

Causal chain analysis

YELLOW SEA

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

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

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

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

Habitat and community modification and freshwater shortage

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

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

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

Environmental impacts

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

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

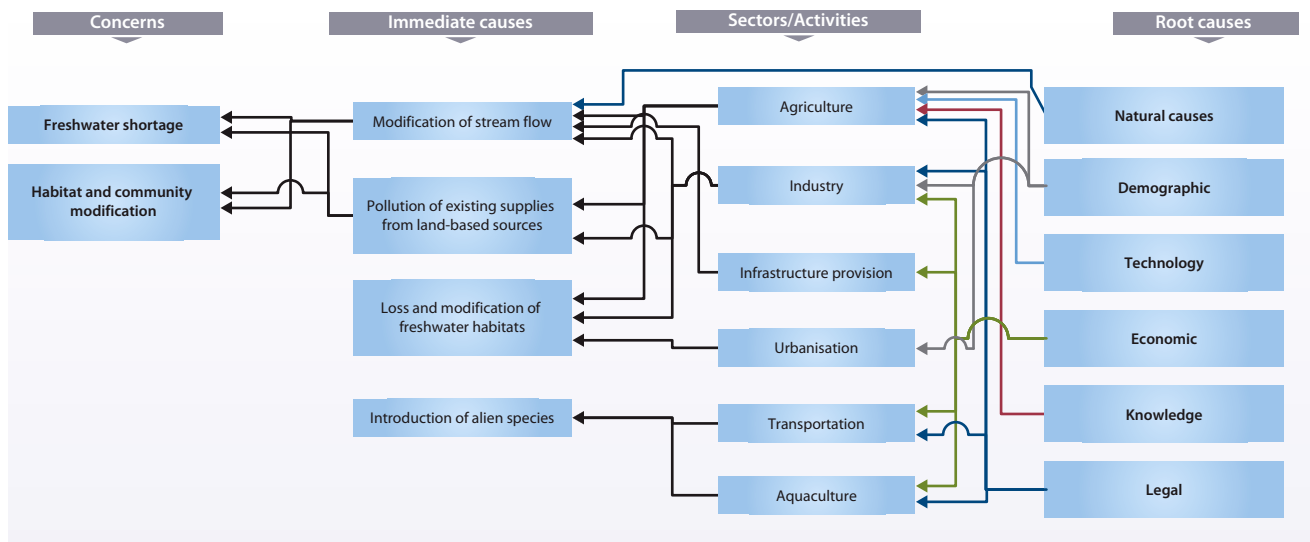


Figure 11 Causal chain diagram illustrating the causal links for habitat and community modification and freshwater shortage in the Yellow Sea region.

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

- More than 10% of the Huai River Basin on the Chinese side of the region has been polluted, causing habitat deterioration and an inability to support fish.
- Fish kills in many drainage basins of more than 25 000 km² have often been reported on the Chinese side of the region, e.g. Huai River, which is the most affected. Fish kills frequently also occur in rivers on the Korean side of the region during summer.
- More than 30% of the total area of freshwater marshlands, lakes, rivers, lagoons and muddy foreshores and 10% of rice fields have been lost over the past 30 years.
- More than 40% of the total area of sandy foreshores have been lost over the past 30 years.
- Significant losses of seagrass beds, e.g. *Zostera marina* has occurred in the Korean side of the region.
- Biodiversity and ecological functions of the neritic systems have been seriously modified.
- Volume and biodiversity of lakes and rivers have changed significantly.
- Muddy shores have been greatly modified with increased number and species of opportunistic organisms.
- Species population structure in estuaries has been greatly modified with increased dominance of red tide organisms.
- There has been obvious replacement of endemic with alien species such as the salt hay (*Spartina marina*) and biodiversity modification through disease introduction, for example disease caused by *Perkinsus* sp. in clams.

Immediate causes

Modification of stream flow

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

Pollution of existing supplies from land-based sources

The region suffers from pollution through waste discharges high in nutrients, trace metals and organics from land-based point and non-point sources that alters the overall biodiversity of the ecosystems. More than 10% of the Chinese part of the Huai River Basin is polluted, mainly by discharges from various chemical and paper pulp factories

located along the River. The number of factories in the Huai River Basin has increased from 365 in 1996 to 1 320 in 2002 (Wang et al 2003). Along the west coast of the Korean Peninsula, mass fish kills involving the death of thousands of fish each time have occurred in river basins more than twice each summer due to oxygen depletion, mainly as a result of industrial discharges and agricultural run-off (US-AEP 2003, MOE 2003).

