Assessment

Table 6 Scoring table for the Caspian Sea region.

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

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

Caspian Sea	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.3* ↗	2.0 →	2.0 →	1.8 →	**2.0**	**4**
Modification of stream flow	1					
Pollution of existing supplies	2					
Changes in the water table	1					
Pollution	1.4* ↗	2.0 →	2.0 →	2.0 →	**2.0**	**3**
Microbiological pollution	1					
Eutrophication	2					
Chemical	2					
Suspended solids	1					
Solid waste	1					
Thermal	1					
Radionuclide	1					
Spills	2					
Habitat and community modification	2.0* ↗	2.4 ↗	2.4 →	2.3 →	**2.6**	**1**
Loss of ecosystems	2					
Modification of ecosystems	2					
Unsustainable exploitation of fish	2.2* ↗	2.0 →	2.0 →	2.4 →	**2.2**	**2**
Overexploitation	3					
Excessive by-catch and discards	2					
Destructive fishing practices	2					
Decreased viability of stock	2					
Impact on biological and genetic diversity	2					
Global change	1.0* ↗	1.5 →	1.5 →	1.0 →	**1.2**	**5**
Changes in hydrological cycle	1					
Sea level change	2					
Increased UV-B radiation	1					
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, Overexploitation 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 6. Detailed scoring information is provided in Annex II of this report.

Freshwater shortage

The Volga drainage basin has the highest water consumption of any basin in the Caspian Sea region (CEP 1998d). In 1996, despite 80% (51.2 km^3) of the total water demands in the basin being met through the progressive use or recycling of water, 28.8 km^3 of freshwater was withdrawn from water bodies within this watershed, amounting to 31% of the total water withdrawal in Russia (CEP 1998d).

Environmental impacts

Modification of stream flow

The annual discharge of water into the Caspian Sea has declined because each of the large rivers draining along its northern coast (Volga, Ural and Terek) have been regulated by the construction of reservoirs that store and supply water for agriculture and hydropower. Between the early 1930s and the 1970s, dozens of reservoirs were built, the largest being the chain of huge man-made reservoirs known as the Volga cascade which is situated on the Volga River above Volgograd (Aubrey 1994). The storage and regulation of large volumes of water in reservoirs has led to increased losses of water through evaporation, which is exacerbated

by the widespread use of spray irrigation and the construction of small irrigation ponds (Aubrey 1994). Moreover, the regulation of stream flow has caused changes in the annual and inter-annual influx of water into the Caspian Sea. Nowadays, water is strategically released from reservoirs in late winter in order to accommodate the influx of water entering rivers with the spring snowmelt and prevent dangerous overflows from the dams (Aubrey 1994). The water released carries with it heavy sediment loads that alters the natural regimes of suspended solids influx to the Caspian Sea (Aubrey 1994).

The modification of stream flow has had considerable consequences on the biota living within these systems, particularly on anadromous species of sturgeon that spawn in the lower reaches of rivers in the region. For example, before 1957, the Atrek River stopped flowing only in exceptionally dry years. However, owing to overabstraction of water in Iran during the 1960s and 1970s, the volume of water entering the Caspian progressively declined until the 1980s and 1990s when its connection with the Sea was virtually lost (1984, 1986, 1990, 1995-1997 and 1999-2000) (CEP 1998f). As a consequence, suitable conditions allowing migration of sturgeon to spawning grounds on the 15 000 ha floodplains of Adjib and Deleyly are increasingly rare, restocking has halted, and stocks, which are subjected to increased fishing intensity, have diminished considerably (CEP 1998f). In an attempt to prevent the continued decline in sturgeon stocks, artificial spawning grounds were created during the early 1970s at Adjib and Adjiyab in the lower reaches of the Atrek River. The decline in the abundance of sturgeon was temporarily curbed, however, often during the last decade there has been no water in the lower reaches of the Atrek River, thereby preventing the migration to and spawning of sturgeon at these grounds (CEP 1998f). In addition, these artificial spawning grounds have fallen into disrepair as a result of lack of funding since 1990, despite the fact that they have contributed to the local populations of sturgeon for more than 25 years. It is now estimated that between 60 and 100 km^3 of water would be required during the critical spawning period between November and June to ensure the normal functioning of the Adjib spawning grounds (CEP 1998f).

Pollution of existing supplies

At the regional scale, moderate environmental impacts resulting from pollution of existing supplies of water occur. The waters of the Volga River are moderately polluted, while those of its major tributaries, the Oka and Kama rivers, and the Ural River are highly polluted (CEP 1998d). In addition, intensive development of the mining (Armenia), metallurgic (Georgia), chemical, power and processing industries (Azerbaijan, Armenia, Georgia) and irrigated agriculture between 1970-1990, has caused a sharp increase in the influx of sewage into the basin of the Kura River resulting in the deterioration of water quality (CEP 1998a). Because of the almost total absence of natural freshwater resources, the rate of freshwater consumption in the Turkmenistan CEH (Balkan velayat) is significantly lower than in the other velayats. In 1995, 1.1 billion m^3 of water was consumed in Balkan velayat, which constituted only 5.5% of the total water consumption of Turkmenistan. However, it is anticipated that after the completion of the Kazandjik-Kizyl-Atrek branch of the Karakum Canal, the subsequent development of new lands will cause the consumption of freshwater to increase markedly. Furthermore, because of the deficiency in potable water, the population often uses mineralised water obtained from underground lenses without preliminary treatment, making them vulnerable to contracting water-borne viral infections.

The Ural River is the main source of potable, industrial and agricultural water in Kazakhstan (CEP 1998c). Pollution of the lower reaches of the Ural River, between Uralsk and its estuary, is mainly a result of inflow of the upper middle portions of the River. Water in the middle reaches of the Ural, between the Iriklin Reservoir and Uralsk, particularly at the confluence of the Ural and Ilek rivers and in the Ilek River itself, is classified as "dirty" according to the Kazakhstan classification (Integrated Ecology Program, Atyrau, 1996). However, the influx of large quantities of water from the spring snowmelt enables the River to flush pollutants accumulated during the remainder of the year from the system. This seasonal flushing provides the Ural with some capacity to clean itself. This is confirmed by comparing data obtained during the first quarter of 1995 from the lower reaches near the borders of Atyrau Oblast, which classified the River as "clean", with data obtained from periods later in the year which classified the River as "moderate-dirty" (CEP 1998c). The general results of monitoring of the concentration of pollutants in the lower reaches of the Ural River are shown in Table 7.

Table 7 Concentrations of various pollutants in the lower reaches of the Ural River.

Pollutant	Concentration (mg/l)	Maximum Allowable Concentration (MAC[1]) (mg/l)	Exceeded concentration (x MAC[1])
Oil products	0.43	0.05	8.6
Phenols	0.001	0.001	1.0
Surfactants	0.03	0.1	0.33
Copper	0.0053	0.001	5.3
Manganese	0.019	0.01	1.9
Iron	0.056	0.5	0.112
Lead	0.02	0.03	0.67
Nickel	0.006	0.01	0.6
Molybdenum	0.003	0.25	0.112

Note: [1] Maximum Allowable Concentration (MAC) of harmful substances in the surface waters were used in the former Soviet Union for assessment of the surface water quality. Even after the disintegration of the Soviet Union, Azerbaijan, Kazakhstan, Russia and Turkmenistan still use MACs for this purpose. (Source: CEP 1998c)

The Russian Federation discharges 1 993 million m^3 of sewage into the Caspian Sea annually. The majority of this is untreated because most wastewater treatment plants in the region do not work or are inefficient resulting in untreated sewage being discharged directly into water bodies. As a consequence, the quality of water in most reservoirs is degraded and does not meet the Russian standards for drinking water which, in general, coincide with standards set by the World Health Organization (WHO).

