of awareness of fisheries resource status, along with no imposition of a total allowed catch (TAC) limit or fishing quotas, compounded by insufficient fisheries administration capability.

At present, the marine fisheries resource is a public resource over which none has complete ownership, so anybody can enter the fishery without payment and there is little accounting of the social costs of resource depletion. Failure to manage fishing and the fisheries resource in the East China Sea has led to a number of serious problems that stand in the way of sustainable development. Resource problems are inevitably linked to social and economic problems, including developing population, pollution, disease, income of fisherman, land shortages and lack of legislation.

Economic

Most of the fishermen along the East China Sea have not been well educated and lack the money to begin new businesses. People continue to become fishers because fishing still can generate relatively higher benefits than other occupations. For example, in Shenjiamen in the Zhoushan Islands, the local fishery authorities are worrying about the future of about 1 200 fishermen who do not have boats. Zhejiang Province now has more than 200 000 fishermen who need new jobs. Without new training, fishing is their sole option.

Eutrophication in the Yangtze River estuary and adjacent inner shelf

The coastal region adjacent to the Yangtze River estuary is one example of an area suffering from the serious impacts of eutrophication, resulting in the proliferation of phytoplanktonic biomass and algal blooms. This type of environmental problem has caused great concern in the scientific community and has become a common topic of discussion in the media, and hence has been studied thoroughly within the framework of a Chinese national research project and through international cooperative efforts such as the Intergovernmental Oceanic Commission/Scientific Committee on Ocean Research, Global Ecology and Oceanography of Harmful Algal Blooms (IOC/SCOR GEOHAB).

Eutrophication is an international problem but its form of expression has a strong regional character: in terms of the East China Sea region, the problem of eutrophication can be linked to either land-source inputs or human-related issues in coastal waters, or both.

The summer effluent plumes from the Yangtze River spread eastward over the East China Sea shelf and cover a surface area of 80 000-90 000 km^2. The front of Yangtze River effluent plumes may reach the break of the continental shelf in the summer. One of the special features of the Yangtze River inflow to the East China Sea is that high N/P and N/Si ratios can be tracked over a distance of 300-400 km from the river mouth in surface waters.

Although the record of harmful algal blooms in the East China Sea can be traced back to the 1930s, the number of HABs increased sharply in 1980s when China launched economic improvements. It was reported that the number of harmful algal blooms in the 1990s had increased to 50-100, which is an increase by a factor of 5 when compared to the 1980s (Zhou et al. 2001). Paralytic Shellfish Poisoning (PSP) and Diarrhetic Shellfish Poisoning (DSP) have been frequently reported. These illnesses cause human health problems and sometimes death in the area affected by HABs (Zhou et al. 2001). The number of HAB species has increased dramatically after the1990s, which parallels the development of eutrophication in coastal waters. For instance, the HAB events induced by *Prorocentrum* sp. in May 2000 covered an area of 5 000-10 000 km^2 in the region off the Yangtze River estuary.

Water quality assessments have been conducted in the East China Sea using the coastal monitoring programs of the SOA and the Ministry of Fisheries, and these assessments have been compared to predictions made by statistical models, using available information for discharges from point and non-point sources, increases in population and other relevant socio-economic data.

Figure 33 summarises the major characteristics of the causal chain analysis with regards to coastal eutrophication in the East China Sea, with links between the problems of eutrophication and immediate and root causes.

Immediate causes

The discharge of nutrients from land sources has increased considerably over the last two decades. For example, the dissolved inorganic nitrogen (DIN) level in the Yangtze River has increased by a factor of 2 on average from 1980-2000. Additional short-term impacts are due to deforestation and damming in the watersheds, followed by erosion and soil loss and trapping of sediments in reservoirs. These kinds of activities affect the riverine nutrient flux and are also responsible for high turbidity in the coastal environment.

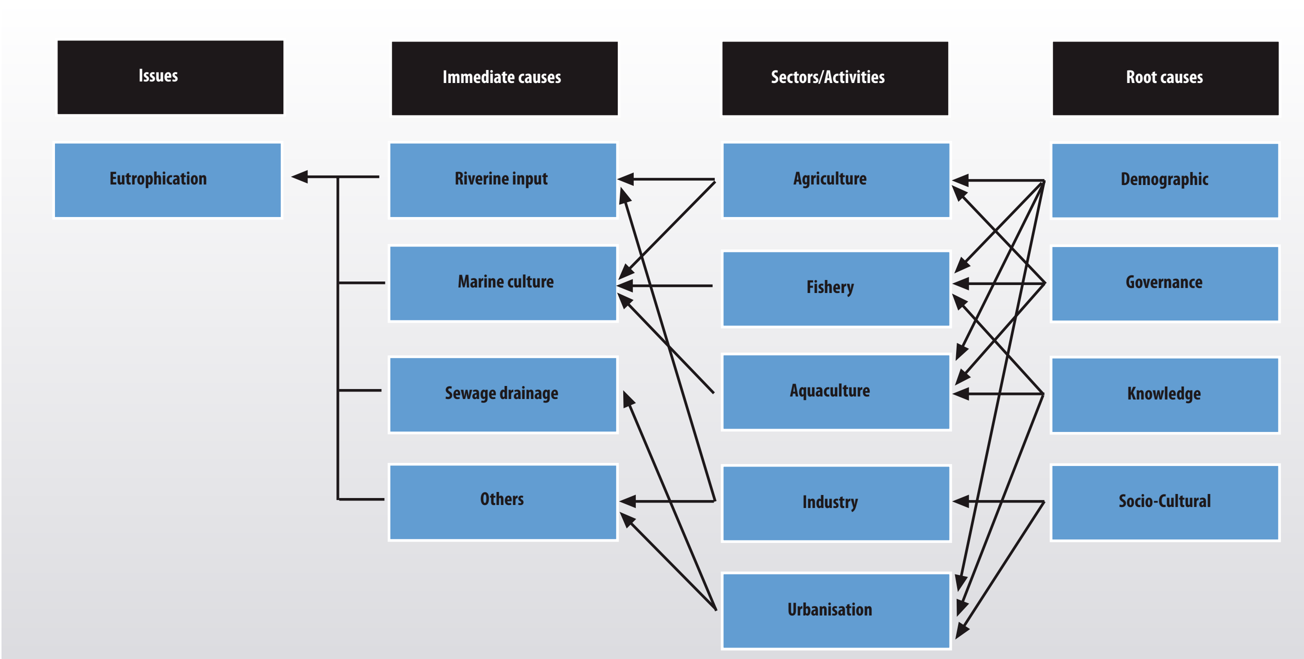

Figure 33 Causal chain diagram illustrating the causal links of eutrophication in the Yangtze River estuary and the adjacent inner shelf.

Data on non-point sources of nutrients can be obtained from riverine monitoring upstream of the estuary. These sources are integrated and show the overall discharge into the coastal environment. The application of chemical fertilisers may not necessarily induce increased coastal eutrophication, because nutrients are required for the annual growth of crops which in turn fix the nutrients in the watersheds, as long as the application of fertiliser does not exceed plant demands and the fertilisers are not washed out just after use. Point source inputs of nutrients to the marine environment are closely related to human behaviour in the coastal region. The coastal provinces and municipal cities cover a surface area of about 5% of the country's land area, but the residential population accounts for about 50% of the national population. The discharge related to human settlements is believed to be the main source of nutrient concentrations in some areas of the East China Sea coast. Sewage treatment capacities are generally low and are only able to treat about 50% of the total sewage production and daily sewage water from Shanghai, which reaches ca. 5 million tonnes. It is believed that a significant part of this contribution could be avoided with reforms, and by improving the area's sewage treatment capacity. Improvements to the existing water supply and drainage system, along with social and economic reforms, should be initiated to ensure that human waste will not enter the coastal waters without proper treatment.

In China, the production of coastal mariculture increased by 50% in the late 1990s and reached ca. 11 million tonnes in 2001, which is a level comparable to the fish catch. It was estimated that production in the tidal flat accounts for 47% of this increase, while the shallow water areas account for 4% and the bay for 7% (State Oceanic Administration 2004c). It is possible that a significant nutrient load has accumulated in concert with mariculture development in the coastal region, together with organic wastes, because aquaculture requires the use of a large amount of organic substances, which have a high of carbon, nitrogen and phosphorus content. Although at present it is difficult to estimate the quantity of nutrients and organic carbon discharges related to mariculture, its contribution to the development of coastal eutrophication may be comparable to that from the direct discharge of domestic waters. Another important source of pollution comes from the discharge of ballast water, as the East China Sea is an important waterway for cargo transport and a number of harbours are located along the coast. The discharge of ballast waters may also introduce HAB species from other regions.

Root causes

Based on the previous discussions, the immediate causes of eutrophication in the East China Sea coastal waters can be summarised as follows: non-point sources, with riverine input of terrestrial plant nutrients either from soil erosion or fertiliser use, or both; point sources, which come from sewage discharges, and releases from mariculture.

Additional sources may be atmospherc deposition (dry and wet) of nutrients and other pollutants. Concentrations of ammonia can be higher than nitrates in rainwater, and the N/P ratio of rainwater can be high. In the middle shelf area of the East China Sea, contributions from atmospheric deposition can be greater than land-source (e.g. river) influences (Tang & Su 2000).

Demographic

Coastal eutrophication is positively correlated with the increase in population in the coastal area, both as a consequence of urbanisation and as a result of the effort to reduce offshore fish catch in recent years and the subsequent increase in mariculture production.

Knowledge

Fertiliser is used extensively in agriculture, because of the need to boost production in response to population increases and the associated demand for agricultural products. Inadequate knowledge about the use of fertiliser and traditional agricultural practices both contribute to the increasing nutrient loads in surface waters. Failures in sewage treatment have the same effect. In many settlement centers, the sewage treatment capacity is not up to international standards and/or sewage is discharged without proper treatment. The population is not well educated in rural and some urban areas about the links between land-source pollutants and harmful effects on the coastal environment.

Socio-cultural

Sewage may be directly discharged without proper treatment to reduce costs to industry, or it may result from a simple lack of adequate capacity, because population growth has outstripped the ability of municipalities to build treatment facilities in a timely manner. The removal of vegetation from coastal wetlands for mariculture (e.g. shrimp ponds) has also become common practice, which eliminates the ability of this vegetation to absorb nutrients. Other traditional activities, such as fishing, suffer from the deterioration of product quality (from disease) while recent advances in sciences and technology are not well understood among fishermen.

