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, please refer to the chapter describing the GIWA methodology.

Introduction

Habitat and community modification was ranked as the concern of highest priority for the Caspian Sea. As a consequence, the causal chain analysis will focus on immediate causes, sector activities and root causes contributing to the severity of impacts caused by this concern. The spatial scale of the analysis is the region under assessment i.e. the Caspian Sea and its coastal zone. Eight immediate causes were identified for this geographical area; pollution, poaching, invasive species, regulation of stream flow, deforestation, coastal erosion/ dredging, land use and eutrophication.

Methodology

The methodology describes the process of selecting the most important immediate causes of Habitat and community modification in the Caspian Sea. Eight immediate causes are described in short in order to provide a background to the prioritisation. By estimating the current situation and the trends for the next 10 years, 12 experts from the five littoral states ranked the immediate causes on a scale from 0-100. The individual ranking by the experts acknowledged that each Caspian country had its own priority regarding the relative importance of each of the different immediate causes. However, there was a general consensus that the negative impacts of most immediate causes are likely to accelerate in the future.

The scores indicate the degree of severity of each immediate cause and were ranked by the experts during the second regional workshop in Baku (Annex III). The first figure presented for each immediate cause refers only to the Caspian Sea and the second to the surrounding freshwater basins.

Pollution 70/75

Pollution exerts negative impacts on habitats both in the freshwater basins and in the brackish Caspian Sea. Pollution has led to changes in benthic and pelagic habitats, water chemistry and sediment composition. The main sources of pollution are oil spills, industry, agriculture and urban wastewaters. The two main hotspots for oil pollution are the marine areas around Baku and Apsheron Peninsula on the west coast and along the Caspian east coast. The situation has been aggravated by sea level rise that has inundated old oil wells. Industrial pollution is considerable but has decreased during the last 10 years due to the economic situation in the region. River inflow is the main source of industrial pollution contributing 80% of the total load. One of the most heavily polluted rivers is the Terek, which exhibits

high concentrations of mercury, lead and chromium. Agrakhana Bay in the mouth of the Terek was previously one of the richest waters in the Caspian Sea with high numbers of shads. Now, it is practically dead, containing essentially nothing but microorganisms. Agricultural activities are the third major source of pollution and are prominent in the Ural, Volga and Kura river basins and in many small rivers on the southern coast. The highest concentrations of pesticides are found in sediments along the Iranian coast.

Poaching 75/70

Poaching has a significant impact on fish populations in both the Caspian Sea and the associated river basins. Changes in population structure and relative abundance of predatory fish have caused changes in the trophic web and subsequently altered the pelagic habitat. Poaching of sturgeon has forced the fishing sector to rely on large-scale releases of hatched juveniles. Fishing has contributed to the current situation which is characterised by general declines in abundance. Both fishing and restocking activities have contributed to changes in species composition from Great (or Beluga) sturgeon (*Huso huso*) and Russian sturgeon (*Acipenser gueldenstaedti*) to Persian sturgeon (*Acipenser persicus).*

Introduction of invasive species 80/25

There have been substantial intentional introductions of fish species in rivers, deltas, artificial reservoirs and in the Sea. Most of these introduced species have remained at naturally low numbers. Accidental introductions of invertebrates and algae have, on the other hand, caused more concern. The latest newcomer, the planktivorous comb-jellyfish, *Mnemiopsis leidyi*, has caused a sharp decline in the abundance of zooplankton in areas where it is found in high densities. This has, in turn, implications for other planktivores such as the economically valuable sprat fishes. The main route of entry for invasive species is the Volga-Don Canal, in ballast water or as fouling organisms.

Regulation of stream flow 55/95

All major Caspian rivers have been dammed, generally for energy production. On the Volga River more than 10 dams have been constructed. As a result, plankton, benthos and fish communities in both rivers and the Caspian have changed. In building the dams, large terrestrial areas have been inundated causing loss of riparian vegetation and river habitats. The primary production of the Caspian Sea has increased as a consequence of changed patterns of river discharge and increased organic loads. The changed conditions have caused environmental stress and made it easier for alien species to establish themselves. The dams have also blocked migration routes and destroyed spawning grounds for anadromous fish.

Deforestation 20/20

Deforestation is a cause of concern only in the southern Caspian region since large stretches of coast are historically devoid of woods in the eastern and northern parts. Deforestation occurs in the Lenkoran region in Azerbaijan and on the Caspian coast of Iran. Deforestation has led to changes in stream flow and increased erosion and turbidity.

Coastal erosion and dredging 30/35

The keeping and transport of livestock have caused coastal erosion in the northern part of the Caspian region, particularly in Kazakhstan and Kalmykia. Pasture is common here, but numbers of grazing animals are low due to freshwater shortage. The lack of proper roads enhances the erosion. Many local people drive on the open terrain causing harm to the already sparse vegetation. In order to facilitate navigation, the Volga and Ural river deltas have been subject to dredging. Dredging has aided the upstream migration of fish but the increased turbidity disturbs other organisms.

Land use 15/35

Land use related activities are of most relevance in Iran and less so in the other littoral countries. The major activity in Iran is agriculture, which occupies half of the territory, while industry occupies one third and human settlements one quarter. The current land use practices have eradicated most natural habitats. In the other littoral countries, there is currently low industrial and agricultural development, slow urbanisation and, as a result, land encroachment rates are low. However, there is a history of vast areas under direct use for agriculture, settlements and industry.