In Azerbaijan, 169 million m^3 of raw sewage and 240 million m^3 of treated sewage is discharged into the Caspian Sea every year. Baku's wastewater accounts for 80% of the municipal discharges from Azerbaijan into the Sea. Sumgayit discharges roughly 10%, and the remaining 10% comes from the other coastal cities. The Govsany municipal wastewater treatment plant in Baku is virtually the only plant operating on the coast of Azerbaijan and it biologically treats approximately half of the city's wastewater. Elsewhere, there is either no treatment or the treatment plants have insufficient coverage or are not operational. Many of these towns and cities are located very close to the coast and the majority of wastewater probably finds its way into the Sea untreated (CEP 1998a).

Municipal wastewater discharge is the primary environmental pollution problem in the Iranian coastal zone. A population of more than 6 million inhabitants is connected to central sewage systems that, in most cases, discharge into rivers or directly to the Sea. None of the cities have installed treatment facilities. The pollution load from human activities is much higher than that from industrial activities, particularly with regard to discharge of total nitrogen and phosphorous. Industrial activities provide 31% of the organic load and the remaining 69% originates from municipal discharges (CEP 1998b).

In Kazakhstan, the wastewater from the city of Atyrau is discharged to evaporation fields and it is purported that no domestic wastewater is discharged to the Ural River or the Caspian Sea. The smaller cities in the area also discharge their wastewater to evaporation fields. Sewage from the centre of the city of Aktau is discharged to the municipal wastewater treatment plant (KOC-1). The wastewater treatment plant receives 75% of municipal wastewater (from approximately 90 000 persons) and also receives industrial wastewater. KOC-1 was constructed in 1972 with a capacity of 40 000 m^3/day. Extension work of the plant was initiated in 1982 but the work was stopped because of a lack of funds. The actual load on the plant today is estimated to be 50 000 to 60 000 m^3/day. During the winter, the treated wastewater is chlorinated and discharged into the Sea. In the summer, the wastewater is reused for irrigation. Raw municipal sewage generated from the upper part of the city of Aktau is discharged into Lake Karakol (25% of the total municipal wastewater) from where it evaporates. Construction of a second treatment plant (KOC-2) began in 1991 but was never completed due to lack of funds and remains only 30% complete. Approximately 40% of municipal wastewater discharged directly into the Caspian has been mechanically treated and in some cases has also been biologically treated. The remaining 60% is discharged directly to the Sea or river usually without the provision of long outfalls that would ensure adequate dilution. Even where treatment facilities have been provided, the treatment efficiencies are low because plants are generally old and largely not working as designed. In terms of overall load on the Sea, direct municipal discharges contribute much less than the rivers. Nonetheless, the quantity of effluent is sufficient to cause health risks close to these coastal cities and, in some cases, hazardous substances are discharged that will have long-term effects on the ecology and human health. The effluent collection systems in coastal cities are currently poorly developed and in poor condition. When these collection systems are improved and extended, municipal effluent flows will increase considerably if counteractive measures, such as proper pricing for water usage along with institutional improvements in water companies, are not instituted.

In the Mangistau Oblast, industrial and domestic sewage is disposed of in 41 facilities that are located far from the coast ensuring that there is no discharge of pollution into the Caspian Sea from this region (CEP 1998c). In Iran, pollution of existing supplies is not a problem, despite the fact that the area has many potential sources of pollution. Samples obtained during a recent investigation of pollution in waters supplying various cities in Mazandaran and in Gilan were free of any chemical pollution. Microbial pollution was found in only 20% of samples from the Mazandaran and in almost none obtained from Gilan (CEP 2002c).

The most widespread pollutants of surface waters are petroleum products, phenols, lightly oxidising organic substances, metals and nitrogen originating from various kinds of industries, agricultural production, municipal services, and from surface rain (CEP 2002c). These same substances occur in groundwater supplies but, at present, these are not as heavily contaminated (Tacis-CEP 2001). Nevertheless, despite the apparent quality of water supplies in some areas, the growing population in the Caspian Sea region and the continued degradation of traditional water sources is causing growing dependence on groundwater to supply drinking water, particularly deeper reserves that have so far escaped the influences of anthropogenic activities (CEP 2002c).

Changes in the water table

Changes in the water table vary across the region according to the influence of both water abstraction and fluctuations in the sea level

of the Caspian. In low-lying areas in the lower Kura-Araks River delta of Azerbaijan, the water table is very high and has risen by 1 to 2 m because of the sea level rise in the Caspian. Such high water table levels, in conjunction with the hot climate, have lead to salinisation of groundwater, reducing the area of land suitable for agriculture (CEP 1998a).

Socio-economic impacts

The economic impacts of Freshwater shortage on the region are moderate. Permanent freshwater shortage has resulted from the salinisation of groundwater in Azerbaijan (CEP 1998a), Iran (CEP 1998b) and Turkmenistan (CEP 1998e). Currently, the main impacts of freshwater shortage on the economy of the region are associated with the increased cost for the supply of drinking water. Although data describing these costs are rare, it could be assumed that the direct costs associated with the supply of drinking water are relatively low because labour costs in the region are low. However, it is the quality and availability of safe drinking water that causes moderate and, in some specific areas, even acute negative impacts on the economy.

In order to mitigate freshwater shortage in Turkmenistan it was decided to construct the Kazandjik-Kizyl-Atrek branch of the Karakum Canal (CEP 1998e). However, the construction of this branch diverts water away from the Aral Sea which may lead to long-term negative impacts and, if not managed properly, jeopardise the positive outcomes expected from the construction.

Inundation of some areas by rising sea levels of the Caspian has reduced the attractiveness of the coastal zone for potential users and developers. In addition, changes in the level of the water table have caused indirect losses for industries and the local population (CEP 2002c). These phenomena have further increased the risks associated with investing in the region, making long-term direct foreign investments, which are considered to be one of the major driving forces for the development of newly emerging economies, increasingly untenable. Tourism has also declined in the region recently, despite usually being a profitable sector of the economy. Although it is very difficult to quantify, expert estimation indicates that about 30% of the decline in tourism could be attributed to freshwater supply problems.

The moderate impacts on human health of freshwater shortage are linked to the deteriorating quality and limited supply of safe drinking water. In Kazakhstan an increasing number of people have to use low quality water for household purposes because river waters in the Atyrau Oblast are chemically polluted, particularly near human population centres (CEP 1998c). Only 40 of 280 inhabited localities in the oblast have piped drinking water. Although the state standards on drinking water quality are quite high, the level of compliance is known to be insufficient. The percentage of illnesses caused, directly or indirectly, by the quality and availability of drinking water varies among different sources from 30 to 70%. Such high figures should have attracted the attention of authorities. However, since the health care system in most of the countries concerned is still state-owned and governed, quantitative estimates and monetary values of the impacts of freshwater shortage on the health of the population are virtually non-existent.

The decline in tourism and agriculture in some areas has prompted some people to migrate to more prosperous areas causing moderate social and community impacts. Populations in the region are becoming increasingly centralised, particularly around the big cities. Ratios of the proportions of the population living in rural and urban areas and in the capital and other cities are very quickly approaching those typical for developing countries. This migratory process degrades traditional values and activities, causes partial loss of ethnic identity and tension between social groups competing for urban employment. The migration of people away from rural areas has been partially compensated by general population growth in the majority rural territories of the region.

Data describing the direct and indirect losses caused by the impacts of different aspects of freshwater shortage on the economic and social situation in the region are not currently available. In order to address this situation, special investigations focusing on these issues should be implemented to obtain quantitative estimates of the impacts of freshwater shortage on the region.