Governance

There is a lack of follow-up with respect to regulations that limit nutrient drainage to the coastal waters, because it is believed that the most efficient way to reduce coastal eutrophication is to have sound environmental management of the watersheds, following principles of sustainable development. Although there are national laws for the protection of the marine environment, oversight and management of offshore activities are often inefficient. Catchment areas and marine waters must be managed together using a participatory approach that includes all stakeholders from both terrestrial and marine environments, combined with an integration of the effects from both public and private sectors. The study of marine environmental management and protection should be a required part of future industrial and agricultural development plans, with these new requirements accommodated for and/or mandated by law, in accordance with United Nations Conventions.

Habitat and community modification in coastal waters

The environment of the East China Sea has been faced with serious problems from pollution from the Yangtze River drainage basin and areas along the coasts where the local economy has expanded. Improper use of natural resources and a short-term economic outlook have resulted in environmental degradation over a fairly short time frame, and degradation has now reached a level at which the health and resources of the coastal region have been damaged.

In the last four decades, rapid industrialisation, combined with economic and social development in the coastal area of the East China Sea have produced three kinds of environmental problems: (1) marine habitats are irretrievably being lost owing to the construction of harbours and industrial installations, tourist facilities, aquaculture, and from the growth of settlements and cities; (2) severance of the links among lakes, rivers and sea channels by construction of sluices and dikes has led to the impoverishment of the natural fisheries resource, especially for migratory fishes, causing a shortage of large-sized economic fish species that are mostly migratory among lakes, rivers and the sea; (3)estuarine and embayment habitats have been modified considerably, so that wetlands areas have been narrowed, and the natural environment of the estuaries and embayments has been altered by the conversion of beach and wetlands to farmland.

An analysis of the Causal chain from immediate causes of habitat and community modification to root causes is shown in Figure 34.

Immediate causes

Loss of wetlands

The wetlands in the East China Sea coastal areas include fragments in the mud flats along rivers. The dominant species in wetlands are fresh and marine water benthos, fish, shrimp and aquatic plants. These wetlands are feeding and spawning grounds where fish and other aquatic animals live. Modification of aquatic habitats is one of the most important problems resulting in the degradation of the fisheries resource. Water pollution is an important source of toxic pollutants in wetland ecosystems.

Extensive reclamation of farmland from the sea is also a serious problem in China. Thousands of hectares of shoals have been reclaimed in the

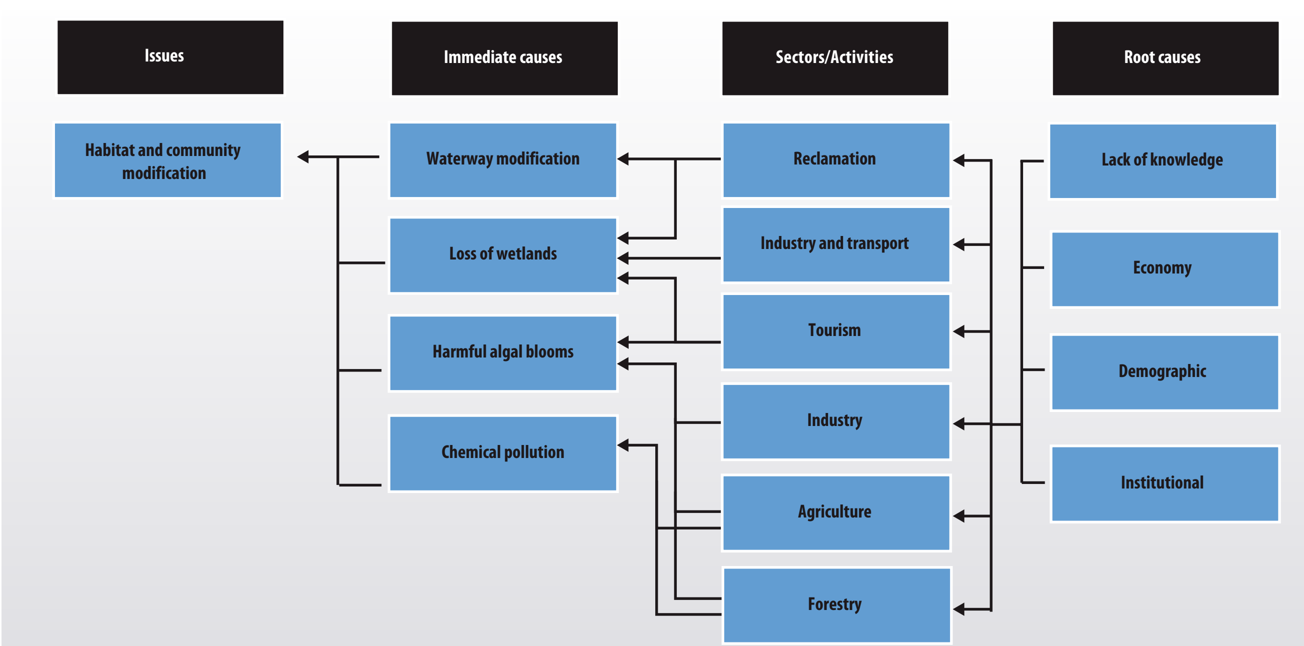

Figure 34 Causal chain diagram illustrating the causal links between habitat and community modification in coastal waters.

Yangtze River Estuary and other river coastal regions of the East China Sea, especially on Chongming Island, and in the Nanhui district of Shanghai, as well as Ningbo, Shaoxing, Zhangzhou and Zhoushan Island. Zhejiang Province is in the process of reclaiming 20 000 ha of shoals. Local governments are eager to have more land to improve the coastal economy, rather than protect living resources. This is the reason behind much of the wetland conversion into farmland.

Harmful algal blooms

Coastal China is an important economic area characterised by rapid economic development and a growing population. This has led to a significant increase of wastewater and sewage discharges directly into the East China Sea, resulting in eutrophication and harmful algal blooms. Fisheries resources and aquaculture operations are affected by these HAB events and eutrophication, which can lead to a reduction in ecological diversity, and human health problems.

Waterway modification

Construction of dams and dikes among lakes, river and sea has led to the destruction of the lake-river-sea ecosystem by severing the interconnections that are important for some migratory fish species. This has caused lakes to be dominated by species of small size and has diminished the populations of migratory species by limiting their ability to reproduce.

Chemical pollution

There are two separate threats that are currently being faced by the East China Sea as a result of the increased discharge of agricultural chemicals. Firstly, pollution from chemical fertilisers that are now widely and indiscriminately used on farmland results in direct damage to marine ecosystems, by causing eutrophication and harmful algal blooms. Secondly, overuse or misapplication of pesticides harms the biota and the ecological balance of the marine environment. More serious but indirect physical damage to the coastal and marine ecosystem results from soil erosion following deforestation, which is a major outcome of the unsustainable exploitation of forest products, which itself has caused over 1.1 million ha, or about 1%, of the region's forests to disappear due to overextraction. For example, cutting trees reduced forest coverage in the upper reaches of the Yangtze River from 30 to 40% in the 1950s to only 10% by 1998 (NBSC 2001).

Root causes

Demographic

The dense population in the coastal area of the East China Sea has inevitably resulted in great pressures on the coastal environment and its resources. The most problematic pressures are: 1) increased volumes of both domestic and industrial waste, 2) increased requirements for land, 3) increased discharges of agricultural chemicals and, 4) increases in construction, tourism and transportation. Problems, such as insufficient financial resources for environmental management, and the need to build institutional capacity to manage these problems, militate against implementing solutions.

Because domestic and industrial effluent discharges, atmospheric deposition, oil spills and other contaminants from manufacturing wastes, shipping, coastal tourism and other economic endeavours are increasing, marine pollution has become a very serious problem in the coastal region. Most of pollutants are composed of nutrients, toxic chemicals and oil from land-based sources. With the developing economy and increasing population, the concomitant pollutant increase from these land-based sources now affects not only on the shallow inshore habitat but also the deeper/wider ocean ecosystem.

Economic

Development along the coast of the East China Sea depends heavily on the shared resources of the sea and the coastal land base. The demand for more land motivates local governments to reclaim coastal wetlands for industry, ports and tourist facilities, in spite of efforts to conserve wetlands. These activities have caused direct harm to coastal habitats, particularly in the estuarine and coastal systems. The need for land results in the loss of biological habitats. The problem is so widespread that it is difficult to estimate its significance.

Institutional

The desire to address marine pollution and other environmental problems is often hampered by the lack of sufficient financial resources. The problem is particularly acute in China where insufficient budgetary allocations are made to control marine pollution and modification of biological habitats. At present, the constraints on the management of environmental problems in China result from insufficient resources (equipment, personnel, training) and inadequate allocation of financial resources for environmental protection. Funds for garbage collection, illegal logging and dumping of wastes, operation of existing sewerage and sewage treatment facilities are simply unavailable at the levels required for environmental protection.

Lack of knowledge

A major problem confronting the countries of the East China Sea is the lack of skilled staff to undertake monitoring, surveillance and enforcement of environmental regulations. Some problems can be attributed to the fact that local environmental bureaus have helped firms obtain permission to build factories and projects beyond what is normally permitted to protect local economies or even because of corruption. Effective law enforcement is essential for the protection of resources and the control of water pollution. In addition, a lack of education and jobs, and the growth in population in the basin are also the root causes of the problems in the marine environment.

Habitat and community modification in inland systems

Reclamation of land from lakes in the middle and lower reaches of rivers, combined with the construction of dams in the first-order tributaries have resulted in serious environmental problems and greatly modified habitats and communities that many species depend on. Central and local governments have paid more attention to these problems in recent years.

Changes in hydrological regimes and reduced winter and spring run-off result in both decreased depth of river delta waterways, reduction in delta vegetation (e.g. reeds) and saltwater intrusions. As the winter and spring water flows are reduced, the salt water of the East China Sea will move backward to the estuary of the Yangtze River longer periods of time, which in turn limits freshwater resources for domestic consumption. Furthermore, migration of fish to upper reaches of the river for spawning is impeded by reductions in river flow and essential nursery areas become inaccessible for adults. The construction of dams also destroys spawning sites. Spawning grounds for migratory species are also lost when delta vegetation is reduced. These factors have caused a drastic reduction in numbers of some species of fish, even leading to extinction of some species.

There are also concerns that the Three Gorges Dam, 2 000 km upstream from the river mouth, will cause serious negative impacts on the environment of the Yangtze River Basin. In addition, large-scale water diversion projects are under consideration for the transport of water to the Yellow River, which may cause further water shortage problems. Scientific research is essential, together with monitoring and an understanding of the effects of climate changes and anthropogentic activity at a subcontinental scale associated with such changes in hydrological cycles.