Eutrophication 20/40

Even though eutrophication is limited in the Caspian Sea, it is currently a problem in the big reservoirs in the Caspian drainage basin. Agricultural run-off, sewage, oil exploration and aquaculture are the main sources of nutrients and the Volga delta and the southern coast are the two locations most heavily impacted. However, it is justified to raise concerns regarding the future since there are many factors that are likely to lead to nutrient enrichment of Caspian waters.

Conclusion

The scores assigned to each immediate cause of Habitat and community modification in the Caspian Sea indicate that they have varying degrees of importance. According to the expert ranking, the three most significant immediate causes in the Caspian Sea are; invasive species, pollution and poaching. In the freshwater basin, modification of stream flow, pollution and poaching were prioritised. Together these four immediate causes were selected for further analysis (Table 14).

Table 14 Absolute and relative importance of each immediate cause contributing to Habitat and community modification in the Caspian Sea region.

Immediate cause	Caspian Sea		River basins	
Pollution	70	19%	75	20%
Poaching	70	19%	75	20%
Invasive species	80	23%	25	6%
Flow modification	55	15%	95	24%
Deforestation	20	6%	20	5%
Erosion/dredging	30	8%	35	8%
Land use	15	4%	35	9%
Eutrophication	20	6%	40	8%

Note: Absolute figures scored from 0-100. (Source: GIWA Task team 2003)

Root causes

Pollution

Pollution is one of the primary immediate causes of Habitat and community modification in the Caspian Sea. Pesticides are considered the most deleterious pollutants and "hot spots" can be found in the dense agricultural areas of river deltas and along the coast of Iran. Oil pollution is currently a localised problem but could become a significant threat in the future due to the expanding oil exploration activities in the region. The following paragraphs explore the main sector activities and root causes responsible for pollution in the coastal waters of the Caspian Sea and its freshwater deltas.

Agriculture

The generally high unemployment rates in the Caspian Economic Hinterland (CEH), as well as the population growth in the coastal provinces of Azerbaijan, Iran and Turkmenistan, have resulted in an increase in small-scale farming along the coastline of the Caspian Sea and in its freshwater deltas (Figure 10). Since most parts of the arable land in the region are already subject to agriculture, new farms have become dependent upon irrigation and pesticides to ensure adequate production. Pesticides are also used in the northern part of the region to shorten production cycles and to enable harvesting earlier in spring, when regional market prices for agricultural products are higher than during the rest of the year. While the use of harmful chemicals, such as DDT, was prohibited by the Soviet regime already in 1970, local authorities in the region currently fail to control both the market supply and consumption. Today, environmentally harmful pesticides are both cheap and readily available on local markets throughout the CEH, whereas modern and less damaging alternatives are relatively expensive and therefore seldom seen as an alternative among poor farmers. Public knowledge about the ecological consequences of pesticides is also generally low in the region.

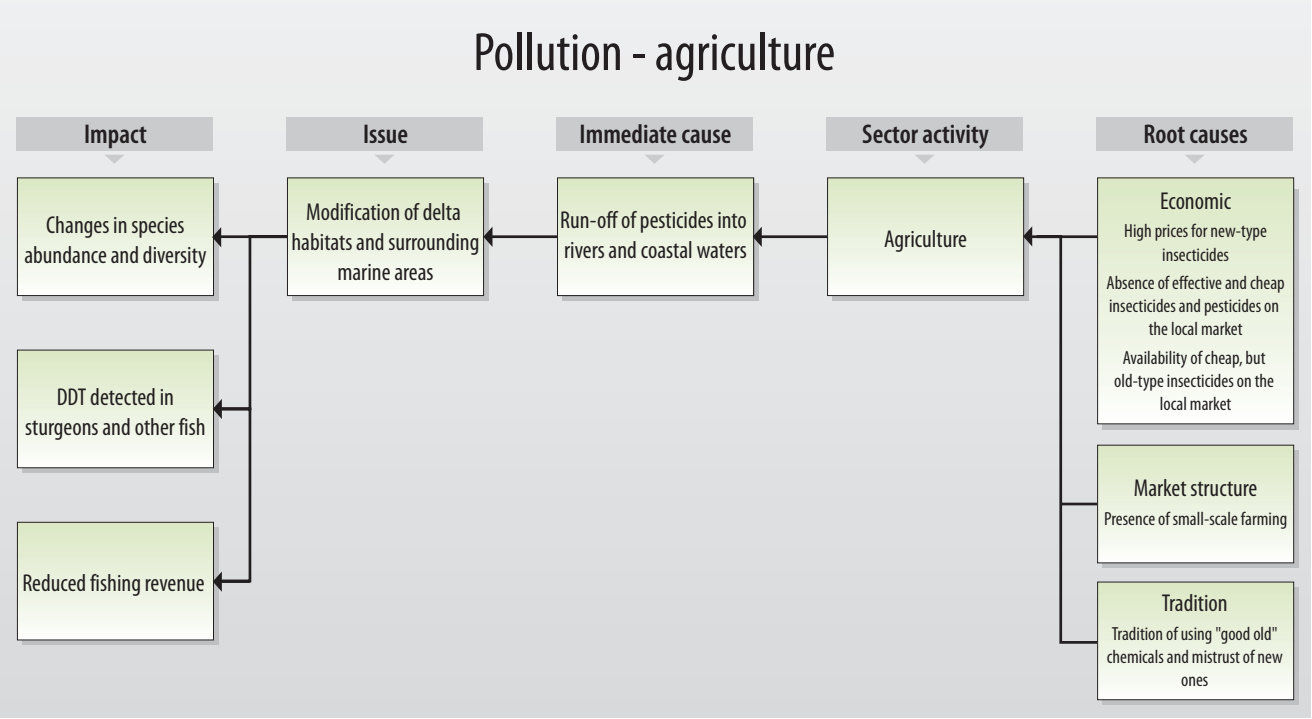

Figure 10 Causal chain diagram illustrating the causal links for agricultural pollution.