Conclusions and future outlook

Freshwater shortage resulting from reduced stream flow is an important problem in some areas of the Caspian Sea region, particularly in the southern part which is characterised by increased population density, profitable agriculture and considerable recreational activities. The construction of water reservoirs and the expansion of irrigation and industrial development have caused an increased loss of non-renewable freshwater supplies resulting in reduced availability of water for drinking and agricultural purposes, and a concomitant decrease in fish productivity in these river basins. While the deterioration of water quality has moderately affected the health of the human population, the present impacts of freshwater shortage on the environment are nevertheless, only slight.

In the future, it is anticipated that water withdrawal from rivers and other sources will increase as a consequence of population growth

and expanding industry. Climate change is also likely to exacerbate freshwater shortages in the region by decreasing the amount of precipitation and increasing evaporation causing further recession of the water level in wells in the southern part of the Caspian Sea region.

Pollution

The Volga River and its tributaries are responsible for 90% of the total pollution load that enters the Caspian Sea (CEP 1998d). The concentrations of pollutants, such as oil hydrocarbons, phenols, synthetic surfactants, organic matter and metals, in river mouths often significantly exceed Maximum Allowable Concentrations (MAC) by 10 times or more and remain constantly high with little variation between seasons or years (CEP 1998d). These pollutants generally originate from anthropogenic activities such as agriculture, mining, oil refining, the petrochemical and chemical industry, machinery, wood and paper manufacturing, energy production and shipping (CEP 1998d).

Point sources are responsible for the remaining pollution that enters the Caspian Sea. These sources are primarily human settlements along the coast such as Baku, Cheleken, Atyrau and Astrakhan. Fortunately, owing to the sparse distribution of these cities, point sources of pollution are few and far between.

Environmental impacts

Eutrophication

Since the early 1980s, the condition of the Caspian Sea, particularly in the Iranian Bank and the Volga River delta, has steadily deteriorated as a result of eutrophication (Salmanov 1999) originating from anthropogenic sources such that it exerts moderate impacts on the region. In the southern Caspian, along the coast of Iran, agriculture, which is mechanised and highly dependent on the application of chemical fertilisers and pesticides, is the primary source of excess nutrients, while the deforestation of a significant area of woodland has increased the nutrient loads leached into rivers discharging into the Sea. In fact, it is estimated that the natural forests of Iran have been reduced from 30 million ha to their present area of 9 million ha within one generation (CEP 1998b) in order to accommodate population increases, urban expansion and the increasing demand for farmland.

Rivers in the region discharge between 6 and 20 times more nitrogen and phosphorus into the Sea than direct discharges from municipalities and industries. The elevated concentrations of nutrients in the region cause several phytoplankton blooms per year and, as a consequence, the annual phytoplankton production of the Caspian exceeds that of both the Black and Azov Seas (Table 8) (Caspian Scientific Network 2000). The decline of phytoplankton blooms produces hypoxic conditions in some areas causing fish and zoobenthos mortality.

Table 8 Average biomass of phytoplankton within regions of the northern Caspian Sea in August 2001.

Algal group	West			East			Total for the Sea
	Shallow water zone	Deep water zone	Whole area	Shallow water zone	Deep water zone	Whole area	
Cyanobacteria (mg/m^3)	1 138	548	614	961	366	470	539
Diatoms (mg/m^3)	1 971	906	1 024	364	260	279	634
Dinoflagellates (mg/m^3)	51	124	116	20	34	32	72
Euglenales (mg/m^3)	0.8	1.5	1.4	1.0	1.1	1.1	1.3
Chlorophyta (mg/m^3)	184	263	255	797	232	325	294
Total (mg/m^3)	3 345	1 843	2 010	2 143	893	1 107	1 540

(Source: GIWA Task team 2003)

Chemical pollution

Oil related activities are the main contributors to the moderate chemical pollution of the Caspian Sea. Oil and gas exploration and production have occurred in the Caspian Sea for nearly 150 years and, currently, there are oil activities in the waters of all riparian countries except Iran. Although high levels of pollution have been attributed to these activities, the actual contribution of these activities to oil pollution in the Caspian is estimated to be less than half of that originating from natural seeps, and only 5% of the total annual inputs of oil into the Sea from all sources. The primary source of oil pollution in the Caspian are oil-related activities such as oil refining, transport, and related industries that tend to pollute rivers that discharge into the Sea (Table 9) (CEP 2002c). For example, in Kazakhstan, serious pollution of landscapes has resulted from the oil and gas fields located on the delta and left banks of the Ural River (CEP 1998c). An extensive area around the city of Atyrau was developed during the Soviet period. Drilling facilities, roads, pipelines, oil storage facilities, maintenance depots, temporary construction sites and homes for the oil and gas workers were built which degraded the semi-desert and desert vegetation. In addition, the impacts from the large newly established Tengiz oil and gas field, south of Kulsary, have been similar to those experienced around Atyrau. However, because of the close proximity of this field to the Sea, the impacts have been more intense with recent rises in sea level causing flooding of a belt of up to 40 km wide that has carried the contaminants to the Sea (Salmanov 1999).

Table 9 Pollution loads from rivers, municipalities and industry in the littoral countries.

Country	Sources	River flow (km^3/year)	BOD (tonnes/ year)	Nitrogen (tonnes/ year)	Phosphorus (tonnes/ year)	Oil (tonnes/ year)
Azerbaijan	Rivers	15.2	36 000	19 000	1 000	600
	Municipalities		38 000	13 000	3 300	9 400
	Industry		7 100	1 100	300	14 000
Sub-total		15.2	81 100	33 100	4 600	24 000
Iran	Rivers	17	49 500	12 000	1 200	400
	Municipalities		68 000	16 000	4 400	7 800
	Industry		28 200	600	210	12 500
Sub-total		17	145 700	28 600	5 810	20 700
Kazakhstan	Rivers	9.8	13 200	6 000	600	400
	Municipalities		800	500	100	200
	Industry		2 900	7 100	100	1 800
Sub-total		9.8	16 900	13 600	800	2 400
Russia	Rivers	257.4	807 900	805 000	87 500	73 100
	Municipalities		1 600	400	100	100
	Industry		1 500	100	3 970	5 400
Sub-total		257.4	3 100	500	4 070	5 500
Turkmenistan	Rivers	0	0	0	0	0
	Municipalities		1 600	400	100	100
	Industry		1 500	100	3 970	5 400
Sub-total		0	3 100	500	4 070	5 500
All countries	Rivers	299.4	906 600	842 000	90 300	74 500
	Municipalities		124 400	34 900	9 300	21 300
	Industry		44 600	9 200	4 680	42 600
Total for Caspian	**All sources**	**299.4**	**1 075 600**	**886 100**	**104 280**	**138 400**

Note: BOD = Biological Oxygen Demand. (Source: CEP 2002c)

The Bay of Saymonov in Turkmenistan is a dead part of the Caspian. Industrial effluents of an oil refinery have been discharging pollutants into this bay since 1942. The bay is separated from the Krasnovodsk Gulf by overflow control facilities, which partly impede the flow of wastewater into the Sea. However, due to increased production of the refinery, the pressure has increased. This has led to reduced bio-productivity of the Krasnovodsk Gulf and contamination of fish tissue. Furthermore, numerous oily lakes in the vicinity of onshore oil fields have caused mass mortality of birds (CEP 1998e).

It is recognised that development of the oil and gas industry has brought about a number of indirect impacts, particularly as a result of increased urban construction and land uses, increased desertification of sites because of infrastructure, and increased freshwater demand. As a consequence, the indirect environmental and socio-economic impacts of increased oil and gas exploration are potentially greater than the direct impacts associated with pollution.