Draining and land reclamation have many adverse influences on the functions of lakes, like the Poyanghu Lake. Because of reclamation, the area of the Poyanghu has been reduced by 1 300 km^2 from 1954 to 1995 (Table 18) and its capacity has been reduced by 8×10^9 m^3, with the regulation coefficient decreased from 17.3% in 1954 to 13.8% in

Table 18 Changes in the area of Poyanghu Lake since 1954.

Year	Area (km^2)	Coefficient of regulation (%)	Drained areas (km^2)
1954	5160	17.3	0
1957	5004	16.9	154
1961	4720	16.0	440
1965	4410	15.2	750
1967	4128	14.2	1040
1976	3914	13.8	1246
1984	3890	13.8	1270
1995	3860	13.8	1300

(Source: Min 1999)

Figure 35 Three Gorges Dam.

1995, while the Poyanghu has been filled with 0.62×10^9 tonnes of sands from 1954 to 1997. These activities not only reduce the area of the Poyanghu and change the lake's shape, but also elevate flood levels and degrade water quality. Land reclamation may heighten the water table during flood peak, lengthen the duration of high floods, and increase the probability of disasters (Min 1999). Aquatic vegetation and fish species are greatly affected by the associated loss of habitats and/or ecotones.

Almost all the large rivers that flow into the East China Sea have been dammed (Figure 35), particularly in the Yangtze River drainage system, to produce energy, prevent floods and improve navigation. In the headwaters of Yangtze River, more than 10 000 dams have now been constructed. As a result, plankton, benthos, birds and fish communities in rivers are affected by these reservoirs. Because of dam construction, large terrestrial areas have been inundated, which has caused a loss of terrestrial habitats. The primary production of the East China Sea has changed as a consequence of the changed patterns of river discharge and organic loads. The dams have also blocked migration routes and destroyed spawning grounds for anadromous fish.

Figure 36 summarises the major characteristics of the causal chain analysis with regards to loss of ecosystems or ecotones and modification of ecosystems or ecotones in this region, linking the problems of land reclamation and changes in stream flow with immediate and root causes.

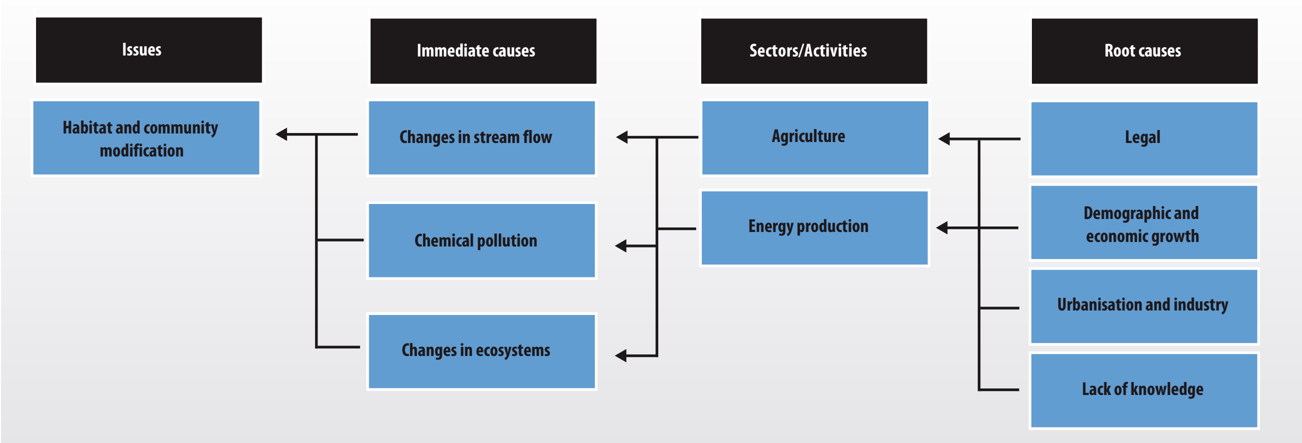

Figure 36 Causal chain diagram illustrating the causal links among habitat and community modification in inland systems.

Immediate causes

The immediate causes behind land reclamation from lakes can be summarised as follows:

- Changes in ecosystems: conversion of ecosystems by changes in land use, for example, conversion of water to farmland, and wetland to urban areas; and flooding of ecosystems as a result of human activities, because of land reclamation, so that the capacity of the Poyanghu to prevent floods is weakened.
- Chemical pollution: unsustainable agriculture practices, such as deforestation and chemical fertiliser use.
- Changes in stream flow: changes in freshwater and sediment supplies due to dams.

Root causes

The root causes that have allowed or resulted in freshwater habitat and community modification are summarised as follows:

Legal

There are no appropriate laws and regulations to control this situation at an international level, and the lack of enforcement of national environmental legislation in regulating the change of stream flow by hydroelectric construction has resulted in freshwater shortages and water quality problems, along with a loss of habitats to a substantial degree. There exist no solutions that can solve the problems of economic development and growth while simultaneously promoting sustainable use of resources.

Demographic and economic growth

The rapid progress in urbanisation and migration of inland population to the coast and the increase in population growth has resulted in the economic development without regard for environment impacts, including, for example, the negative effects of reclamation for agriculture and settlement. With the increasing population and economic growth, the demand for resources (electrical energy) increases as well. Thus the construction of facilities (e.g. dams and power station) cannot be avoided.

Urbanisation and industry

More and more arable lands have been taken over for infrastructure development and expansion of cities, which has caused irreversible problems in the basin (e.g. loss of habitats and ecotones).

Lack of knowledge

The population is not been well educated about environmental protection, and there is a general lack of awareness of environmental protection. There is inadequate scientific understanding and unreliable information for industry concerning the problem of environmental damage.

Conclusion

Some specialists who deal with environmental protection projects have been frank and open about the problems of pollution from land and the governmental issues that cause them. In the East China Sea, the level of environmental awareness on the part of the population, government officials, and business leaders is ever increasing. The problems enumerated above demand attention. The marine environment in the East China Sea is critical to the environmental and economic health of the region. Technical and human resources and financial assistance are available and should be found, both in China itself and from international support.

Policy options

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

Overexploitation of living resources in the East China Sea

Background

China has a five-year-long vessel-scrapping program, begun in 2002 and funded with 33 million USD per year. The program aims at delicensing and scrapping a total of 30 000 ships, or 6 000 vessels each year, thus reducing the overall capacity of China's 440 000-ship fishing fleet by about 7%. In 2002, China scrapped and withdrew the licenses of 5 000 ships. A related regulation mandates that new fishing vessels cannot be built unless the new unit will replace and inherit the license of an existing vessel. Other recent agreements with Japan and Korea have reduced China's offshore fishing grounds. The scrapping program is aimed in part at creating nearshore opportunities for fishermen currently working offshore. Because the increase of fishing effort plays an important role in the decline of the fisheries resources in the East China Sea, the reduction of fishing effort is significant, particularly in its effects on fishers' daily lives and futures.

Identification of potential policy options

Fish farming as an alternative

Overemployment in the fisheries sector, however, requires China to face overall unemployment and underemployment problems, which are particularly acute for fishermen and semi-skilled workers. The increasing mobility of China's labor force also contributes directly to the oversupply of fishermen and consequent overfishing. It is necessary to deter poor farmers from becoming fishermen. Back-of-the boat labour is almost impossible to control because the average income for a fisherman (500-800 USD per year) is still as much as double what a farmer might earn. As long as that gap exists, there will be demand for work in the fishing industry. To avoid this situation, China has invested money and effort in promoting aquaculture as an alternative. Aquaculture can effectively promote economic development and social progress, through creating significant employment opportunities, absorbing and using surplus fishing labourers, increasing fishers' income and assisting in poverty alleviation. Aquaculture also should be developed as an economic activity that can provide significant export earnings.

Fishing ban

The Chinese government has promulgated many policies, such as forbidding the use of fishing lines, closing fishing periods and zones, licensing, setting minimum mesh sizes and minimum landing sizes. Among these, the fishing ban was the most successful. An annual three-month fishing ban for commercial fishing in the East China Sea from June 15 to September 14 was first issued in 1995. To mitigate pressures from overfishing, 100 000 fishing boats must stay in port during the ban. Patrol ships and planes are dispatched to the marine areas to enforce the ban. The campaign aims to reduce illegal activities in the fishing grounds such as fishing during the ban and marine contamination. There is also currently a two-month freshwater fishing ban (February-March) in the middle and lower reaches of the Yangtze River. The Bureau of Fisheries expanded this in 2003 to include a further two-month (April- May) ban in the upper reaches of the river. There are no plans to lift or relax any of these moratoria. These measures have effectively protected juvenile fish so that the overall catch and quality could be increased and improved.

Up until the present the fishing ban has proven effective in protecting fishing resources and marine life. Catches of *Larimichthys polyactis* have increased from none in 1975 to 450 000 tonnes in 2000 (FAO 2004). This species is now the second most sought-after fish by the Chinese fishery. To further protect juvenile populations of *Larimichthys croceus, Larimichthys polyactis, Trichiutus lepturus* and other economic species, it is necessary to expand the fishing ban from the hatching areas such as Lvsi and the Zhousan Islands to the areas where young fish mature in the north of the East China Sea at the beginning of spring.

Enforcing fishery management

Other actions for the management of China's marine fisheries resource should include:

- Efforts to improve the existing legal system to better cope with overfishing.
- An improved fishing license system, with a quota system and strengthened management of the fishing industry.
- Support for monitoring of fisheries resources, which is fundamental for the conservation and rational use of the resource, and is also an essential prerequisite for any quota system.

Immediate policy options

Knowledge

Because of insufficient knowledge regarding the limits of the fisheries resource, along with a lack of systematic monitoring and surveys of the fishery stocks, the dynamics of the resource and the maximum sustainable catch are not well understood. As a consequence, marine fisheries in the East China Sea have been managed without regard for sustainable yields. Many fishers and fishing businesses continue to believe that the fisheries resource is unlimited, and that the more fishing vessels are used, the more fish will be caught. It is essential that national scientific funding agencies support the study of the dynamics of fish stocks in the East China Sea.

Improved institutional capacity for fisheries management

Although China has taken measures to control fisheries, these measures have not fundamentally reversed the overfishing situation, partly owing to insufficient capability on the part of government agencies to administrate fishing programs. The development of an increased fisheries capacity will require the development of institutional capacity to administrate fisheries programmes and regulations.