The frequent use of chemicals in small-scale agriculture has resulted in substantial run-off of these pollutants into the Caspian freshwater basins and the coastal waters. After the mass invasion of locusts (grasshoppers) in the Atyrau region in Kazakhstan in 1999, DDT concentrations in the delta increased significantly and traces of DDT could be found in tissues of many gobies and sturgeons. As a result of this event, the number of gobies was drastically reduced in the Ural delta. Traces of pesticides have also been found in coastal sediments, particularly along the Iranian coastline (Watanabe et al. 1999). The highly mechanised agriculture and abundant use of pesticides and fertilisers in the coastal provinces of Iran have resulted in a considerable run-off into rivers and coastal waters (CEP 2002c).

While farmlands constitute the major source for chemical run-off, regular spring flooding of chemical stores also contribute to water pollution. Since small-scale farmers in the region seldom protect their stores from flooding, chemicals have on several occasions been dissolved and discharged into rivers. While these events are not officially recorded by any of the Caspian authorities, expert data suggest that they are not uncommon in the region. Two particularly severe events occurred in the Ural River during spring 2000 and 2001, resulting in a considerable amount of dead sturgeons, carps and zanders.

Industry

Industrial discharges contribute substantially to the pollution in the Caspian Sea (Figure 11). Even though purification technology is readily available, most old industries in the CEH have so far lacked the necessary financial resources to introduce wastewater treatment systems, and effluents are therefore often directly discharged into the Caspian Sea. The four former Soviet states still use environmental quality standards developed during Soviet times to control water pollution. These build on standards for maximum allowable discharges of pollutants from point sources and maximum allowable concentrations of pollutants in water bodies (CEP 2001). While the sufficiency of these standards is debated, it is clear that the level of compliance and enforcement is inadequate in most of the Caspian states. This problem is directly linked to the economic difficulties in the region as well as the limited resources given to local authorities. In the Atyrau district for instance, the Department of Environmental Control only has three officers and five inspectors with authority to control and sample water pollution. These officials do not have access to modern equipment and must perform their analyses in old and inefficient laboratories.