In 1995, all seawaters monitored in the Caspian Sea were classified as polluted, despite the fact that concentrations of pollutants in the northern part had stabilised or even decreased (CEP 1998d). Average annual concentrations of oil hydrocarbons were 0.3 to 1.6 times greater than the Maximum Allowable Concentration (MAC), while the concentrations of phenols were 4 to 5 times higher than the MAC. Levels of ammonium and synthetic surfactants did not exceed the appropriate MAC. Concentrations of oil hydrocarbons in bottom sediments varied from 1-14 mg/g; those of copper, from 4.6-27.9 mg/g; and lead, from 0.1-4.2 mg/g.

Apart from oil and agriculture, other factors have influenced the load of chemical pollutants in Caspian waters. In Azerbaijan, for instance, the former highly developed industrial city of Sumgait has virtually closed down but pollution from historical activities still persists in this area. Natural factors, such as water level rise, have also brought buried pollutants to the surface in formerly polluted land areas (CEP 1998a).

Analysis of long-term data describing the water quality of the Kura River shows that the concentrations of dissolved oxygen are generally satisfactory and ranged between 82 and 100% of the saturation point. The biological oxygen demand (BOD_5), which is an index of the content of lightly oxidised organic matter in the water, varies between 2.0-2.5 mg O_2/l and does not exceed the sanitary norm. Also, the concentration of phosphorus ranges between 0.06-0.09 mg/l, nitrate between 0.008-0.015 mg/l and ammonium 0.08-0.14 mg/l, and do not exceed the MAC. On the other hand, the degree of mineralisation and content of sulphates exceeds the sanitary norm by 20 to 100%. In the mouth of the Kura River, high concentrations of phenol (0.015 mg/l) and copper compounds (0.0012 mg/l) that exceed the MAC by 8 to 15 times are recorded. In addition, the concentration of oil products exceeds the MAC by 5 times (0.25 mg/l) (CEP 1998a).

Falling industrial activity since the early 1990s has resulted in generally less pollution of coastal waters by industrial sewage. Nevertheless, various persistent contaminants still pose a serious threat to the fishes in and around the Caspian Sea. High concentrations of DDT metabolites, chlordane, PCBs, hexachlorocyclohexanes (HCH), and other organics, as well as some heavy metals (zinc, copper, cadmium and lead) have been measured in sturgeons (CEP 2002c).

Spills

Spills of oil and oil products during navigation and from offshore oil and gas fields as well as flooded coastal oil fields are significant sources of marine pollution (Figure 7). The areas bordering the Russian coast that are most significantly contaminated by oil are the port of Makhachkala and navigable routes and oil fields. A typical example of an accidental oil spill occurred as a result of the overfilling of cargo

Figure 7 Aerial view of the Neft Dashlari (Oily Rocks) 110 km^2 artificial island (Azerbaijan).
(Photo: Corbis)

tanks during the loading of the Volgoneft-147 tanker in the port of Astrakhan in August 1995 (CEP 1998d). This accident resulted in the spillage of about 34.5 tonnes of oil into the Volga River, which resulted in 180 000 USD in damage and the clean-up operations took 120 hours and cost 2 000 USD. In 1996, accidental discharges of oil products into the aquatic environment in the Astrakhan Oblast amounted to 270 kg, which caused 3 500 USD in damages. Most frequently, such accidents arise from the sinking of old ships that are not properly repaired, maintained or guarded.

To date, there have been no severe spills in the Caspian Sea; although a spill from the old block oil well in the Tajigali oil field occurred, however figures describing the size of the spill and the extent of the impacts were not available. Nevertheless, with the high volume of oil being shipped through the Volga-Don river system to the Black Sea, there is great potential for oil tanker accidents resulting in the release of significant quantities of oil into the marine environment. These activities are currently having a moderate impact on the ecosystems of the Caspian Sea. While major spills cause immediate and obvious environmental consequences, the presence of large oil carrying ships in the Caspian and adjoining river systems causes other problems, such as the day to day release of contaminated water from ships' holds. According to data collected during 1995 and 1996, pollution of the aquatic environment resulting from deliberate discharges of pollutants from ships has increased. The main reason is the relatively high price of effluent treatment services compared with possible fines for discharging such effluents into the watercourses (CEP 1998d).

Operational spills are occurring as a consequence of the present development of the shelf zone by international oil companies. A consequence of the release of oil into the surface waters of the Caspian Sea is that there are very few tar free beaches around the Caspian Sea. Oil and gas issues are of particular concern, partly due to extensive oil slicks observed in some portions of the Caspian Sea. In some cases, the origin of these slicks has been traced to industrial activities, but in many other cases the source is not as obvious (CEP 2002c).

Degradation of the marine environment can be caused by single large-scale pollutant discharges during accidents at industrial and treatment facilities as well as from the inoperative water treatment systems of industries, agriculture and human settlements in the coastal zone. In such cases, discharges are characterised by high concentrations of pollutants that are released over brief periods and affect a relatively small area. In recent years, Astrakhan and Makhachkala have remained

Figure 8 Kara Bogaz Gol (Turkmenistan).
(Photo: NASA).

the largest sources of accidental pollution of this type in the Caspian region. In 1995, accidental and single large-scale discharges of pollutants into water bodies of the Astrakhan Oblast occurred on 36 occasions and exceeded 42 tonnes. Approximately 13 tonnes were recovered during clean-up operations. Twenty-eight of these accidents were attributable to breaches of environmental requirements during operations of sea-going and river vessels, the fish processing industry, ship repairs or military units (CEP 1998d).

Other pollution sources

The environmental impacts of suspended solids, solid waste, thermal, microbiological and radionuclide pollution in the Caspian Sea are considered slight (CEP 2002c). Radioactivity is present locally as a result of industrial processes involving activated charcoal in the basin of Kara Bogaz Gol (Figure 8), from the radium mines near Aktau (Kazakhstan) and possibly from underground nuclear explosions in the north Caspian region (CEP 2002c). Data obtained during the International Atomic Energy Agency cruises conducted in the late 1990s show low levels of radioactivity in the sediments and waters of the Caspian Sea (CEP 2002c).

Socio-economic impacts

Pollution causes moderate impacts to the economy of the region and affects the priorities for regional development. The main economic losses are associated with declining fishing revenues, changes in fishing expenditure, decreased aquaculture developments and property devaluation. In addition, there are costs for freshwater treatment, cleaning of tar covered beaches and prophylactic health care for humans. The area is also losing much of its attractiveness to tourists. As a result, the competitiveness of the coastal economy is decreasing. It is difficult to single out one cause of economic decline because political, macro-economic and environmental factors are synergistically contributing to the present situation (CEP 2002c).

Pollution affects only a limited number of people within the CEH relative to the total population of the region (CEP 2002d) and, as a consequence, the impacts of pollution on the health of the human population in the region are moderate. Environmental pollution in the region is often blamed for diseases of the central nervous system, the digestive tract, respiratory diseases and cancer (CEP 2002a, d). Some data on health indicators by country are presented in Table 10. The most common diseases are typhoid, dysentery and tuberculosis, which are 15 times more prevalent in coastal areas than in the remaining parts of the region (CEP 2002c).

Other social impacts resulting from environmental pollution are moderate and mostly indirect. The regional tanker fleet needs to be renewed, as there is risk of transboundary pollution because of incidents. In official environmental reports of the region's countries, this factor is under consideration (CEP 1998a-e, Vladimirov et al. 2002). In addition, countries' governments cannot allocate sufficient funds to ensure adequate environmental protection, which impedes problem solving in the region (CEP 2002c).

Conclusions and future outlook

At present, the most important forms of pollution in the Caspian Sea region are chemical, nutrients causing eutrophication and oil spills, which significantly influence the economy and human health of the region and exert moderate impacts on the environment. These pollutants originate primarily from sewage, agricultural run-off and oil-related activities and are transported by rivers and discharged into the

Table 10 Population health indicators in the littoral countries.