Shifting employment away from exploitive fishing

Fishing bans pose severe economic challenges for those employed in the industry or on their own. Government aid is needed to help with the economic problems that result from fisheries management. The following programmes are necessary to achieve this goal.

- Encourage the growth of freshwater and coastal aquaculture, and encourage technology transfer to improve the breeding and supply of young fish.
- Encourage fishing activity in the open sea, with technology transfer and assistance.
- Strengthen education and the availability of information to improve public awareness regarding environmental protection.
- Strengthen information and education in the rural population regarding environmental protection.

Recommended policy options

International cooperation

The East China Sea is known to be a very productive fishing area. However, management of resources in the area has been complicated due to territorial claims made by Korea, Japan, and China. The three countries ratified the 1982 United Nations Convention on the Law of the Sea in 1996. To adjust to the new situation arising from overlapping claims, the countries need to alter their claims under the United Nations Convention. Thus far there has been a Japan-China Fisheries Agreement (1997), a Korea-Japan Fisheries Agreement (1998), and a Korea-China Fisheries Agreement (1998), which provide legal frameworks for a new fisheries regime. But these bilateral agreements are not enough to resolve complex legal issues relating to boundary problems. It is necessary for the three countries to cooperate on a new fisheries order in the Northeast Asian seas, especially in expanding seasonal fishing bans and structured bans.

Legal and institutional frameworks

The importance of legal, procedural and institutional frameworks designed to facilitate sustainable fishing industry development must be emphasised in China. There are no universally applicable models. The nature of any improvements will depend on existing laws, traditions, and institutional structures. But law, traditions and institutional structures need to be modified or adapted to develop a system that is relevant enough to play a role in building a sustainable fishing industry.

The ideal framework would allow for vertically (national to regional) and horizontally (across sectors) integrated policy-making and planning with a significant role for strategic, sectoral or regionally integrated environmental assessments as an input to the planning process. Such a framework should allow for adaptation in both directions, i.e. national policy should inform local planning; local planning and public involvement should inform the development or adaptation of policy at higher levels.

The adoption of the "Law of Fisheries of the People's Republic of China" in 1986 was a very important step in the development of China's fishery policy. From that time up until the present, laws and regulations under the umbrella ofChinese fisheries law have been established. The Law of Fisheries as a legal provision defined a fishery development policy suitable for the Chinese economy. It has showns ignificant importance in the adjustment of fisheries production relationships, in the standardisation of fisheries activities, and for the conservation and rational use of the fisheries resource. It is also necessary to take steps to control illegal, unregulated and unreported fishing by blacklisting bad actors and enacting strict regulations. A joint fisheries commission between the East China Sea littoral states should be established as a part of new international fisheries agreements.

Eutrophication in the Yangtze River estuary and adjacent inner shelf

Eutrophication has been identified as one of major problems that affect the sustainability of East China Sea and its coastal water ecosystems. In particular, coastal eutrophication has been identified as a key cause in the deterioration of coastal environment, with subsequent socio-economic effects.

Root causes for eutrophication in the East China Sea

In the Causal chain analysis section the primary root causes for coastal eutrophication in the East China Sea were identified as the following:

- Demographics: The development of coastal eutrophication is correlated with land-source nutrient inputs, which result from increased human activities (e.g. growth in population and agriculture). Moreover, the influence of domestic wastes can be seriously underestimated owing to the lack of sanitation systems in the watersheds.
- Knowledge and education: Rural populations have no understanding of cause and effect that can start with agricultural practices, both on land and coast, and end at marine food –webs that are seriously harmed by eutrophication. Failure to adequately treat sewage has the same effect.
- Economics: Traditional agricultural practices result in increased fertiliser use and soil and water losses. In some regions burning before cultivation is quite common in watersheds, as is the exchange of wastewater from marine culture pounds with clean seawater, which is the most typical and cheapest method for coastal aquaculture. Coastal mariculture has become one of the most important economic forces following fishery production agreements between neighbouring countries in the East China Sea. Sustainability of aquacultural practices in the coastal region may not be a high priority among the population, because of problems of land and property tenure. There is little provision for controls or monitoring of waste discharges because of attempts to cut costs.
- Governance: The reduction of eutrophication will only come through a sound environmental management by legislation and protection. A combined effort on regional agreements and actions will help solve eutrophication problems.

Identification of policy options

The cross-link of causes listed above corresponds to numerous possible policy options in dealing with the problems associated with coastal eutrophication.

Demographic issue

It is necessary that each country reduce nutrient inputs from land-based sources. Coastal activities should also be carefully designed and managed to reduce direct waste discharges.

Knowledge

Awareness on the part of the public about the detrimental consequences of coastal eutrophication needs to be improved. This issue should be incorporated into the national education curricula. While short-term targets are important to convince the population to improve farming methods and in aquaculture, technological innovations can also contribute to reducing nutrient input into marine waters. Such information and knowledge should be freely accessible through the education of farmers and fishermen about the appropriate use of fertiliser in agriculture and feedstocks in aquaculture as well as the relationship between inappropriate cultural activities and the eutrophication of coastal waters. Technological improvements should also be adopted to increase the capacity of water purification systems.

Economic issues

Financial constraints constitute one of important causes of these problems, but the corresponding policy options should go beyond improving water quality frameworks. Economics at the provincial level, as well as trade barriers and protectionism by industrialised countries and differences in trade policies for agricultural and fisheries products must be addressed, because these issues limit the ability of the region to advance economically.

Cultural issues

Cultural differences are an important constraint in the sound management of the coastal environment. However, overcoming these problems will result from cultural evolution, in which different traditions are progressively and naturally blended, particularly in coastal areas, where education and economics are on average already mostly developed.

Governance and Legislation

Coastal waters should be managed as sustainable ecosystems, and the authorities, through their governance of water policy both on land and in marine environment, should work towards this goal. Integrated management of water systems within the context of whole East China Sea is required, through the efforts of land and marine authorities in neighbouring countries. This approach is already a part of the fisheries agreements among the countries of the East China Sea. An East China Protection organisation should be established, first by creating an advisory body, which can gradually be expanded to consultation, technical management, and the evaluation of financial allocations for water quality improvements.

Immediate policy option: Establishment of a regional monitoring system for water pollution and coastal eutrophication.

The recommended policy options to combat coastal eutrophication in the East China Sea must address the root causes identified above and should be based on the ongoing national and regional programs with efforts at the institutional and/or organisational level. Existing facilities and databases should be taken into account in designing frameworks and projects. Therefore, the recommended policy option is the implementation of a regional monitoring system for coastal eutrophication in East China Sea, which is critical to the:

- Establishment of an agreement between neighbouring countries (Japan, Korea and China), which should be based on the free exchange of opinions from provincial governments, industry and local communities.
- Registration and monitoring of pollution sources, which should be taken into account during the early stages of the formulation of economic and social development programmes.
- Environmental assessment of pollution impacts and selection of indicator species for marine water quality. Such an assessment should include water profiles, sediment sampling and evaluation of living organisms.
- Organisation of an institutional network in the field of marine water quality, which will provide an assessment of eutrophication-related issues, e.g. effects on ecosystems and biodiversity.
- Establishment of a network for the systematic observation of coastal waters and the definition of an observation frequency and measurement parameters.
- Definition of a financial mechanism for monitoring activities, which allows inter-comparison of monitoring results from neighbouring countries, compilation of monitoring results, and an assessment of changes in eutrophication-related issues.
- Establishment of a joint consultation board, composed of representative of countries in the East China Sea. National representatives should include experts, policymakers, people from industry and local communities in coastal areas.
- Other related recommendations for policy options can be outlined at this stage, and can be defined in more detail later or altered, based on the progess of existing organisations, such as:
    - Improvement of technological methodologies used in agriculture or/and marine fisheries (such as aquaculture);
    - Prohibition of economically harmful techniques (traditional marine culture techniques) through legislation and education;
    - Introduction of environmental friendly and non-polluting industries in coastal areas and the replacement of traditional fisheries with of new techniques;
    - Reinforcement of mechanisms such as taxes or penalties to discourage certain practices that may cause coastal pollution;
    - Promotion of the spread of the knowledge and regulation of environmental protection through training and education;
    - Creation of a communication network between countries to exchange information regarding pollution issues and to inform coastal populations;
    - The IMO regulations for ballast water need to be more strongly enforced by the East China Sea countries.

Performance of the recommended policy options

The recommended policy options can be implemented, as provisions exist for such options in existing regional frameworks agreed to by the countries of East China Sea, for example, under the umbrella of Northeast Asia Region-Global Ocean Observation Systems (NEAR-GOOS).

Efficiency

The recommended policy options can be undertaken in different ways, such as by creating a forum where individuals from different organisations as well as different countries can identify problems, and exchange information, ideas and knowledge. The recommendations for regional measurements can be adopted for eutrophication in relation to cultural practices in watersheds and coastal areas. The monitoring system must be carefully designed to be on the same scale as the problems to be addressed as well as to the financial resources available long-term to address them. Existing facilities should be used to their fullest capacity and should be elevated to a higher level. The system should enable the production of an annual report on eutrophication in the East China Sea. Follow-up programmes, and comparisons of indicators/parameters should allow the creation of an early warning system for authorities in case of serious and rapid coastal water quality deterioration. The system should also identify sources and impact areas to be dealt with, and actions to reduce pollution and to restore damaged ecosystems.

Equity and feasibility

The proposed policy options are equitable as they aim to include, in equal numbers, governmental representatives, industry, research institutions and communities. With regards to implementation, the existing regional framework is designed to give priority to the actions planned by the governments of the East China Sea countries. Political feasibility will be guaranteed by strong cooperation between the countries of the East China Sea. Furthermore, links between industries and communities will provide balance and openness during the process.

Implementation capacity

The countries of the East China Sea have sufficient human resources and facilities to carry out such a campaign; however, attention should be paid to the upgrading and standardisation of facilities. The existing technical organisations of participatory countries will be the local contact points for routine data collection and compilation.

Habitat and community modification

Definition of problems

Numerous factors make it difficult to control pollution of the East China Sea. Wastes may come from a sewage outfall, a population center or a canal. These kinds of point sources are relatively easy to locate and simple enough to control. But occurrence of marine pollution has often linked with complicated circumstances. It usually is affected by non-point pollution sources, which are much more difficult to treat. For example, the largest agricultural application of irrigation water occurs in the Yangtze River drainage basin, which is faced with serious pollution from fertilisers and pesticides, resulting in aquifer contamination. There are also some other problems such as ineffective regulation, insufficient resources, the need for capacity building at all levels of government, and a lack of political will.