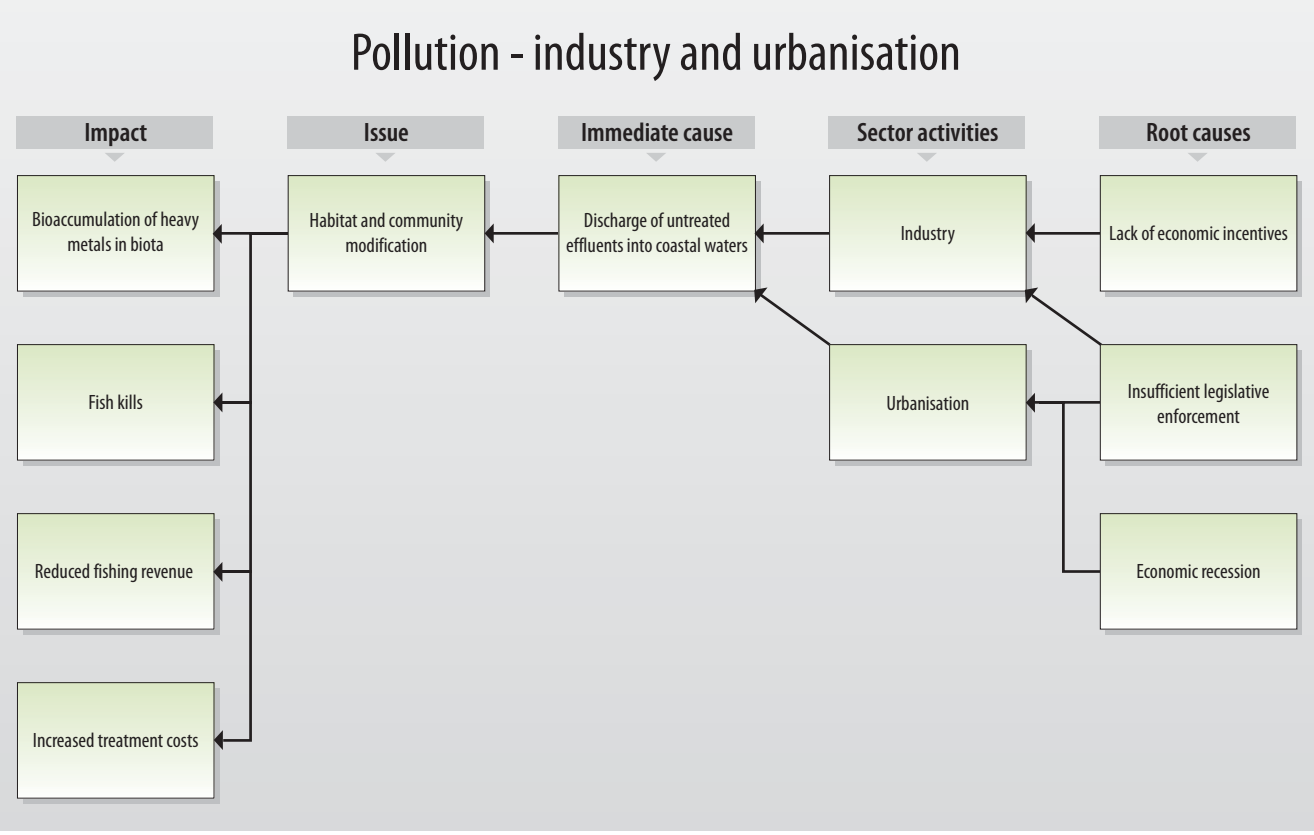

Figure 11 Causal chain diagram illustrating the causal links for industry and urban pollution.

The failure to comply with existing legislation is also due to the lack of economic incentives to improve environmental performance. While most Caspian states have introduced economic penalties for industries that exceed their pollution limits, most enterprises today find it more economically viable to pay the fines than to treat their wastewater. Since many industries in the region have closed down in recent years, the level of discharges into the Caspian Sea has automatically dropped. Therefore, industrial pollution is not currently the main cause of habitat modification in the Caspian Sea, except in some areas with high industrial activity and poor wastewater treatment systems such as in the Terek Delta.

Urbanisation

The causes of urban water pollution are similar to those of industrial discharges. Most of the urban areas around the Caspian Sea rely on old Soviet wastewater treatment systems that are not adjusted to the modern levels of water consumption and therefore are in desperate need of reconstruction. In Sumgait city in Azerbaijan, for instance, the entire wastewater system has collapsed and effluents are discharged into the Sea without any purification. Since the reconstruction requires large investments, the city has been unable to comply with the urban pollution limits enacted by the government. In other cities around the Caspian Sea, the situation is not quite as acute, but the high urbanisation rates in the CEH have lead to increased volumes of wastewater in most cities and old wastewater treatment systems are hence put under pressure.

Oil industry

To date, the Caspian Sea has not experienced any large-scale oil spill, but the increasing regional oil extraction and transport is a matter of great concern (Figure 12). Many parts of the Caspian Sea are so far unaffected by oil pollution. This is true for the northern, mid- and southeastern parts of the Caspian Sea as well as for the Iranian coastline. However, around the Apsheron Peninsula in Azerbaijan, oil pollution is an acute problem and the primary immediate cause of habitat and community modification. The waters outside Turkmenbashi and Cheleken in Turkmenistan and Ataraya in Kazakhstan are also severely affected by oil pollution (CEP 2002c).

While it is difficult to control accidental spills, improved technologies and trained staff could reduce the risks of future large-scale disasters and the sporadic smaller spills. Currently, there is a great need to modernise