Characteristics	Azerbaijan	Iran	Kazakhstan	Russia	Turkmenistan
Tuberculosis cases per 100 000 people (1998)	61	18	126	82	89
Malaria cases per 100 000 people (1997)	130	60	ND	ND	ND
People living with HIV/AIDS aged 15-49, % (1999)	<0.01	<0.01	0.04	0.18	0.01
Pregnant women with anemia, % (1975-1991)	36	17	27	30	ND

Note: ND = No Data. (Source: CEP 2002a)

Caspian Sea. This situation is unlikely to change in the future because of industrial development and population growth in the coastal zone (CEP 2002c). In addition, rehabilitation of the economy and agriculture is likely to cause an increase in the quantity of wastewater discharged into the Sea (CEP 2002c).

Much of the economic improvement in the future will result from oil exploration. However, despite the economic benefits that increased oil production will yield and the application of modern environmentally sound technologies for hydrocarbon exploration and production, the current extent and intensity of oil-based industries provides no basis for an optimistic prognosis concerning oil pollution in the future. In the Kazakhstan sector of the northern Caspian where prospecting and development of new oil fields is most intense, the annual production will, in the short-term, reach 50 million tonnes, based on forecasted reserves of 5 to 7 billion tonnes. In addition, the oil and gas reserves on the shelf of the northeast Caspian Sea are estimated to be as large as 10 billion tonnes (CEP 1998c).

At present, this shelf zone is being developed by a number of international oil companies. Azerbaijan has signed contracts concerning oil prospecting and extraction in Azeri, Chirag, Guneshli, Karabakh, Yalama, Lenkoran-deniz, Talysh-deniz and others oil fields that are already operating. For example, the first oil has already been extracted from the Chirag deposit. At present, four international oil consortia have been established, of which the biggest is the Azerbaijan International Operating Company (AIOC) (CEP 1998a). Drilling in the Sea is planned from the fixed platforms in Turkmenistan and in the Galkanysh region where the depth of oil wells is estimated to be 3 050 m. Also, 10 additional wells are being constructed in the Korpedje region (CEP 1998e).

Continued development of existing oil fields will increase the risks of contamination occurring in the future and, moreover, the construction of new pipelines, particularly the underwater pipeline between Aktau and Baku, and the transportation of the Tengiz oil by tankers to Baku will exacerbate the potential for significant environmental damage resulting from oil exploration and transport.

Habitat and community modification

The coastal landscapes and habitats in the Caspian region are degraded by a number of natural and human induced factors. Natural factors include fluctuations in the sea level, earthquakes, and climate change. Some of the anthropogenic causes of degradation of coastal landscapes and damage to coastal habitats are deforestation, regulation of rivers, urbanisation, industrial development, inadequate agriculture/aquaculture development, inadequate recreational development and land- and sea-based pollution.

The current Caspian transgression during the last two decades has resulted in a sharp increase in sea level by approximately 2.5 m which has displaced wetlands and other habitats located in shallow waters and along the coast. This has caused a concomitant decline in biodiversity and loss of ecosystem stability, particularly in the CIS-Caspian Lowland (Kazakhstan, Russia), lowland deltas in Azerbaijan and offshore shoals. A number of species, such as the rare Nut lotus (*Nelumbo nucifera*), which has almost disappeared in the eastern part of the Volga delta, have lost their environment, although, in the long-term, these habitats are likely to re-establish themselves along the new coast. In addition, the advance of the Sea has caused the progressive salinisation of soils and a shift in the surge zone in the coastal area. Moreover, the impacts associated with the inundation of coastal areas by rising sea levels have been exacerbated by the contamination of marine and wetland habitats with pesticides, herbicides and oil products that were previously contained within coastal or inland areas.

The impacts of sea level rise have not all been negative. Despite the temporal loss of biodiversity, the inundation of coastal areas has also provided new habitats. The rise in sea level has in some areas favourably influenced restoration of shallow spawning grounds (e.g. carp), nesting locations for birds (e.g. flamingos and swans), diversity of flora and productivity and quality of feeding grounds.

Environmental impacts

Major anthropogenic causes of habitat destruction in the Caspian region include construction of hydropower dams, oil exploration, domestic and industrial sewage, and eutrophication. The construction of dams on the Volga, Kura and Atrek rivers for hydropower, which

Table 11 Loss of spawning grounds for sturgeon due to stream flow regulation.

River	Area of spawning grounds before river regulation (ha)	Area of remaining spawning grounds (ha)
Kura	ND	160
Terek	ND	130
Sulak	ND	200
Ural	1 700	1 100
Volga	3 390	372

Note : ND = No Data. (Source: CEP 2002c)

started in the 1930s, caused a decline in water flow and alterations of the natural water regimes and concomitant changes in environmental conditions and structure of habitats in their deltas. In particular, a large part of the natural spawning grounds of sturgeons in the Volga River and semi-anadromous fish in the Atrek River (e.g. zander, carp and Caspian roach) have been lost resulting in declines of fish stocks in all littoral states (Table 11) (CEP 2002c). However, in order to offset the decline in stocks of these species resulting from decreases in natural recruitment, several hatcheries have been constructed, with more being planned in the future. Indeed, the number of fry released from hatcheries is one of the main factors that determine how quotas for catches of valuable fish species are allocated.

Conflicts arise because the regulation of rivers affects the size of stocks of commercial fish species in the entire region but only those countries that have constructed dams benefit from the electricity and water for irrigation that these reservoirs provide. Under these circumstances, nations that do not benefit from the construction of these dams do not have any incentives to restore natural spawning grounds. Moreover, one of the main principles outlined in the "Agreement on the preservation and use of Caspian bio-resources" states that the "distribution of aquatic bio-resources depending on the input of Parties into their reproduction and preservation as well as bio-productivity of coastal waters" is not fully implemented within the region. As a consequence, the preservation of other natural habitats of sturgeons, such as feeding and wintering grounds, is not encouraged.

In Azerbaijan, the oil industry has long been by far the greatest culprit in destroying landscapes in the coastal zone, especially on the Apsheron Peninsula and the area south of Baku. Oil fields developed prior to the achievement of independence cover 20 000 ha of the Peninsula, of which more than 8 000 ha are severely contaminated by oil and 2 000 ha are occupied by artificial oil-water lakes and pits. These areas are classified as severely degraded semi-desert landscapes. In addition, wastes from the oil industry have contaminated 165 natural lakes (CEP 1998a and f, CEP 2002c).

The existence of persistent bio-accumulative toxic compounds in the environment, which have generally originated from the oil industry, jeopardises offshore habitats and wetlands of Azerbaijan, Russia and the northeastern coast of Kazakhstan. Eutrophication, on the other hand, threatens enclosed water bodies of wetlands (gulfs, lagoons and delta lakes) in the deltas of the Volga and the Kura rivers.

In the Caspian Sea region, anthropogenic activities have caused a considerable decline in the resource and functional value of many habitats. As a consequence, rehabilitation and reconstruction of degraded habitats is a regional priority. Although a thorough inventory of the habitats of the Caspian Sea region has not been conducted, sufficient data were available to prioritise the following areas (CEP 1998f):

Marine habitats:

- The contaminated oil areas in the Azerbaijan sector;
- The contaminated areas of the transitional zone along the northeastern coast of Kazakhstan between the Emba delta and the Tub-Karagan Peninsula where oil wells have been inundated by rising sea levels;
- The oil fields in shallow waters of Turkmenistan (Komsomolskoye, Koturdele oil fields);
- The introduction of alien species, such as Mnemiopsis leidyi, into the Caspian Sea, particularly the southern regions.