Identification of potential policy options

Reforestation

In recent decades, the primary goal has been broadened from solely increasing growth production to maintaining and enhancing various ecological functions such as preventing desertification and coastal erosion, and reducing run-off in river basins. Efforts to increase forest cover received a further boost after 1998 when a flood caused a heavy losses in China and widespread deforestation in the upper reaches of the Yangtze River was identified as one of the main contributing factors. Because of deforestation and loss of aquifers, a huge amount of nutrients generated by agriculture and aquaculture enters water bodies of the East China Sea in non-point run-off. Nutrients make up the second most important group of pollutants in the marine environment and are the main reason for eutrophication and harmful algal blooms. Reforestation is an efficient way to achieve the long-term goal of ecological reconstruction to protect the marine environment of the East China Sea.

Controlling use of fertilisers and pesticides

Excessive use of fertilisers and pesticides (fungicides, herbicides and insecticides) has produced serious problems for the health of aquatic ecosystems. Traditional farming may lead to large quantities of soils entering stream channels and contribute to the sediment load in river discharges to the marine environment.

Detecting pesticide presence in aquatic environments and removing it requires expensive methods. Funding such activities will be difficult at the local level. The high concentration of chemicals from agriculture, especially fungicides, herbicides and insecticides, in the marine and related freshwater environments can result in the loss of biodiversity and reduction of productivity. There is a need to encourage farmers to employ environmentally friendly farm practices that minimise the use of fertilisers and biocides, and to enhance soil retention of fertilisers.

Wetland protection

Reclamation of intertidal areas has been a national priority for many years. Massive reclamation projects have also been undertaken in the coastal areas of the East China Sea. It is believed that the substantial investments that have already been made in seawalls will continue to produce losses in wetland habitat.

Reclamation of wetlands was usually promoted by local governments for short-term economic benefits. Protecting wetlands will take years and will be difficult. Knowledge and institutions will be very important components, and legal frameworks for the Law of Wetland Protection are another. The law is the only hope of holding out against the pressures of economic demands for reclaiming wetlands.

Reconnecting migratory links

Over the past decades, lakes in the Yangtze River Basin and in the East China Sea region have been artificially severed from rivers by hydroelectric and irrigation projects, and as a result, migratory fish can no longer move between lakes and sea, or to and from thesea via rivers. This has lead to a sharp decline in species such as the Chinese sturgeon *(Acipenser sinensis*) and *Cyprinus,* for which both lake and river spawning grounds are essential. The construction of fishways is a good solution that can be enacted now. Any future construction of irrigation facilities should alos consider effects on fishways.

Reduction in land-based pollution

The major pollutants in the East China Sea are oil, inorganic phosphorus, inorganic nitrogen and heavy metals. Long-term monitoring in coastal waters from the East China Sea shows that seawater quality is steadily deteriorating. Wastes from domestic, agricultural, and industrial sources, along with sediments and solid wastes, are the major sources of pollutants that affect both freshwater and coastal systems in the Yangtze River and the East China Sea. Land-based sources play a major role in both inland and coastal pollution. Ship-based sources, such as split oil and ballast water, contribute relatively small amounts. There is a need to collect data on atmospheric inputs, which can also be considered a source of land-based pollution.

Immediate policy options

Public involvement

Substantial public involvement is a desirable and necessary part of any planning initiative with regard to the health of ecosystems. This involvement can take different forms, all of which are important:

- Communication of information between decision makers, planners or technical specialists to the public;
- Participation, shared responsibility and decision making with comprehensive public involvement should be increasingly emphasised in any assessment or planning;
- Planning that makes assessments about issues of widespread public concern, the quality of life, the value of resources, and the trade-offs between different resource uses;
- Requiring any assessments to be properly evaluated and/or validated through the widest possible consultation.

Balancing economic and environmental goals

It is often difficult in policy-making to reconcile the conflicting objectives of economic development and social values associated with environmental conservation. Uncontrolled and unplanned industrial, commercial and residential development that does not include adequate provisions for potable water, management of solid waste, and collection and treatment of wastewater should no longer be allowed.

Pollution penalities

A person, company, or agency responsible for environmental damage or actions that cause pollution in the marine environment should be made responsible for the cost for remedying the situation. This provision is not universally included in legislation, but has been adopted as a matter of policy. Compensation should include all the expenses actually incurred by the government service for the clean-up of pollution. Although the government has adopted the principle of compensation for damages and penalties for illegal activities it is often too expensive to stop the pollution. More strict laws or regulations should be adopted and carried out.

Performance of the recommended policy options

Legal frameworks

Since the 1980s, China has been taking steps to complement and then replace administrative measures with a legislative and regulatory framework as a foundation for economic and social behaviour. The legal system has yielded an impressive amount of laws, regulations, and standards in a way that has truly changed basic rules in Chinese society. But the system is still far from complete. Still, the work so far to create a legislative and regulatory framework should not ignore the fact that administrative measures play an important role as a tool for environmental actions. Legislation has often been accompanied by large-scale investment projects targeted with government funds. For example, the government will complement its the marine pollution bills by investing heavily in land-based pollution control, and by closing down many polluting enterprises.

Integration and coordination

By definition, integrated coastal management implies a greater level of integration than is typical with conventional approaches. It implies a holistic analysis and synthesis of complex technical, social, economic and ecological information. It also implies correspondence between local initiatives and international-level policies. It is necessary to create improved cooperation between different sectors. Increased integration therefore implies increased complexity. Decision-making is likely to be slower and more difficult as the degree of integration increases. Key requirements are:

- High quality, well-presented and effectively communicated/exchanged information,
- Clearly and widely agreed upon decision criteria,
- Clear and transparent decision-making processes; and (if necessary),
- A clearly designated (and widely agreed upon) final authority and arbiter (whether individual or committee).

Where a single policy alone cannot guarantee the achievement of the desired impact, for instance, fishing quotas, the active involvement of the countries of the East China Sea region will be critical in the follow-up to the GIWA endeavour. The assessment of perturbations and feedback mechanisms shows that anthropogenic activities have accelerated the environmental degradation of natural systems and resources, both on land and in the East China Sea. Increased land-source nutrient run-off, modification of habitats and overfishing are the predominant challenges to development in the region. The improper management of water resources, coastal entrophication and an unsustainable fishery have been identified as the most severe issues, while other issues also merit attention. It should be recognised that most of the impacts discussed in this report are very much linked to human activities.

Conclusions and recommendations

In the GIWA effort in the East China Sea, a fourstep process has been used to provide a series of insights into the main issues in the region, based on data compilation and analyses. In addition, the causal chain analysis has resulted in the identification of the following root causes:

- Lack of public awareness and education, which slows down the distribution of information and existing knowledge;
- Poor organisation/control of investment planning and priorities, which results in harmful investments and actions;
- Inadequate structure and capacity building, which results in an imbalance between resource consumption and legislation;
- Weak international cooperation between neighbouring countries, which hinders coordination of implementation.

There are significant knowledge gaps in the quantitative estimates of benefits and costs in both physical and financial terms for the East China Sea, with respect to water and economic resources. In-depth studies should be carried out to establish necessary processes and to determine input and response feedback loops in various parts of society. This will help in the evaluation of potential influences on human health and the determination of mechanisms for the remediation processes.

The analyses of policy options has generated a series of recommendations, which include:

- Establishment of a regulatory framework in the region and improvements in compliance through stakeholder involvement;
- Investment in legal enforcement and an increase in capacity building to remedy pollution and habitat loss;
- Creation of education programmes to improve public awareness and participation in actions;
- Improvement in opportunities for increasing revenue and employment from environmental protection industries
- Enactment of legislation and international agreements to reduce pollution from land-based activities.

Finally, because of the similarity of environmental problems in the East China Sea to other marginal seas, the causal chain and policy option analyses presented in this report should be combined with documents from other regions to synthesise a GIWA approach for marginal seas of the world.

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Annexes

Annex I
List of contributing authors and organisations

Name	Institutional affiliation	Country	Field of work
Jianguo Qu	State Key Laboratory of Estuary & Coastal Research, East China Normal University, Shanghai, 200062 China	China	Environmental Science
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Qian Long	Library of East China Normal University, Shanghai, 200062 China	China	Information Science
Liang Wang	School of Resources and Environment Science, East China Normal University, Shanghai, 200062 China	China	Ecology
Xiaomin Shen	State Key Laboratory of Estuary & Coastal Research, East China Normal University, Shanghai, 200062 China	China	Fishery Resource
Jing Zhang	State Key Laboratory of Estuary & Coastal Research, East China Normal University, Shanghai, 200062 China	China	Chemical Oceanography
Yongli Cai	School of Resources and Environment Science, East China Normal University, Shanghai, 200062 China	China	Ecology

Annex II
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	1	30	Freshwater shortage	**1.7**
2. Pollution of existing supplies	2	40		
3. Changes in the water table	2	30		

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

N/A = Not applied

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	1	10	Pollution	**1.7**
5. Eutrophication	3	35		
6. Chemical	1	20		
7. Suspended solids	1	10		
8. Solid wastes	1	10		
9. Thermal	1	5		
10. Radionuclides	N/A	N/A		
11. Spills	1	10		

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

N/A = Not applied

III: Habitat and community modification

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

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

N/A = Not applied

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	60	Unsustainable exploitation of fish	**2.4**
15. Excessive by-catch and discards	N/A	10		
16. Destructive fishing practices	3	10		
17. Decreased viability of stock through pollution and disease	2	20		
18. Impact on biological and genetic diversity	1	10		

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

N/A = Not applied

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	50	Global change	**0.5**
20. Sea level change	0	50		
21. Increased UV-B radiation as a result of ozone depletion	N/A	N/A		
22. Changes in ocean CO_2 source/sink function	N/A	N/A		

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

N/A = Not applied

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	
Freshwater shortage	1.7	2	1	1	0	0	0	1	**0.84**
Pollution	1.7	2	1	1	1	1	2	1	**1.34**
Habitat and community modification	2	3	1	0	0	0	2	1	**1.12**
Unsustainable exploitation of fish and other living resources	2.4	3	2	0	1	0	0	1	**1.18**
Global change	0.5	1	0	0	0	0	1	1	**0.44**

Weight averaged environmental and socio-economic impacts of each GIWA concern

Present (%) (i)	Future (%) (j)	Total (%)
60	40	100

Environmental (k)	Economic (l)	Health (m)	Other Social and Community impacts (n)	Total (%)
40	20	20	20	100