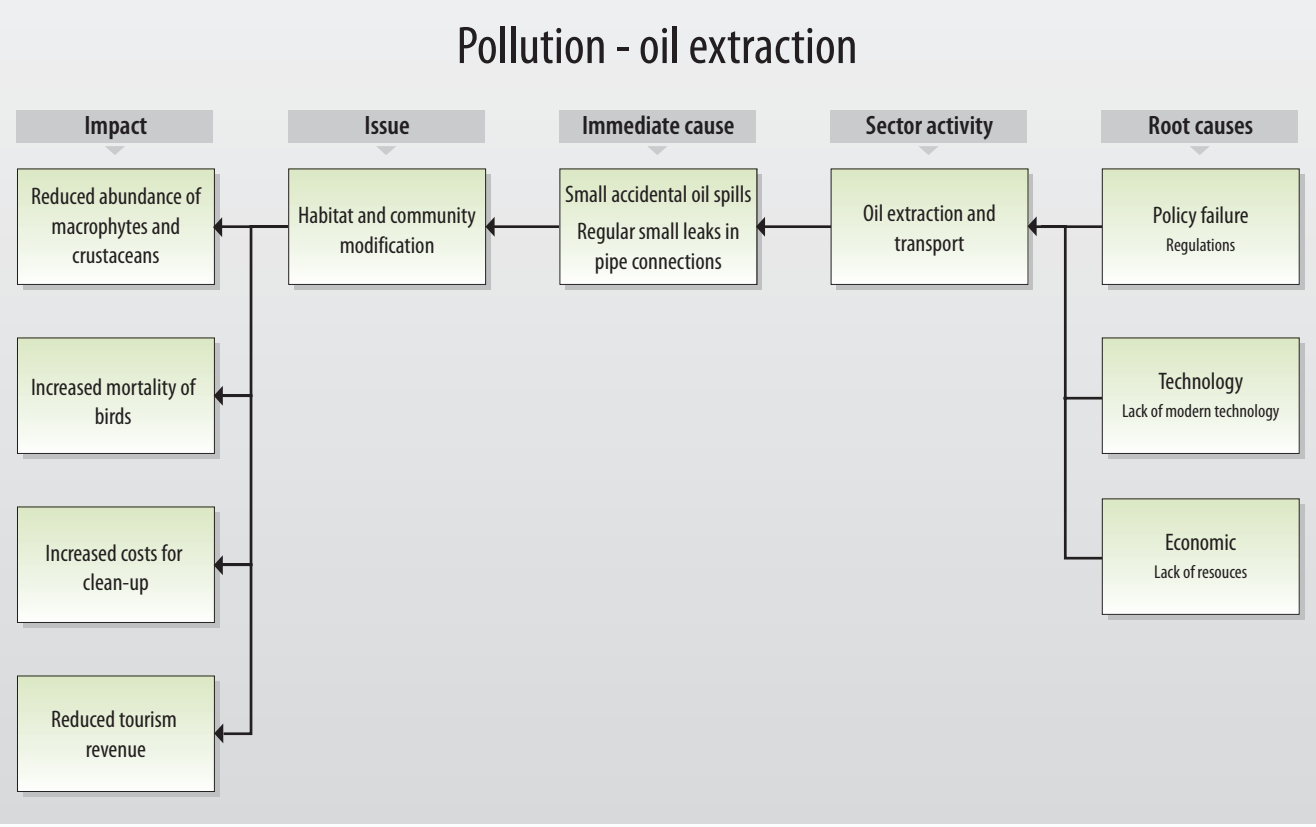

Figure 12 Causal chain diagram illustrating the causal links for oil extraction.

the technology and infrastructure used for the older and often leaking oil wells in the region. For instance, the numerous pipelines along the seabed outside Baku have been leaking since Soviet times. These ongoing small spills have similar impacts as other types of pollution, such as changes in the content of water and sediments, diseases and a decrease in the number of aquatic organisms ranging from micro-organisms to higher plants and animals. Even though they are local, small spills may also have transboundary impacts by affecting critical habitats (spawning, nursing and feeding grounds) of transboundary bioresources (sturgeon, shad, sprat and seals).

Since it is fairly easy to identify the source of smaller oil spills and leakages, oil pollution could be controlled by local or national authorities. However, in Azerbaijan, national oil companies were granted oil deposits by the former Soviet Union and do not have to comply with the pollution limits established by the "Law On Subsoils" from 1998 (CEP 2001). Also, international oil consortia are placed above national legislation and are instead subject to the restrictions established in their contract with the State Oil Company (CEP 2001). In Kazakhstan, it is practically only one international company - the consortium OKIOC - that has the right to develop oil deposits along the Kazakh coast. In 1993, the national government in Kazakhstan adopted a decree that allows the development of oil deposits within the Northern Protected Area. This is a reserve in the northern part of the Caspian Sea established with the purpose of protecting fish resources and creating optimum habitat conditions and natural spawning grounds for sturgeon and other valuable fish species. Also, the Russian government has adopted a decree that permits the oil company Lukoil to explore the Northern Protected Area. Even though the Kazakh decree requires that underground mineral resources users identify ecologically sensitive areas, conduct environmental impact assessments, forecast the ecological consequences of oil extraction and prepare an emergency plan, the compliance with these regulations is debated (CEP 2001).

Poaching and unsustainable harvest practices

Fish has always been a significant part of the diet of people living in the Caspian Economic Hinterland and fishing in the nearby river is an important part of the local lifestyle. The high unemployment rates in most Caspian states have increased the intensity of small-scale fishing for subsistence (Figure 13). Since the black market price for one sturgeon buys food for an entire family for one month, illegal fishing is also increasing in the region. However, the impact of small-scale poaching