Coastal habitats:

- The relic gyrcanic forests on the coasts of Iran and Azerbaijan;
- The areas damaged by the oil fields along the eastern coast of Kazakhstan (Teren-Uzyak, Western Prorva, Karajanbas) and Turkmenistan;
- Desertified areas throughout the Caspian Sea region, particularly in Russia and Kazakhstan.

Marshy areas:

- The spawning area and migration routes of sturgeons in navigable channels and riverbeds of the Volga, Ural, Kura River deltas;
- Divichi estuary and the Apsheron-Gobustan area that are valuable habitats for waterfowl, shore birds and rare species of flora;
- The spawning areas in the lower Atrek River;
- The contaminated areas of Saymonov Bay and the Turkmenbashy Gulf (Turkmenistan).

Loss and modification of habitats by country

In Azerbaijan, the abundance and viability of animals and plants in coastal habitats, particularly trout (*Salmo trutta caspius*), South Caspian Danubian bream (*Abramis brama orientalis*), Marine zander (*Stizostedion lucioperca*) and the Caspian lamprey (*Caspiomyzon wagneri*), have sharply declined as a consequence of intensified oil activities. Additionally, the migration and wintering of waterfowl and shore birds have been affected by desiccated wetlands and changes in crops. The wetlands of protected areas in the Salyan and Lenkoran districts and hunting reserves in the Samur-Devechi and Neftchala districts are under threat of extinction (CEP 1998f).

In Kazakhstan, fluctuations in discharge of the Ural River (from 6 to 12 km^3 per year) and an increase in the volume of water entering the Caspian Sea during the past few years have led to siltation of its delta. This process has severely hampered passage of sturgeons to their spawning grounds. Coastal habitats located within the territory of oil fields developed during the Soviet period (Tazhigaly, Teren-Uzyak, Eastern and Western Prorva, Karazhambas and Noviy Uzen) have been lost due to oil production (CEP 1998f).

In Russia, the main factor causing the degradation of habitats is pollution from industrial discharges, agro-chemicals and oil products. The most vulnerable habitat is the Volga Delta, particularly in the lower reaches of its fore delta. During the sea level rise, about 150 000 ha along the coast was flooded, and the surge that occurred in March 1995 (1.7 m) caused considerable damage (CEP 1998f).

There are few cases of degradation of habitats in Turkmenistan. There has been a progressive fall in the water levels of the Atrek River during the last 40 years as a result of withdrawal of water in the Iranian part of the River (CEP 1998f). This is directly responsible for the reduction of spawning grounds in the lower reaches of the Atrek where semi-anadromous fishes such as Caspian roach (*Rutilus rutilus caspicus*) and common carp (*Cyprinus carpio*) reproduce.

In Iran, the impacts of extensive salinisation of soils have been exacerbated by livestock farming. The most important critical habitats of the southern regions of the Caspian Sea are situated in two main areas: the Anzali Complex, which is located in a coastal lagoon; and Gorgan Bay, which is a coastal bay (CEP 1998f). Deforestation of the coastal zone is also an important problem in northern Iran and a main factor in the destruction of coastal habitats.

Loss of biodiversity

Concerns over loss of biodiversity in the Caspian Sea at genetic, species and habitat levels are widespread in the region. Loss of biodiversity is occurring as result of many factors including overfishing, poor water and sediment quality, damming of rivers, loss of habitat and the introduction of alien species (Aladin 2001). With clear threats to some of the economically important fish species (including sturgeon), general concern over loss of biodiversity is increasing. Documentation of the loss of biodiversity in the Caspian region is generally sparse. First, basin-wide assessments of biodiversity at repeated intervals are not available because of the large expenses associated with this kind of monitoring. Red books of the four northern Caspian countries list rare and endangered species but lack a general context of their impact on overall diversity. Sturgeons, for instance, reflect only a few of more than hundred species of fish in the Caspian Sea, and therefore, their loss may not represent a major decline in the overall biodiversity. Country reports on biodiversity and coastal habitats provide largely incomplete lists that do not permit quantitative assessment of the loss of biodiversity in the Caspian Sea. There is clearly an information gap for this issue. The damage to biodiversity is evident, but quantitative evidence is sparse (CEP 2002c).

Socio-economic impacts

The economic impacts of habitat and community modification are moderate. The main feature of degraded habitats is the decreased capacity to meet the basic needs, such as food and fuel, of the population in the region. The elevated sea level has affected the quality of agricultural land and increased the expenses for harvesting. Agricultural production has steadily declined as a result of desertification and failed to provide for the needs of the progressively increasing population in the region. In Kazakhstan, agricultural outputs decreased by 21% between 1993 and 1994 and by half between 1993 and 1995. More recently though, agricultural production has improved. In 1998-1999, the relative growth in this sector was 29% but the situation in the region continues to be precarious.

Rises in sea level and the subsequent surges have not only affected the agricultural sector but also inundated communications and production facilities in some areas. Inundation further increases production costs, fertiliser use, unemployment and requires implementation of land protection measures in local communities.

In addition, the aesthetic and recreational value of the coastal territory has decreased for both local inhabitants and tourists. The number of international and national tourists visiting the region has declined since the disintegration of the former Soviet Union (CEP 2002c).

Modification of habitats has moderately influenced the health of the population in the region. The incidences of tuberculosis and typhus in the Caspian region of Russia are 15 times greater than the national average. The prevalence of infectious diseases in the Caspian region exceeds that recorded in more favourable territories. Territories of the northern and eastern lowlands directly affected by sea level rise, climate and soil changes or areas dependent on resources from the Sea have suffered most. The modification of habitats might contribute to increased child and infant mortality, birth pathologies and reduced life expectancy through the general stress imposed on the population by the inappropriate natural conditions. In Azerbaijan, child mortality is 34% higher in coastal areas compared with mid-country areas where effects of habitat modification of the Caspian Sea are less pronounced.

However, habitat and community modification is not the only reason for deteriorating health conditions. It should be mentioned that pollution is probably more responsible than habitat modification. Significant socio-economic factors caused by the formation of national economic systems and the legacy of the economic complexes of the Soviet Union also contribute to the current situation (CEP 2002c). The disintegration of the Soviet Union caused loss of production and working places through the collapse of economic relationships between the industries that were the interactive units within the now defunct all-union economic complexes.

Other social and community impacts are moderate but less serious than impacts on economy and health. In general, these concerns include increased charges for preservation of biodiversity and protection of endemic species, support for sustainable utilisation of habitats, increased costs for preservation of cultural heritage and the loss of educational and scientific values of the coastal territories. In the Russian coastal area, about 200 houses in Makhachkala, Derbent and Lagan have been destroyed and 800 families displaced as a result of salinisation caused by poor irrigation techniques (CEP 2002c).

Conclusions and future outlook

Ecosystems in the Caspian Sea region have been modified by the construction of hydropower dams, oil exploration, domestic and industrial sewage and eutrophication. The changes to regional ecosystems have influenced the regional economy, particularly through the impacts on fish stocks.

In the future, the situation is expected to worsen if measures are not taken to address existing problems. Further decline and commercial extinction of endangered fish species such as sturgeon, trout and Caspian inconnu (salmon) will be observed during the coming decades as more of their spawning grounds are lost. Benthic communities in the shelf area and the pelagic ecosystem are expected to suffer further damages with the increase of human activities, particularly oil exploration. Based on experiences from the Black Sea, it is anticipated that the pelagic habitat will be adversely affected by the impacts of the introduced comb-jellyfish *Mnemiopsis leidyi*. Decreased biological diversity, desertification and increased pollution are some of the conditions that the coastal areas around the Caspian Sea will face in the future. With the expansion of oil and gas activities and growth of populations in the region, it is likely that urbanisation will increase as well as landfilling, and industrial development. The combined socio-economic pressures accompanying these stresses will result in increased land encroachment and possibly more contamination and, in turn, more degradation of landscapes and habitats.