Concern	Types of Impacts					Rank
	Time Weight Averaged Environmental Score (o)	Time Weight Averaged Economic Score (p)	Time Weight Averaged Human Health Score (q)	Time Weight Averaged Social & Community Score (r)	Time Weight Averaged Overall Score	
	(a)x(i)+(b)x(j)	(c)x(i)+(d)x(j)	(e)x(i)+(f)x(j)	(g)x(i)+(h)x(j)	(o)x(k)+(p)x(l)+ (q)x(m)+(r)x(n)	
Freshwater shortage	1.82	1	0	0.4	**1.01**	**4**
Pollution	1.82	1	1	1.6	**1.45**	**2**
Habitat and community modification	2.40	0.6	0	1.6	**1.40**	**3**
Unsustainable exploitation of fish and other living resources	2.84	1.2	0.6	0.4	**1.58**	**1**
Global change	0.70	0	0	1	**0.48**	**5**

Annex III
List of laws and regulations related to water

1. **1974 UNEP Regional Seas Programme, UNEP,** established in 1974, is a global program for the sustainable management of coastal and marine environment areas on a regional basis.
2. **1979 Rules of the People's Republic of China governing vessels of foreign nationality,** came into force on Sept. 18, 1979, safeguard ports and coastal waters, ensure the safety of navigation and prevent the pollution of waters.
3. **1983 Regulations of the People's Republic of China on the prevention of vessel-induced sea pollution,** came into effect in 1983, aim to protect marine environment.
4. **1985 Regulations of the People's Republic of China on control over dumping of wastes in the seawater,** come into effect on Mar 6,1985, control dumping of waste.
5. **1990 Regulations of the People's Republic of China on the prevention of pollution damage to the marine environment by land-sourced pollutants,** came into effect on June 22,1990, focus on strengthening the supervision and administration of land pollution sources and preventing pollution damage to the marine environment by land-sourced pollutants.
6. **1991 Law of the People's Republic of China on Water and Soil Conservation,** came into force on June 29, 1991, supports the decrease of land-based pollution of the marine zone.
7. **1992 Law of the People's Republic of China on the Territorial Sea and the Contiguous zone,** came into effect on Feb. 25, 2002, defines and protect territorial sea and contiguous zone of the People's Republic of China.
8. **1992 Maritime Code of the People's Republic of China,** came into force on Nov. 7, 1992, governs commercial transactions to do with shipping and navigation.
9. **1992 North Pacific Marine Science Organization (PICES),** established in 1992 with Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and the United States of America, is an intergovernmental scientific organisation to advance scientific knowledge about the ocean environment.
10. **1996 Decision of the Standing Committee of the National People's Congress on approval of the United Nations Convention on the Law of the Sea,** approved by the Standing Committee of the National People's Congress on 15 May 1996, is a full adoption of UNCLOS treaty norms by China, including particularly the concept of the 200 nm EEZ and a Continental Shelf generally limited to 200 nm.
11. **1996 Decision of the State Council on several issues concerning environmental protection,** came into force on Aug. 3, 1996, aims at strengthening the prevention and control of water pollution in rivers, lakes, reservoirs and coastal waters.
12. **1998 People's Republic of China Exclusive Economic Zone and Continental Shelf Law,** came into effect on 26 June 1998, defines the EEZ and the continental shelf of PRC China and specifies the jurisdictional powers that China will be exercised in these maritime areas.
13. **1998 Seawater Quality Standard of the People's Republic of China,** came into force on July 1, 1998, classifies seawater quality into four grades, and gives quality standards for each grade of seawater.
14. **1999 Wetland Biodiversity Conservation and Sustainable Use Programme, People's Republic of China,** issued by the State Council on Jan. 1, 1999, provides the foundation for the conservation and better management of the wetland resources in China.
15. **2002 Administration Law on the Use of Ocean Space of the People's Republic of China,** came into effect on Jan. 1, 2002, promotes the rational development and sustainable use of ocean space.
16. **Economic and Social Commission for Asia and the Pacific (ESCAP), UN,** addresses various issues about water.
17. **Large Marine Ecosystem Project,** The Large Marine Ecosystem Project is a global effort initiated by the World Conservation Union (IUCN), the Intergovernmental Oceanographic Commission of UNESCO (IOC), other United Nations agencies, and the US National Oceanic and Atmospheric Administration (NOAA). The project aims to improve the long-term sustainability of resources and environment of the Large Marine Ecosystems (LMEs) worldwide.
18. **Nautilus Institute for Security and Sustainable Development,** is a policy-oriented research and consulting organisation which promotes international cooperation for security and ecologically sustainable development including the marine environment

Annex IV
List of laws and regulations related to environmental protection

1. **The Water Act of People's Republic of China,** approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China; a law for management, utilization and protection of water resources.
2. **1982 The Marine Environment Protection Act of People's Republic of China,** approved by the Standing Committee of National People's Congress on Aug. 23, 1982; a law especially for marine environment protection.
3. **1983 The Marine Petroleum Exploitation and the Environment Protection Regulation of People's Republic of China,** issued by the State Council on Dec. 29, 1983; a detailed and supplementary rule for the Marine Environment Protection Act.
4. **1983 The Regulation for Preventing Marine Pollution from Ship, People's Republic of China,** issued by the State Council on Dec. 29, 1983; a detailed rule for the Marine Environment Protection Act.
5. **1984 The Water Pollution Control Act of People's Republic of China,** approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China on May 1, 1984; a law dealing with inland water pollution control.
6. **1985 The Marine Waste Disposal Management Regulation of People's Republic of China,** issued by the State Council on March 6, 1985; a detailed rule for implementing the Marine Environment Protection Act.
7. **1988 The Wild Animal Conservation Act of People's Republic of China,** approved by the National People's Congress on Nov 8, 1988; the first law in China dealing with wild animal conservation.
8. **1989 The Environment Protection Act of People's Republic of China,** approved by the Standing Committee of National People's Congress on Dec. 26, 1989; a basic law for comprehensive environment protection.
9. **1990 The Regulation for Controlling Marine Pollution by Inland Pollutants, People's Republic of China,** issued by the State Council on June 22, 1990; a detailed rule for the Marine Environment Protection Act.
10. **1990 The Regulation for Preventing Marine Pollution from Coastal Construction, People's Republic of China,** issued by the State Council on May 25, 1990; a detailed rule for the Marine Environment Protection Act.
11. **Mineral Resources Law of the People's Republic of China,** covers the development of the mining industry and promotes the exploration, development, utilization and protection of mineral resources in the present and the long term.

Annex V
List of laws and regulations related to fisheries

1. **The Water Act of People's Republic of China,** approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China; a law for management, utilization and protection of water resources.
2. **1953 The Charter of the Ship Inspection Bureau of People's Republic of China,** approved by the State Council on Oct. 7, 1963; a rule suitable to all kinds of ships except military ship, sport boat, tourism boat and small wooden boat.
3. **1982 The Marine Environment Protection Act of People's Republic of China,** approved by the Standing Committee of National People's Congress on Aug. 23, 1982; a law especially for marine environment protection.
4. **1982 The Food Hygiene Act of People's Republic of China,** approved by the Standing Committee of National People's Congress on Nov. 19, 1982; a law preventing unhealthy food from endangering people's health.
5. **1983 The Marine Petroleum Exploitation and the Environment Protection Regulation of People's Republic of China,** issued by the State Council on Dec. 29, 1983; a detailed and supplementary rules for the Marine Environment Protection Act.
6. **1983 The Regulation for Preventing Marine Pollution from Ship, People's Republic of China,** issued by the State Council on Dec. 29, 1983; a detailed rules for the Marine Environment Protection Act.
7. **The Export Food Hygiene Management Regulation of People's Republic of China,** issued by the State Commodity Inspection Bureau and the Ministry of Health on July 16, 1984; a law to guarantee the quality of exported food.
8. **1984 The Water Pollution Control Act of People's Republic of China,** approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China on May 1, 1984; a law dealing with inland water pollution control.
9. **1985 The Fishing Vessel Registration Charter, People's Republic of China,** issued by the Ministry of Agriculture on Nov. 9, 1985; a detailed rule for both domestic and foreign fishing vessels.
10. **1985 The Marine Waste Disposal Management Regulation of People' Republic of China,** issued by the State Council on March 6, 1985; a detailed rule for implementing the Marine Environment Protection Act.
11. **1986 The Fishery Act of People's Republic of China,** approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China on Jan. 20, 1986; a basic law dealing with national principle for fishery management including aquaculture, fishing and fishery resource enhancement, utilization and conservation.
12. **1987 The Detailed Rule for Implementing The Fishery Act of People's Republic of China,** approved by the State Council and issued by the Ministry of Agriculture on Oct. 19, 1987; a supplementary regulation for The Fishery Act of People's Republic of China.
13. **1988 The Wild Animal Conservation Act of People's Republic of China,** approved by the National People's Congress on Nov. 8, 1988; the first law in China dealing with wild animal conservation.
14. **1989 The Environment Protection Act of People's Republic of China,** approved by the Standing Committee of National People's Congress on Dec. 26, 1989; a basic law for comprehensive environment protection.
15. **1989 Regulations on fishing license management,** aimed to protect and rationally utilize fishery resources, regulate fishing intensity, maintain production order and safeguard the legitimate rights and interests of fishing operators whilst promoting fishery development.
16. **1990 The Regulation for Controlling Marine Pollution by Inland Pollutants, People's Republic of China,** issued by the State Council on June 22, 1990; a detailed rule for the Marine Environment Protection Act.
17. **1990 The Regulation for Preventing Marine Pollution from Coastal Construction, People's Republic of China,** issued by the State Council on May 25, 1990; a detailed rule for the Marine Environment Protection Act.
18. **1990 The Regulation on Making and Clearing Fishing Port, People's Republic of China,** issued by the Ministry of Agriculture on Jan. 26, 1990; a detailed rule for the management of fishing vessels.
19. **1991 The Animal and Plant Import & Export Quarantine Act of People's Republic of China,** approved by the Standing Committee of National People's Congress on Oct. 31, 1991; a law preventing animal and plant disease and pest infection.
20. **1993 Regulations of the People's Republic of China for the implementation of wild aquatic animal protection,** Oct 1993; aimed at the management and conservation of wild aquatic animal resources.