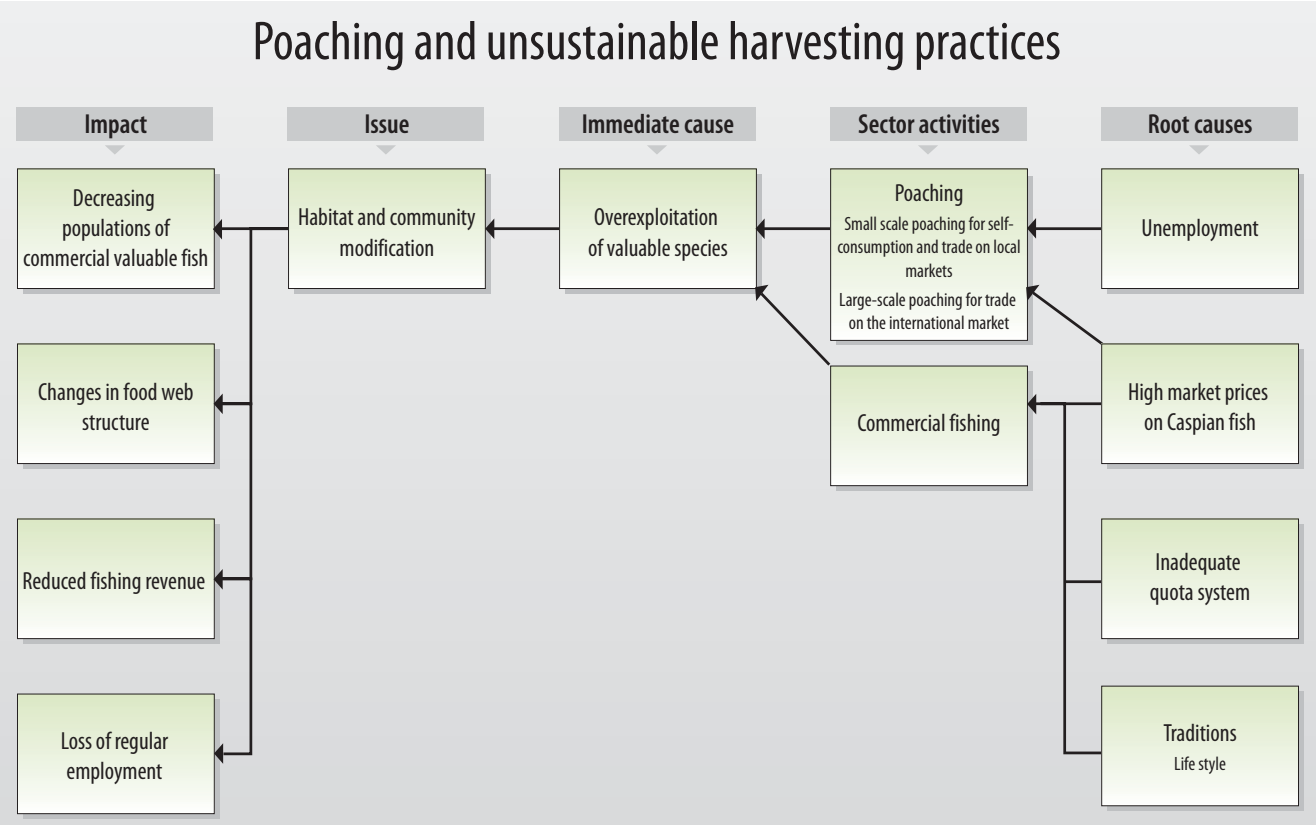

Figure 13 Causal chain diagram illustrating the causal links for poaching and unsustainable harvesting practices.

is limited compared to commercial fishing. The fishing industry is, at present, focused on the most valuable and easily accessible species in the Caspian Sea and ecosystem effects of harvesting are therefore highly disproportionate. Drastic decreases in one species, such as the Great sturgeon (Beluga), have altered the population structures and food web in the Caspian Sea. The negative impacts of commercial fishing are exacerbated by the ongoing "semi-governmental poaching". Since black caviar from the Great sturgeon costs more than 7 500 euro per kg on the international market, illegal organisations, in cooperation with some of the littoral governments, are currently selling unknown amounts of sturgeon abroad.

Fishing is primarily regulated at the national level in the Caspian region. Today, each of the five littoral states has introduced state permits or licences for fishing in specific aquatic areas, and the catches are generally regulated by national quotas (CEP 2001). The quotas in the four former Soviet States are established on the basis of advice provided by the regional Commission on Aquatic Bioresources, which was established in 1992. Each year, the Commission's scientific experts estimate the total fish stock in the Caspian Sea and, on the basis of their estimations, recommend quotas for catches in the coming year. While these scientific recommendations guide the political negotiations between the littoral states, the final allocation of national quotas is in the end a political process that does not always follow the Commission's advice.

The effectiveness of the current quota system is debated. First of all, the system is affected by an old Soviet tradition to exceed quotas. In Soviet times, regional fishing organisations were given quotas by the state as part of the annual organisational plan. If the organisations managed to catch more fish than planned, they were rewarded with a prize, and to exceed quotas was therefore highly beneficial. Today, the reward system is no longer in place, but the tradition survives in many parts of the Caspian region. However, national quotas have not been exceeded by more than 5-10% in recent years. More problematic is the large scientific uncertainty surrounding the ecological processes in the Caspian Sea and the limited appreciation of maximum sustainable yields. The regional scientific expertise is currently underfunded and has, to date, not had the financial or technical resources to conduct a thorough assessment of the living resources in the Caspian Sea. Regional scientists are also exposed to pressure from the littoral governments and the regional fishing industry to adjust the scientific recommendations according to political and economic factors rather than ecological realities.