IMPACT Unsustainable exploitation of fish and other living resources

There are four primary groups of commercial fish in the Caspian Sea:

- Fishes of the Sea: kilka (*Clupeonella cultriventris caspia*), shad (*Alosa kessleri kessleri* and *Alosa saposchnikowii*), and gobies such as (*Benthophilus stellatus*).
- Fishes of the rivers: perch (*Perca* spp.), Tench (*Tinca tinca*), Rudd (*Scardinius erythrophthalmus*), and Sterlet (*Acipenser ruthenus*).
- Anadromous fishes: lamprey (*Lampetra* sp.), Trout (*Salmo trutta caspius*), Caspian roach (*Rutilus rutilus caspicus*), and all sturgeons (Acipenseridae) except Sterlet (*Acipenser ruthenus*).
- Semi-migratory fishes: Breams (*Abramis brama orientalis*), Carp (*Cyprinus carpio*) and Zander (*Stizostedion lucioperca*).

Sturgeons are abundant, having originated from freshwater forms and acclimatised to higher salinity so that they are now distributed throughout the entire Caspian. The traditional Caspian sturgeon fishery is well known because of the high economic value of the caviar. However, in recent years, landings have decreased significantly, despite the introduction of a quota system and a temporary ban on pelagic fishing.

The impacts of unsustainable exploitation of fish and other living resources are moderate in the region. Overexploitation is the main issue since many stocks are heavily fished both legally and illegally. Decreased viability and changes in genetic structure are of moderate concern while by-catch and destructive fishing practices cause slight impact.

Environmental impacts

Overexploitation

Overexploitation of aquatic organisms is severely affecting the regional environment. Overfishing, in conjunction with pollution, river regulation, the introduction of alien species, loss of habitats and poaching, have reduced the stocks of some commercially important fish and nearly eliminated some of them from catches.

The Caspian Basin sustains an important fisheries sector. In the past, more than 400 000 tonnes of fish, particularly valuable species such as sturgeon and Caspian roach, were caught annually. This situation remained unchanged until the early 1950s but, since then, sprat fishing has significantly intensified in the middle and southern Caspian in order to compensate for poor catches of more valuable fish species. Between 1960 and 1980, the total volume of fish caught was largely maintained by the annual extraction of between 300 000 to 400 000 tonnes of sprat (Table 12, Figure 9).

Table 12 Average annual fish catch in the Caspian Sea.

Fish	Commonwealth of Independent States							Iran	
	1910-1930	1932-1959	1960-1970	1971-1978	1979-1980	1991-1995	1996-1998	1927-1998	1996-1998
Sturgeons (1 000 tonnes/year)	13.8	12.8	15.3	22.1	21.2	6.4	1.8	1.3	1.5
Bony fish (excluding kilka) (1 000 tonnes/year)	382	349	107	86.4	60.5	72.1	72.5	6.2	16.6
Kilka (sprat) (1 000 tonnes/year)	ND	37.3	308	357	283	149	133	2.0	63.3
Total (1 000 tonnes/year)	395.8	399.1	430.3	465.5	364.7	227.5	207.3	9.5	81.4

Note: ND = No Data. (Source: CEP 2002c)

The official sturgeon catch from the Caspian CIS countries has dropped from an average of 13 800 tonnes per year between 1910-1930 to 1 800 tonnes per year between 1996-1998, peaking in the 1970s at about 22 000 tonnes per year. Official catch statistics are unable to account for illegal poaching which makes it very difficult to estimate the actual catch. For example, the quota of Turkmenistan for offshore sturgeon catches was 3 tonnes in 2001 (for research purposes), but according to approximate calculations, the real amount of sturgeon meat sold at markets only in Ashghabad was of the order of 300 tonnes.

During the 1970s and 1980s, there was a ban on offshore fishing for sturgeon and salmon but, since the cancellation of the ban, poaching has been uncontrollable, particularly during the 1990s as a result of declining living conditions and a high rate of unemployment (CEP 2002c). Data of Caspian Scientific Research Institute of Fisheries (CaspNIRKh) show that illegal fishing throughout the Caspian region exceeds the quotas for catches by a factor of 10 to 13. Rapacious overfishing of sturgeons in estuaries during spawning run inflicts significant damage to populations and their resource potential.

Decreased viability of stock

Decreased viability of stock through pollution and disease is causing moderate impact on the Caspian ecosystem, particularly on populations of the Caspian seal (*Phoca* (*Pusa*) *caspica*). The Caspian seal, which is endemic to the Caspian Sea, is the only mammal within the aquatic fauna of the region. The main threats to the seal are oil exploration, pollution and viral outbreaks. Since April 2000, thousands of Caspian seals have died primarily as a result of an epidemic of canine distemper virus (CDV), although other complex factors are said to have contributed to the mortality. Estimates of the present population of Caspian seal span a factor of 10, between 30 000 and 400 000 individuals compared with historical data (19th century) describing 1 million seals (CEP 2002c).

Impacts on biological and genetic diversity

Impacts on the biological and genetic diversity of the region are moderate. The flora and fauna of the Caspian Sea include species introduced from the Arctic, Atlantic and Mediterranean complexes. Although many of these introductions occurred in the distant past, between 1930 and 1970, intentional and unintentional introduction of a number of species has occurred. Fourteen species of commercial fishes; the flounders, three salmon species, eel, mullets, mosquito fish, anchovy, and mackerel have been introduced deliberately, while two other species of fish (pipefish - *Syngnathus* and silverside - Atherinidae) and several other species such as invertebrates like the polychaete worm (*Nereis diversicolor*), bivalve (*Abra ovata*) and shrimp (*Palaemon elegans*) have accidentally been introduced.

Three new alien species of jelly plankton have been found in the Caspian during the last 50 years, two jellyfish *Blackfordia virginica* and *Aurelia aurita* and one comb-jellyfish *Mnemiopsis leidyi*. At present, the two jellyfish both occur in the Black and Azov Seas and have most likely invaded the Caspian from these Seas by travelling through the extensive shipping networks that connect these systems. Both species of jellyfish are planktivores but it seems that they are not as voracious as *Mnemiopsis* and their impact on the pelagic ecosystem has been low (CEP 2002c). *Mnemiopsis*, on the other hand, is a voracious planktivore that invaded the Black Sea during the 1980s causing considerable disruption to the marine ecosystem as a result of competition for food between *Mnemiopsis* and fish, leading to the decline in fish stocks in this system.

Mnemiopsis, which originate from the northwest Atlantic and invaded the Black and Azov Seas and subsequently the Caspian Sea, has the capacity to reduce its metabolic rate when food supplies are inadequate, allowing it to survive long periods in ballast water. The probability of transportation of *Mnemiopsis* from the Black Sea into the Caspian in ballast waters of ships was acknowledged several years ago and preventive measures, namely the replacement of ballast water in the freshwater part of the Volga-Don navigation system, were recommended. Even so, *Mnemiopsis* was found along the coast of Kazakhstan and then Turkmenistan in late 1999. Since then, it has rapidly migrated southwards where the salinity and temperature of the Sea are favourable. At present, *Mnemiopsis* occurs throughout the Caspian, except in the extreme north and northeast, where the salinity is too low (CEP 2002c). The current abundance of *Mnemiopsis*

Figure 9 Fishermen catch sturgeon with nets near the town of Atyrau (Kazakhstan).
(Photo: Corbis)

in the Caspian is about twice as high as the maximum ever recorded in the Black Sea. The greatest potential impacts from the introduction of this species would be exerted on the sprat fishery primarily because of competition for food between these two species and predation of *Mnemiopsis* on the planktonic sprat larvae. In addition, because sprat is the main component of the diet of Caspian seals, declines in sprat stocks are likely to cause further declines in the population of this endemic mammal.