Modification and loss of freshwater habitats

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

Introduction of alien species

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

Sectors

Agriculture

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

Industry

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

Infrastructure provision

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

Urbanisation

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

Transportation

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

Aquaculture

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

Root causes

Demographic

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

Technology

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

Economic

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

Knowledge

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

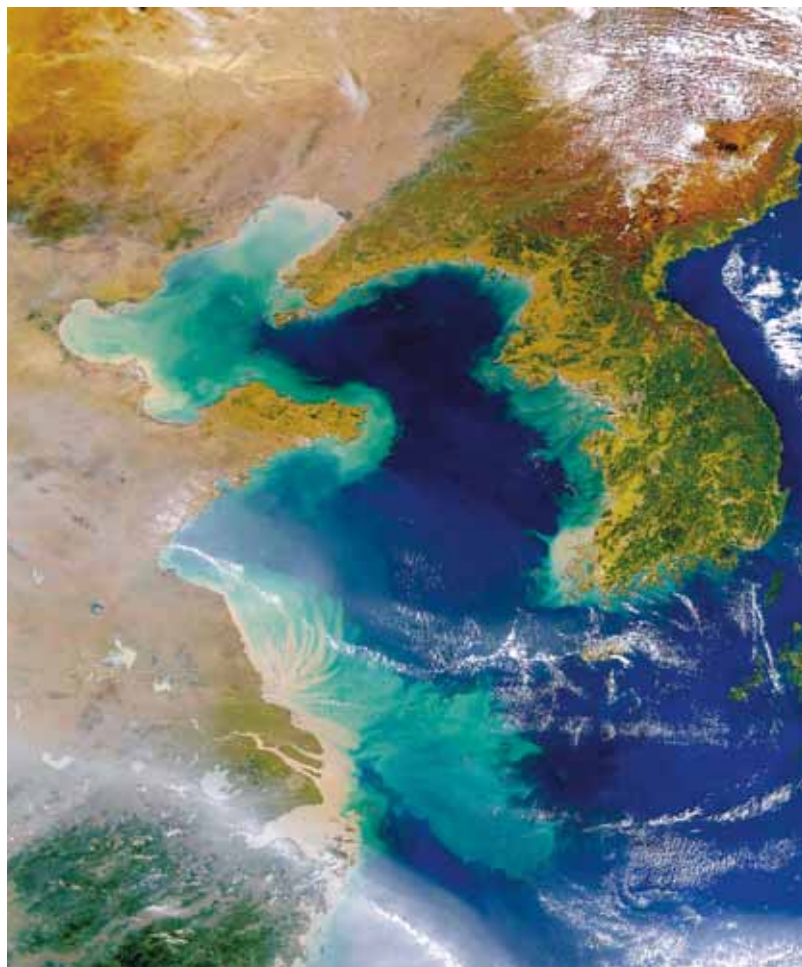


Figure 12 The Yellow Sea.

(Photo: NASA)

environmental impacts, which results in an excessive use of fertilisers and pesticides to enhance crop production.

Legal

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

Natural causes

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

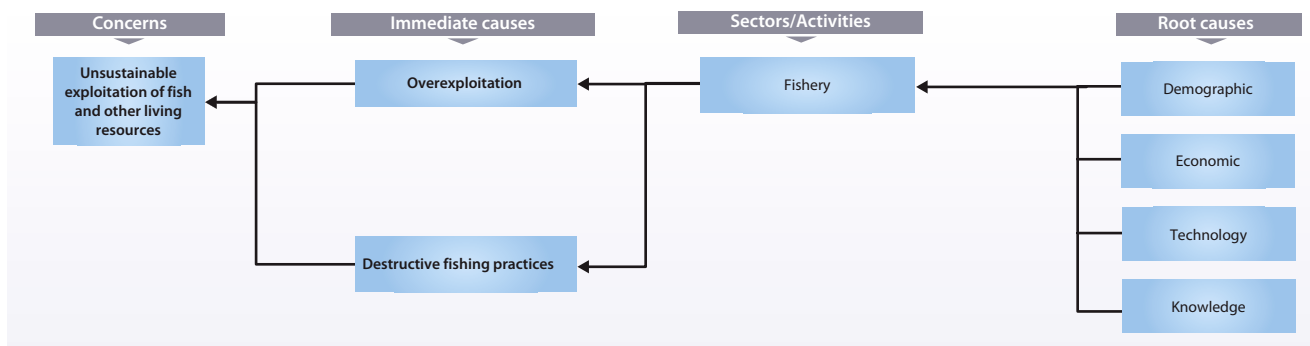


Figure 13 Causal chain diagram illustrating the causal links for unsustainable exploitation of living resources in the Yellow Sea region.

Unsustainable exploitation of fish and other living resources

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

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

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

Environmental and socio-economic impacts

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

- Fisheries resources have been highly overexploited, exceeding their maximum sustainable yields (MSYs);

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

Immediate causes

Overexploitation

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

Destructive fishing practices

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

Root causes

Demographic

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

Economic

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

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

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

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

Technology

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

Knowledge

The lack of public awareness of the consequences of destructive

fishing practices has led to uncontrolled use of such destructive fishing techniques.

Conclusions

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