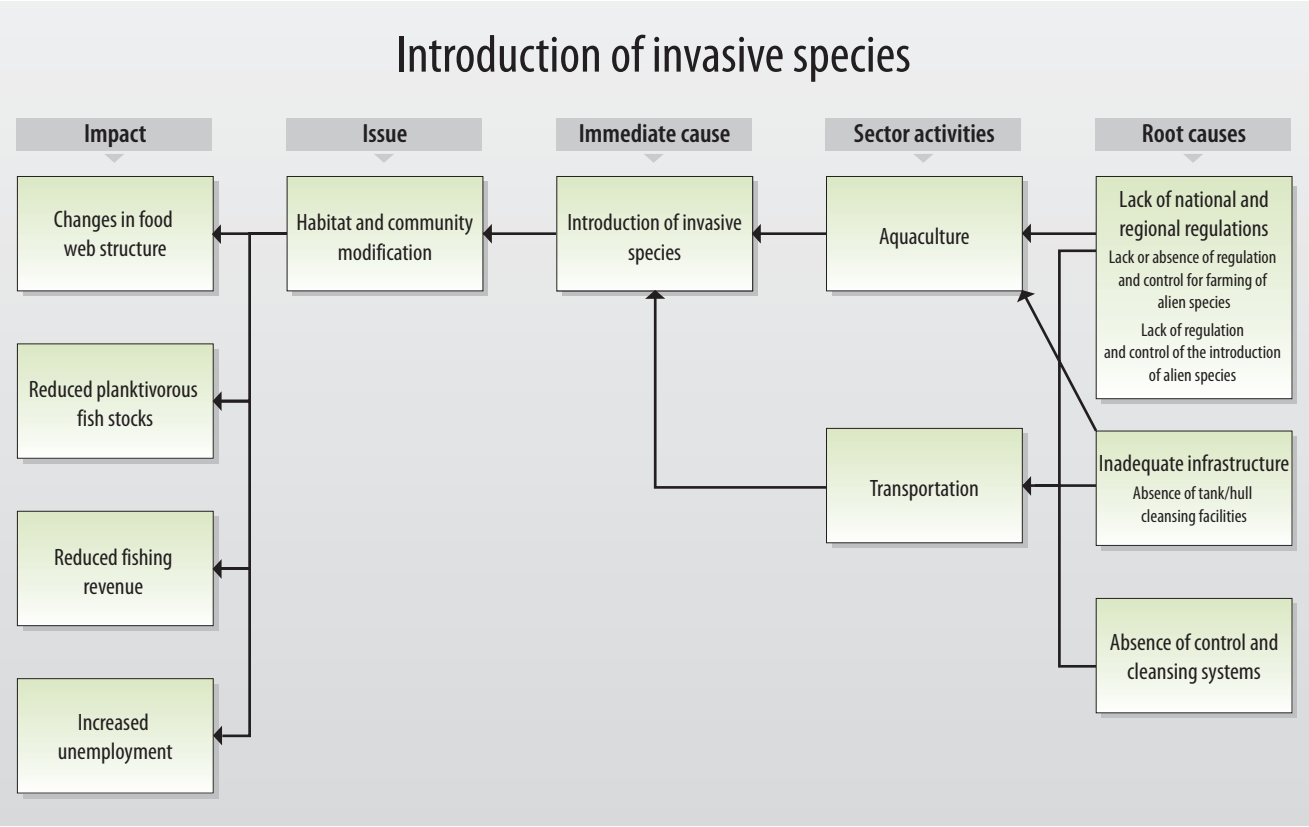

Figure 14 Causal chain diagram illustrating the causal links for the introduction of invasive species.

Introduction of invasive species

Species introduction has a long history in the Caspian region and was initially conducted for commercial purposes. During the period between 1930 and 1975, a range of commercially valuable species was introduced into the Caspian region (Figure 14). During the 1930s the Grey mullet (*Liza auratus*), the Leaping Grey mullet (*Liza saliens*) and the polychaete *Nereis diversicolor* were introduced into the Sea. In the 1960s and 1970s, the Grass carp (*Ctenopharyngodon idella*), the Silver carp (*Hypophtalmichthys molitrix*) and the Spotted silver carp (*Hypophtalmichthys nobilis*) were brought into several river systems in the region, while the Chum salmon (*Oncorhynchus keta*), the Pink salmon (*O. gorbusha*) and the Coho salmon (*O. kisutch*) were introduced into the Caspian Sea (Kazancheev 1981, Mitrofanov 1999, Ivanov 2000). This deliberate species introduction resulted in the elimination of several native species (e.g molluscs such as *Mytilaster* sp. and *Abra* sp.) and also changed some benthic (*Nereis* sp.), plankton (*Rizosolenia* sp.) and fish communities. However, many of the commercial species did not survive in the Caspian waters, and those that found suitable living conditions in the Sea are today part of the modern Caspian ecosystem and no longer pose a threat to natural habitats.

In contrast to the deliberate introduction of species during the 20th century, the existence of invasive species in the Caspian Sea is today primarily accidental. Most of the invasive species pass through the artificial shipways from the Black Sea via the Don and Volga rivers. Since these canals cannot be closed and do not have any system for controlling or preventing migration, small mobile species such as eel and planktonic freshwater organisms are migrating into the Caspian Sea. Alien species are also accidentally introduced into the Sea via ballast water and as fouling organisms on the hulls of ships. While many of these invaders have only limited impact on Caspian ecosystems, others can radically change food webs and hence have the potential to affect many native habitats. The comb-jellyfish, *Mnemiopsis leidyi,* is an example of a recent invader that has managed to alter the habitats of planktivorous species and predators in all areas where it has appeared in large numbers.

Aquaculture is another source of invasive species in the Caspian Sea. Many alien species are today subject to farming (including sturgeon hybrids and paddle fish) and a range of alien feeding organisms is also used in this process. While most hatcheries in the Sea require re-construction in order to prevent accidental penetration of species into open water, aquaculture is today poorly regulated by the littoral states. Regional regulation to control invasive species in the Caspian Sea is in general missing, and the scientific understanding of the consequences is highly inadequate. In the absence of adequate national and regional legislation as well as a shared perception of the risks of invasive species, few investments are currently made to better control the migration of invasive species via shipways or to develop a regional control system for decontamination of ballast tanks and hulls of visiting ships.

Regulation of stream flow by the construction of hydroelectric dams

Regulation of the many rivers flowing into the Caspian Sea has both chronic and acute impacts on the biodiversity of the Sea. Changes in hydrological regimes and reduced spring run-off result in both decreased depth of river delta waterways and reduction in delta vegetation (e.g. reeds, cat-tail and bushes). As spring flows are reduced, the upstream migration of fish for spawning is impeded and essential nursery areas are inaccessible. The construction of dams also floods and destroys spawning sites immediately upstream and, even if special fish ways and lifts are constructed, sturgeon and salmon often fail to reach potential spawning grounds further upstream. Spawning grounds for migratory species are also lost when delta vegetation is reduced. Together, these factors have caused a drastic reduction in the Caspian salmon and sturgeon populations. The only remaining natural spawning grounds for sturgeon are located along the Ural River and in the few Iranian rivers that are not affected by the extraction of sand and gravel from the riverbed.