Socio-economic impacts

The substitution of high value fish for lower priced fish in the catches, changed species composition, decreased catch efficiency and low investments, indicate that fishing in the Caspian Sea is becoming unsustainable. However, the unsustainable exploitation of fish stocks has not, to date, caused changes in the formal economic structure of the region. Nevertheless, in the early 1990s in Baku, the street price of caviar was pushed to its lowest levels ever by the illegal poaching of sturgeons. The combined impact of unsustainable exploitation on the economic sector was considered moderate. It is difficult to discern the impacts of overexploitation despite the decline of fish exports and small domestic market during the last 10 years.

Health impacts are also moderate and are determined by the overall economic situation in the region. Reduced fish catches are affecting health in the sense that it contributes to reductions in living standards (CEP 2002c).

Other social impacts are moderate and largely attributable to rising unemployment. Because of the decline in fishing the level of unemployment in the region has increased. For example, in Kazakhstan, unemployment has risen from 1.1% in 1994 to 3.9% in 1999. Unemployment is associated with the 50% decline in fish processing

industries during the last 10 to 12 years. Currently, it is difficult to accurately assess the social impacts of overexploitation because it is obscured by the general economic recession. Because of poverty and high unemployment fish poaching is becoming common (CEP 2002c).

Conclusions and future outlook

Unsustainable exploitation of fish and other living aquatic resources, particularly in river mouths, has a significant negative impact on the ecology of the marine environment and the economy of the region. The sharp decline of sturgeon stocks have necessitated stock enhancement. In the future, overexploitation is likely to continue because of lack of enforcement, despite international conventions and agreements. Bottom trawling, catching of under-sized fish and fishing in the river mouths will increase and continue to degrade the marine ecosystem. Increased chemical pollution, eutrophication, microbiological pollution, and oil spills will also adversely affect fish stocks. With increasing maritime transport, ballast water will continue to introduce alien species into the Caspian which will further affect local fauna and flora.

Global change

Natural fluctuations in sea level have been occurring in this region throughout history right up until present times. However, at present, there is no reliable information that connects fluctuations in the sea level of the Caspian with global change.

Environmental impacts

Changes in hydrological cycle

The changes in the regional hydrological cycle are slight and mainly related to human activities and global climate change. These are observed in the more extreme magnitude of fluctuations between high and low water in the rivers, as well as in the dynamics of the surface level variation of the water bodies. The river spates in spring and the dry periods in summer are more intensive and longer. Also, because winters are becoming warmer, significantly less ice cover is observed. The seasonal fluctuations, as well as the wind-induced surges, have had a significant impact on the fluctuations in the level of the Caspian Sea. The wind-induced surges are maximal in the northern Caspian, while in the middle and southern parts they are smaller. Wind induced surges of 1.5 to 3 m high have been observed in the Caspian Sea within the past few decades. In the northern Caspian, the wind-induced surges may even penetrate up to 20-30 km inland and remain in the shore depressions up to 15-20 days (CEP 2002c).

Sea level change

The impacts of sea level change are moderate. Sea level fluctuation is primarily due to: climatic changes; regional precipitation and evaporation from the Sea; wind stresses/surges; changes in atmospheric transport patterns; as well as human activities, such as construction of dams on the major rivers. The rise in sea level of the Caspian (2.5 m) has had both positive and negative impacts on the biotic life in the region. While some habitats have been lost, others have been created, facilitating among other things, spawning of anadromous fishes (CEP 1998f).

Increased UV-B radiation

There is a slight impact of increased UV-B radiation and changes in the carbon storage capacity of the water bodies. There has been an increase in UV-B radiation but at the same time there is no evidence of this affecting the sea ecosystem.

Socio-economic impacts

There is moderate impact on the economic sector because of elevated sea level mainly connected to changing agricultural efficiency, fishing and nature protection. Even for the socio-economic sector, sea level rise has brought about some positive implications, particularly by reducing industrial pollution of the shallow waters and the need to dredge harbours. Wind-induced surges causing a temporary increase in sea level have resulted in inundation of vast areas of the coast causing some economic losses to the Caspian littoral states (CEP 2002c).

Impacts caused by global change on the health of the population in the region and to society are slight and the effects indirect.

Conclusions and future outlook

No improvement of the situation is anticipated in the future but instead impacts will continue to increase. An anthropogenic threat of global warming due to the greenhouse effect is a distinctive feature of the 21st century. In accordance with the calculations by Budyko (1988) and Klige and Myagkov (1992), global warming should lead to a drop in sea levels of the Caspian as a result of greater rates of evaporation relative to freshwater inflow. The occurrence of global warming would result in cyclones bringing considerably more rainfall into the catchment of the Caspian Sea which would increase the volumes of water discharged from rivers into the Sea. At the same time, an increase of global temperatures would lead to a higher rate of evaporation from the surface of the Caspian, not only compensating, but even exceeding, the amounts of water gained through increased precipitation. If these calculations prove correct, then the Caspian will experience a recession of levels in the near future which will, in turn, affect the state of its biotopes and its biodiversity.

Priority concerns

The Caspian Sea Basin plays an important role on the Eurasia continent both in terms of environmental sustainability and socio-economic development. The environmental situation in the region is far from sustainable and deterioration of environmental conditions may have significant negative impact on the economy of Europe and Asia.

Having assessed the complex environmental and societal impacts of each concern within the Caspian Sea Basin and considering the Caspian Economic Hinterland as a discrete system with transboundary water-related problems, the results of the assessment have produced the following ranking of concerns in descending order of importance:

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

As a result of the analysis, and considering the trends of the problems for the region, a Causal chain and Policy option analysis of Habitat and community modification was recommended in order to develop mechanisms by which the impacts of this concern can be mitigated in the future.

Besides the formal results of the assessment presented in Annex II, there are other arguments to justify this conclusion. It was stated during the assessment of each concern that Habitat and community modification has significant linkages with other GIWA concerns and issues such as modification of stream flow, pollution, overfishing and the introduction of alien species that are responsible for the degradation of habitats and changes to community structure and species composition. It was concluded that by focusing the Causal chain and Policy option analysis on Habitat and community modification, these associated concerns and issues would indirectly benefit from the resulting policy options.

This conclusion corresponds with the outcome of the Transboundary Diagnostic Analysis (TDA) for the Caspian Economic Hinterland carried out within the framework of the Caspian Environment Programme (CEP) (CEP 2002b-d). Table 13 shows that the issues identified by the TDA as the highest priorities, namely the decline in certain fisheries, biodiversity and threats from invasive species, (CEP 2002c) are similar to those included within the GIWA concern Habitat and community modification. Although the GIWA addresses these issues from a broader global perspective, the similarities between the GIWA and the TDA becomes more evident at the level of policy options.

Table 13 Stakeholder group prioritisation of major perceived problems and issues according to Caspian Sea Transboundary Diagnosic Analysis.
(High priority, Medium priority, Low priority)

Stakeholders	Major perceived problems and issues							
	Decline in certain fisheries	Degradation of coastal landscape	Decline in biodiversity	Decline in overall environmental quality	Decline in human health	Damage to coastal infrastructure and amenities	Potential damage from oil and gas activities	Threats from invasive species
Environmental ministries								
Agriculture and fishing ministries								
Energy ministries								
Regional and municipal governments								
Multinational corporations								
Industry								
Scientific community								
NGOs								
Public healthcare providers								
Fishermen								
Coastal zone residents								

(Source: CEP 2002c)