

Causal chain analysis

BOHAI SEA

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

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

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

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

Habitat and community modification and freshwater shortage

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

Environmental and socio-economic impacts

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

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

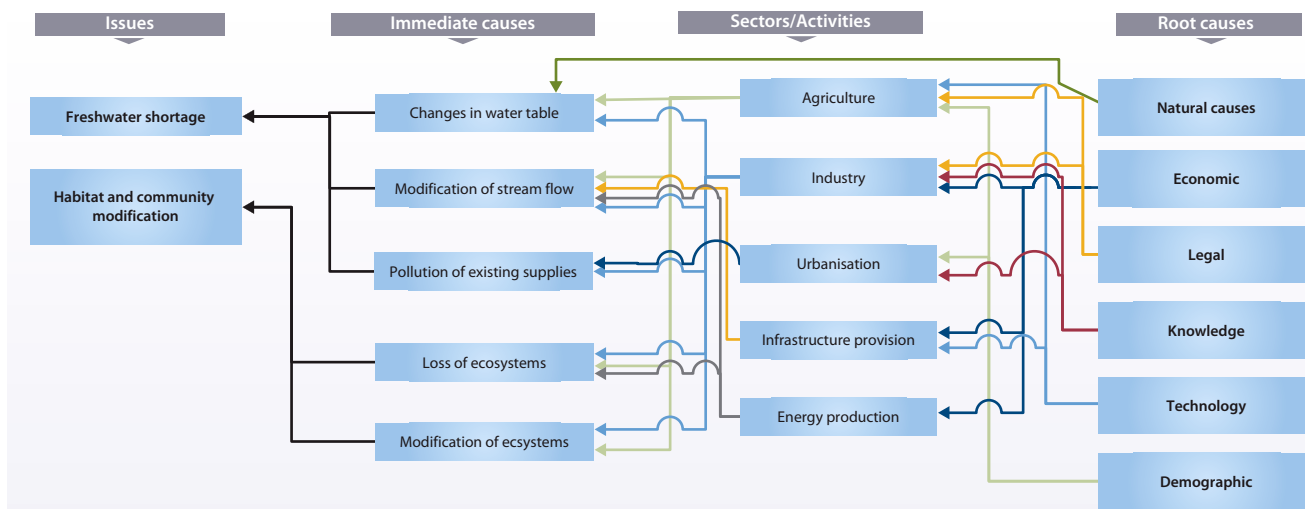


Figure 7 Causal chain diagram illustrating the causal links for habitat and community modification and freshwater shortage in the Bohai Sea region.

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

Immediate causes

Modification of stream flow

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

Pollution of existing supplies

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

Changes in the water table

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

Loss of ecosystems

Land use conversion such as the change of wetlands into rice fields has resulted in the loss of freshwater habitats in the region. The decreased input of freshwater due to seasonal drying up of major river systems in

the region and diversion of river waters for agricultural and industrial uses, have also led to the losses of some freshwater ecosystems. Increased development of oil fields in the Bohai Bay has resulted in the loss of coastal habitats around in the Bay.

Modification of ecosystems

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

Sectors

Agriculture

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

Industry

In the region, changes in industrial activities and increased human settlements following industrial development over the past decades

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

Infrastructure provision

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

Energy production

Building of dams and dikes upstream in the river systems, has also been intended to establish the hydroelectric plants in addition to flood

control, which has led to substantial modification of stream flows in the region in the past decades. The energy production in the oil industry has increased the exploration and production of petroleum and natural gas in the region that has caused loss of ecosystems or habitats.

Urbanisation

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

Root causes

Demographic

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



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

Technology

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

Legal

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

Economic

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

Knowledge

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

Natural causes

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

Unsustainable exploitation of living resources

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

Environmental and socio-economic impacts

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

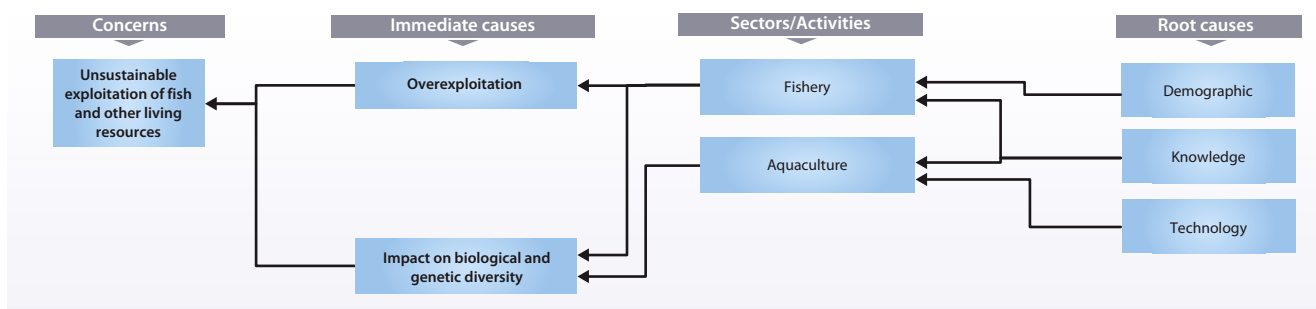


Figure 9 Causal chain diagram illustrating the causal links for unsustainable exploitation of living resources in the Bohai Sea region.

Immediate causes

Overexploitation

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

Impact on biological and genetic diversity

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

Sectors

Fishery

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

Aquaculture

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

Root causes

Demographic

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

Knowledge

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

Technology

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

Conclusions

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

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

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