Annex VI
Other laws and regulations

1. **1979 Regulations on the Protection and Breeding of Aquatic Resources,** made public in Feb 1979.
2. **1979 The Law on Environmental Protection of the People's Republic of China (trial implementation)** in Sep 1979.
3. **1983 Circular of the State Council on Strict Protection of Valued and Rare Wild Animals** in 1983.
4. **1984 Forest Law of the People's Republic of China,** passed by the Seventh Session of the standing Committee of the Sixth National People's Congress on Sep 20, 1984, with a view to protecting, nurturing and rationally utilizing the forest resources.
5. **1985 The Law on Grasslands of the People's Republic of China** in June 1985.
6. **1986 The Law on Land Management of the People's Republic of China** in June 1986.
7. **1987 The Check-list for the Protection of Key Wild Animals"** in 1987.
8. **1988 The Law on the Protection of Wild Animals of the People's Republic of China** issued in Nov 1988.
9. **1992 The Enforcement Regulations on the Protection of Terrestrial Wild Animals in the People's Republic of China** in Feb 1992.
10. **2003 Measures regarding the Grant of State-Owned Land Use Rights by means of Negotiation,** approved by Ministry of Land and Resource on Aug 1, 2003; provided for new minimum pricing standards with respect to granting land use rights through negotiation with relevant government departments.
11. **2004 The Port Law of the People's Republic of China,** issued by Standing Committee of the National People's Congress on Jan 1, 2004; establishes the regime for planning, construction, operation and supervision of China's sea and river ports.

Annex VII
Records of main economic freshwater species in the estuary areas of the East China Sea

Species	Species
Coilia mystus (Linnaeus)	*Hemibarbus longirostris* (Regan)
Coilia ectenes (Jordan et Seale)	*Belligobio nummifer* (Boulenger)
Salmo gairdneri (Richardson)	*Hemibarbus labeo* (Pallas)
Protosalanx hyalocranius (Abbott)	*Pseudorasbora parva* (Temminck et Schlegel)
Anguilla japonica (Temminck et Schlegel)	*Sarcocheilichthys sinensis* (Bleeker)
Elopichthys bambusa (Richardson)	*Pseudogobio vaillanti* (Sauvage)
Squaliobarbus curriculus (Richardson)	*Coreius heterodon* (Bleeker)
Aphyocypris chinensis (Günther)	*Abbottina rivularis* (Basilewsky)
Mylopharyngodon piceus (Richardson)	*Saurogobio dabryi* (Bleeker)
Ctenopharyngodon idellus (Cuvier et Valenciennes)	*Saurogobio dumerili* (Bleeker)
Plagiognathops microleps (Bleeker)	*Spinibarbus hollandi* (Oshima)
Xenocypris argentea (Günther)	*Acrossocheilus (Lissochilichthys) wenchowensis* (Wang)
Distoechodon tumirostris (Peters)	*Cyprinus carpio* (Linnaeus)
Pseudobrama simony (Bleeker)	*Carassius auratus* (Linnaeus)
Aristichthys nobilis (Bleeker)	*Misgurnus anguillicaudatus* (Cantor)
Hypophthalmichthys molitrix (Cuver et Valenciennes)	*Silurus asotus* Linnaeus
Rhodeus sinensis (Günther)	*Pelteobagrus fulvidraco* (Richardson)
Toxabramis swinhonis (Günther)	*Glyptothorax fukiensis* (Rendahl)
Hemiculter leucisculus (Basilewsky)	*Orysias latipes* (Temminck et Schlegel)
Culter erythropterus (Basilewsky)	*Mugil cephalus* (Linnaeus)
Pseudolaubuca sinensis (Bleeker)	*Liza hematocheila* (Temminck et Schlegel)
Megalobrama amblycephala (Yih)	*Monopterus albus* (Zuiew)
Megalobrama terminalis (Richardson)	*Siniperca chuatsi* (Basilewsky)
Sinibrama macrops (Günther)	*Siniperca undalata* (Fang et Chong)
Erythroculter ilishaeformis (Bleeker)	*Odontobutis obscura* (Temminck et Schlegel)
Erythroculter mongolicus (Basilewsky)	*Ctenogobius giurinus* (Rutter)
Parabramis pekinensis (Basilewsky)	*Boleophthalmus pectinirostris* (Linnaeus)
Hemibarbus maculatus (Bleeker)	*Channa argus* (Cantor)

Annex VIII
Records of main economic fishes in the East China Sea

Species	North of East China Sea		South of East China Sea		Taiwan Strait	Korea	Japan
	Pelagic sea	Offshore	Pelagic Sea	Offshore			
Raja kenojei (Müller et Helle, 1841)	√	√	√	√	√	√	√
Raja porosa (Günther, 1874)	√	√		√		√	√
Sardinella zunasi (Bleeker, 1854)	√		√		√		√
Sardinella lemuru (Bleeker, 1853)	√				√		√
Ilisha elongata (Bennett, 1830)	√		√		√	√	√
Coilia ectenes (Jordan et Seale, 1905)	√	√				√	√
Coilia mystus (Linnaeus, 1758)	√	√				√	√
Engraulis japonicus (Temminck et Schlegel, 1846)	√	√	√	√	√	√	√
Setipinna taty (Valenciennes, 1848)	√	√	√		√	√	√
Argentina semifasciata (Kishinouye, 1904)		√		√			√
Saurida elongata (Temminck et Schlegel, 1846)	√	√	√	√		√	√
Saurida undosquamis (Richardson, 1848)	√	√	√	√	√	√	√
Saurida wanieso (Shindo et Yamada, 1972)	√	√	√	√			
Synodus macrops (Tanaka, 1917)	√	√	√	√			√
Trachinocephalus myops (Bloch et Schneider, 1801)	√		√	√	√	√	√
Saurida sp.		√	√	√	√		√
Harpadon nehereus (Hamilton, 1822)	√	√	√	√	√	√	
Alloconger anagoides (Bleeker, 1864)	√	√	√	√	√		√
Anago anago (Temminck et Schlegel, 1846)	√	√	√	√	√		√
Conger myriaster (Brevoort, 1856)	√	√	√			√	√
Rhynchoconger ectenurus (Jordan et Richardson, 1909)	√	√	√	√			√
Rhynchocymba sivicola (Matsubara et Ochiai, 1951)	√	√	√	√			√
Muraenesox cinereus (Forskål, 1755)	√	√	√		√	√	√
Gymnothorax reticularis (Bloch, 1795)	√	√	√	√	√		√
Ariosoma shiroanago shiroanago (Asano, 1958)	√	√	√	√			√
Dysomma anguillare (Barnard, 1923)	√	√	√	√	√		√
Ophichthus apicalis (Bennett, 1830)	√	√	√	√	√		
Bregmaceros macclellandi (Thompson, 1940)	√	√	√	√	√		
Coelorhynchus multispinulosus (Katayama, 1942)	√	√	√	√			√
Neobythites sivicola (Jordan et Snyder, 1901)	√	√	√	√			√
Fistularia petimba (Lacépéde, 1803)	√	√	√	√	√	√	√
Sphyraena japonica (Cuvier et Valenciennes, 1829)	√	√	√	√	√	√	√
Sphyraena pinguis (Günther, 1874)	√	√	√	√	√	√	√
Eleutheronema tetradactylum (Shaw, 1804)	√	√			√	√	√
Doederleinia berycoides (Hilgendorf, 1878)	√	√		√		√	√
Synagrops japonicus (Steindachner et Döderlein, 1884)	√	√	√	√	√		
Cookeolus boops (Cuvier, 1829)	√	√	√	√			√
Priacanthus macracanthus (Cuvier et Valenciennes, 1829)	√	√	√	√	√	√	√

Acropoma japonicum (Günther, 1859)	√	√	√	√	√	√	√
Apogon lineatus (Temmick et Schleger, 1842)	√	√	√	√	√	√	√
Branchiostegus japonicus (Houttuyn, 1782)		√	√	√		√	√
Caranx equula (Temminck et Schlegel, 1842)		√	√	√	√	√	√
Decapterus maruaelsi (Temminck et Schlegel, 1842)	√	√	√	√	√	√	√
Selar crumenophthalmus (Bloch, 1793)	√	√	√	√	√	√	√
Trachurus japonicus (Temminck et Schlegel, 1842)	√	√	√	√	√	√	√
Seriola aureovittata (Temminck et Schlegel, 1845)		√		√			√
Argyrosomus argentatus (Houttuyn, 1782)	√	√	√	√	√	√	√
Nibea albiflora (Richardson, 1846)	√	√	√			√	√
Collichthys lucidus (Richardson, 1844)	√	√				√	√
Collichthys niveatus (Jordan et Starks, 1906)	√	√				√	
Miichthys miiuy (Basilewsky, 1855)	√	√	√			√	
Larimichthys crocea (Richardson, 1846)	√		√		√	√	
Larimichthys polactis (Bleeker, 1877)	√	√	√		√	√	
Pagrosomus major (Temminck et Schlegel, 1843)		√		√	√	√	√
Evynnis cardinals (Lacépède, 1802)	√		√		√		√
Sparus macrocephalus (Basilewsky, 1855)	√					√	√
Dentex tumifrons (Temminck et Schlegel, 1842)		√	√	√		√	√
Banjos banjos (Richardson, 1846)		√	√	√			√
Hapalogenys mucronatus (Eydoux et Souleyet, 1841)	√	√	√		√	√	√
Upeneus bensasi (Temminck et Schlegel, 1842)	√	√	√	√	√	√	√
Parapercis sexfasciata (Temminck et Schlegel, 1843)	√	√	√	√	√		√
Gnathagnus elongatus (Temminck et Schlegel, 1846)	√	√		√		√	√
Uranoscopus japonicus (Houttuyn, 1782)	√	√	√	√			√
Champsodon capensis (Regan, 1908)	√	√	√	√	√		√
Callionymus beniteguri (Jordan et Snyder, 1900)	√	√		√			√
Callionymus kaianus (Günther, 1880)	√	√	√	√	√		√
Callionymus virgis (Jordan et Fowler, 1903)	√	√	√	√	√		√
Calliurichthys doryssus (Jordan et Fowler, 1903)		√	√	√		√	√
Callionymus richardsoni (Bleeker, 1854)		√	√	√			√
*Trichiurus lepturus (*Linnaeus, 1758)	√	√	√	√	√	√	√
Scomber japonicus (Houttuyn, 1782)	√	√	√	√	√	√	√
Scomberomorus niphonius (Cuvier, 1831)	√	√	√	√	√	√	√
Sarda orientalis (Temminck et Schlegel, 1844)	√		√	√			√
Pampus argenteus (Euphrasen, 1788)	√	√	√	√	√	√	√
Pampus cinereus (Bloch, 1793)	√	√	√	√	√		√
Psenopsis anomala (Temminck et Schlegel, 1844)	√	√	√	√	√		√
Cubiceps squamiceps (Lioyd, 1909)		√		√			√
*Amblychaeturichthys hexanema (*Bleeker, 1853)	√	√	√			√	√
*Chaeturichthys stigmatias (*Richardson, 1844)	√	√	√	√			√
Odontamblyopus rubicundus (Hamilton, 1822)	√	√					√