In addition to these long-term and chronic impacts on the biodiversity of the Caspian Sea, hydroelectric plants also have acute effects. In order to prevent dangerous overflowing of dams, many reservoirs in the region have in recent years chosen to release water prior to the spring thaw. These early releases carry heavy sediment loads and alter the flux of biogeochemically active substances in the Caspian Sea (Aubrey 1994). This large and early nutrient input into the still frozen sea, alters both the location and timing of the entire north Caspian phytoplankton-based food web and inhibits spring spawning migrations by damaging bottom and coastal ecosystems. During periods of low flow in the summer and winter, the water levels are on the other hand kept high in the reservoirs for the production of hydroelectricity. While this regulation of stream flow reduces river influx into the Caspian Sea, shallow branches of rivers and flood plains downstream tend to dry up.

There is an additional conflict between energy and ecological interests in the regimes of water flow discharge regulation, i.e. intra-daily distribution of water flow. From the energy production point of view, discharges of water through the dams should be timed so as to provide for the increased (peak) energy demands that occur during two-three hours in the morning and evening while from the environmental point of view this discharge should be distributed evenly throughout the day. At the present time, the operational guidelines for the regulation of

stream flows through the existing hydropower plants do not meet this environmental demand. The lack of national environmental legislation controlling the regulation of stream flow by hydropower plants is one of the underlying reasons of habitat and community modification in the Caspian Sea and river deltas. National and regional expert advice on environmentally sound control for the regulation of stream flow is also inadequate.

Conclusion

The causal chain analysis of Habitat and community modification in the Caspian Sea and its coastal zone has identified a number of recurring drivers or root causes (Figure 15). It seems that many of the immediate causes are primarily affected by insufficient enforcement of national legislation, absence of regional regulations, inadequate expert advice and both the overall economic situation in the region, and low levels of public participation and environmental awareness/transparency. Some of the root causes such as regional poverty and the economic recession are difficult to change in the immediate future and are, to a large extent, dependent upon international and national factors. Other root causes are more specific to the Caspian Economic Hinterland and are hence within reach of local and regional governance.

This study identified four primary immediate causes of habitat and community modification in the Caspian Sea and its coastal zone: pollution as a result of oil spills and agricultural discharges; poaching and unsustainable fishing practices; introduction of invasive species; and regulation of stream flow by dams on rivers discharging into the Caspian Sea. The following root causes were identified as the most pressing for each immediate cause:

- Pollution: Old technology and infrastructure for oil extraction and insufficient control of harmful pesticides;
- Poaching and unsustainable fishing practices: Inadequate expert advice on quotas and insufficient enforcement of existing legislation;
- Introduction of invasive species: Absence of cleansing facilities to treat ship ballast water and hulls; and
- Regulation of stream flow: Insufficient control of water discharges by dams.

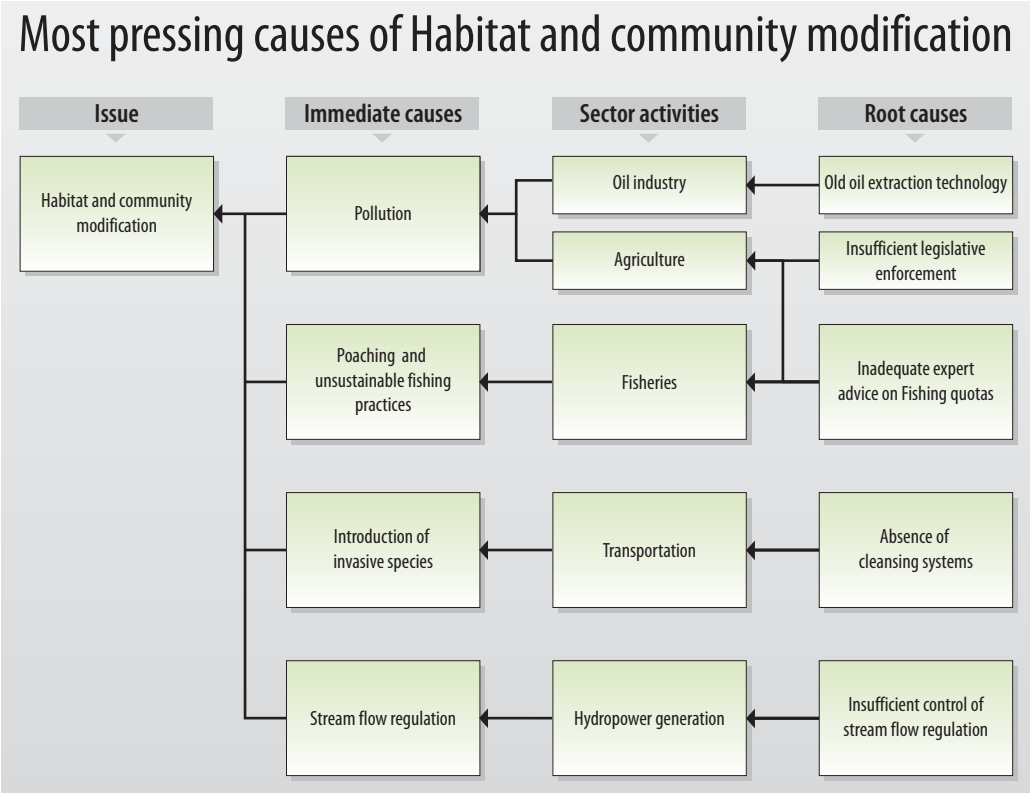

Figure 15 A summary illustrating the main causal links for Habitat and community modification in the Caspian Sea and its coastal zones.