Ctenotrypauchen chinensis (Steindachner, 1867)	√	√					
Sebastiscus marmoratus (Cuiver et Valenciennes, 1829)	√	√	√	√		√	√
Scorpaena neglecta (Temminck et Schlegel, 1848)	√	√	√	√		√	√
Minous monodactylus (Bloch et Schneider, 1801)	√	√	√	√		√	√
Chelidonichthys spinosus (McClelland, 1844)	√	√		√		√	√
Lepidotrigla abyssalis (Jordan et Starks, 1902)		√	√	√			√
Lepidotrigla alata (Houttuyn, 1782)	√	√	√	√	√	√	√
Lepidotrigla guentheri (Hilgendorf, 1879)	√	√	√	√		√	√
Lepidotrigla japonica (Bleeker, 1857)	√	√	√	√		√	√
Lepidotrigla kishinouyei (Snyder, 1911)	√	√	√	√			√
Lepidotrigla micropterus (Günther, 1873)	√	√	√	√		√	√
Pterygotrigla hemisticta (Temminck et Schlegel, 1850)		√	√	√			√
Erisphex pottii (Steindachner, 1897)	√	√	√	√			√
Bembras japonicus (Cuiver et Valenciennes, 1829)		√	√	√		√	√
Onigocia spinosus (Temminck et Schlegel, 1843)	√	√	√	√		√	√
Platycephalus indicus (Linnaeus, 1758)	√	√		√		√	√
Pseudorhombus arsius (Hamilton, 1822)	√	√		√			√
Pseudorhombus pentophthalmus (Günther, 1862)	√	√	√	√		√	√
Pseudorhombus quinquocellatus (Weber et de Beaufert, 1929)	√	√	√	√			
Arnoglossus tenuis (Günther, 1880)	√	√	√	√			√
Arnoglossus yamanakai (Fukui, Yamada and Ozawa, 1988)	√	√	√	√			√
Pleuronichthys cornutus (Temminck et Schlegel, 1846)	√	√	√	√	√	√	√
Cynoglossus abbreviatus (Gray, 1832)	√	√		√			
Cynoglossus Kopsii (Bleeker,1851)			√	√			
Cynoglossus gracilis (Günther, 1873)	√	√	√			√	
Cynoglossus interruptus (Günther, 1879)	√	√	√			√	√
Cynoglossus oligolepis (Bleeker, 1854)	√	√	√				
Triacanthodes anomalus (Temminck et Schlegel, 1847)		√	√	√			√
Aluterus monoceros (Linnaeus, 1758)	√	√				√	√
Thamnaconus septemtrionalis (Günther, 1874)	√	√	√	√		√	√
Thamnaconus hypargyreus (Cope,1871)	√	√	√	√	√		√
Takifugu xanthopterus (Temminck et Schlegel, 1847)	√	√	√			√	√
Lophiomus setigerus (Vahl, 1797)	√	√	√	√		√	√
Lophius litulon (Jordan, 1902)	√	√	√	√	√	√	√
Malthopsis luteus (Alcock, 1891)		√	√	√			

Annex IX
Environmental quality standards for surface water

National Standards of the People's Republic of China (GHZB1-1999)

This standard is applicable to the surface water bodies of rivers, lakes and reservoirs within the territory of the People's Republic of China.

The water bodies are divided into five classes according to the utilization purposes and protection objectives:

- Class I is mainly applicable to the water from sources, and the national nature reserves.
- Class II is mainly applicable to first class of protected areas for centralized sources of drinking water, the protected areas for rare fishes, and the spawning fields of fishes and shrimps.
- Class III is mainly applicable to second class of protected areas for centralized sources of drinking water, protected areas for the common fishes and swimming areas.
- Class IV is mainly applicable to the water areas for industrial use and entertainment which is not directly touched by human bodies.
- Class V is mainly applicable to the water bodies for agricultural use and landscape requirement.
- The water bodies with various functions are classified based on the highest function.

The Global International Waters Assessment

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

The need for a global international waters assessment

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

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

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

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

International call for action

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

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

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

The Global Environment Facility (GEF)

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

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

United Nations Environment Programme (UNEP)

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

UNEP work encompasses:

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

University of Kalmar

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

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

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

The conceptual framework and objectives

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

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

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

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

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

International waters and transboundary issues

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

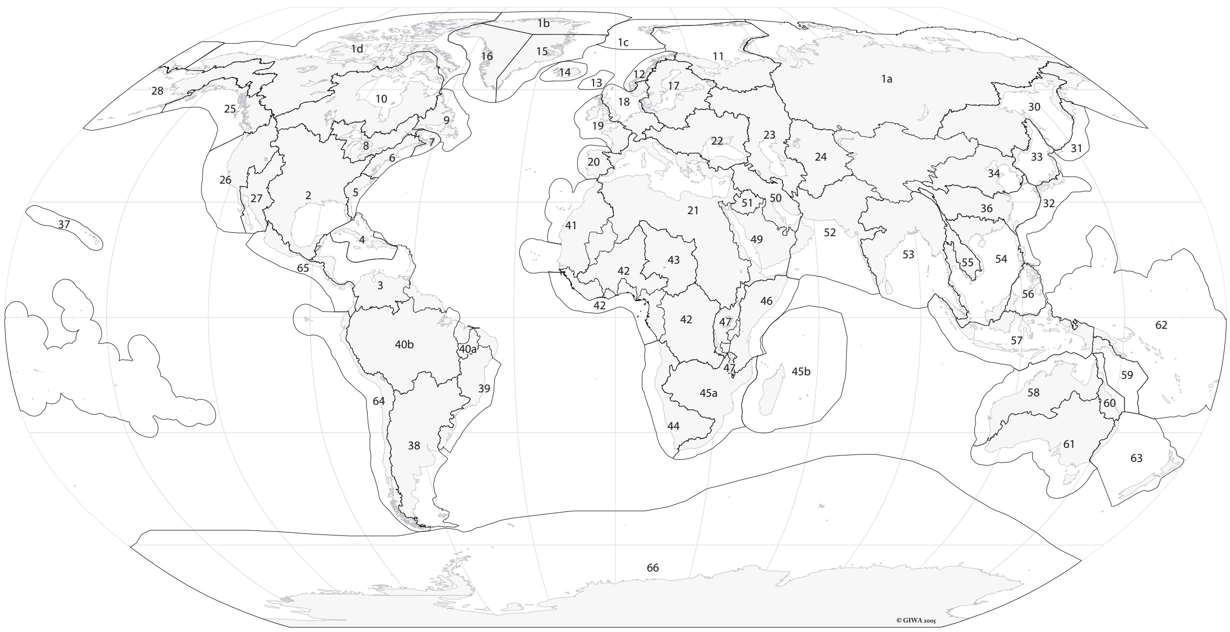
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and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

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

The organisational structure and implementation of the GIWA

The scale of the assessment

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



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

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

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

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

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

Large Marine Ecocsystems (LMEs)

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

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

The global network

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

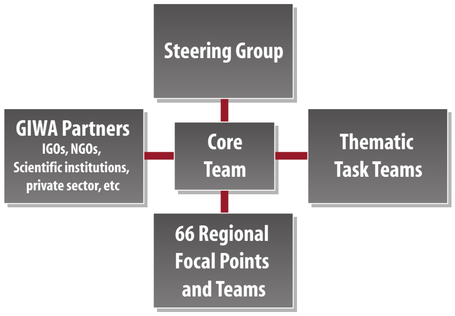


Figure 2 The organisation of the GIWA project.

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

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

GIWA Regional reports

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

UNEP Water Policy and Strategy

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

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

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

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

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

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

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

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

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The GIWA methodology

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

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

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

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

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

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

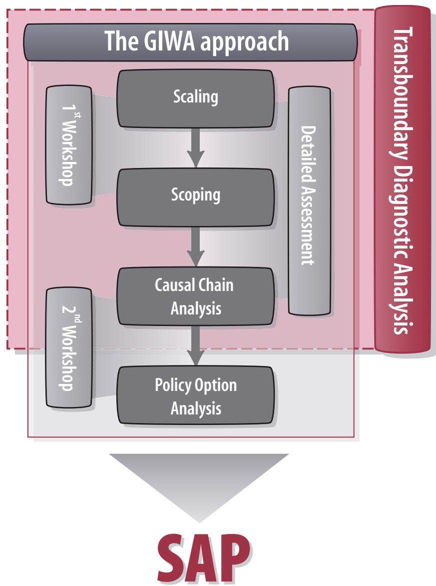

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

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

Scaling – Defining the geographic extent of the region

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

Scoping – Assessing the GIWA concerns

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

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

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

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

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

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

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

Table 2 Example of environmental impact assessment of Freshwater shortage.

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

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

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

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

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

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

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

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

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

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

Causal chain analysis

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

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

Conceptual model

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

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

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

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

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

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

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

Policy option analysis

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

Construct policy options

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

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

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

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

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

Global International Waters Assessment

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

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

Table 5b: Scoring criteria for environmental impacts of Pollution

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

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

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

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

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

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

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

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

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

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

Broad Transboundary Approach

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

Regional Assessment – Global Perspective

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

Global Comparability

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

Integration of Information and Ecosystems

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

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

Priorities, Root Causes and Options for the Future

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

This Report

This report presents the results of the GIWA assessment of the East China Sea region, which is one of the largest marginal seas in the world. This region receives tremendous inflow of freshwater and terrestrial sediments, predominantly from China's mainland. The region is characterised by a large population and rapid economic development. The natural landscape in the region's drainage basins has been greatly modified by the development and expansion of agriculture, the construction of dams as well as urbanisation. Aquaculture and coastal area reclamation alter natural wetlands and destroy spawning and nursery grounds in the East China Sea. Overexploitation of fish, eutrophication and habitat modification are of particular concern in the region. The past and present status and future prospects are discussed, and the transboundary issues are traced back to their root causes. Policy options have been recommended that aim to address these driving issues in order to significantly improve environmental quality and secure the region´s future prosperity.

UNEP

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