Assessment

Table 3 Scoring table for the Humboldt Current region.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter)

- 0 No known impacts
- 1 Slight impacts
- 2 Moderate impacts
- 3 Severe impacts

The arrow indicates the likely direction of future changes.

- ↗ Increased impact
- → No changes
- ↘ Decreased impact

Humboldt Current	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.9* →	2.5 →	1.9 →	2.0 →	2.2	1
Modification of stream flow	1					
Pollution of existing supplies	2					
Changes in the water table	2					
Pollution	1.9* →	2.0 →	1.9 →	2.0 →	2.1	2
Microbiological pollution	2					
Eutrophication	1					
Chemical	2					
Suspended solids	2					
Solid wastes	2					
Thermal	1					
Radionuclides	1					
Spills	2					
Habitat and community modification	2.0* →	1.6 →	0 →	2.0 →	1.4	5
Loss of ecosystems	2					
Modification of ecosystems	2					
Unsustainable exploitation of fish	2.1* →	2.8 →	0 →	2.0 ↗	1.8	4
Overexploitation	3					
Excessive by-catch and discards	0					
Destructive fishing practices	1					
Decreased viability of stock	0					
Impact on biological and genetic diversity	1					
Global change	1.6* →	2.0 →	1.8 ↘	2.4 →	2.1	3
Changes in hydrological cycle	2					
Sea level change	1					
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.

** This value represents the overall score including environmental, socio-economic and likely future impacts.

*** Priority refers to the ranking of GIWA concerns.

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 3.

Freshwater shortage

The Humboldt Current region has abundant freshwater reserves; most sources are linked to the Andes mountain range. Nevertheless, there are zones where water is scarce, e.g. the north of Chile and the central and southern areas of Peru (CPPS 2001b).

Environmental impacts

Modification of stream flow

The fragmentary information available for the region does not provide evidence of modifications of stream flow. This issue was subsequently considered to have slight impacts. However, potential changes related to upstream damming are expected in the future. Availability of water resources was also considered. In general, climatic diversity and geomorphologic distribution patterns are primary factors determining freshwater availability in the region.

In Ecuador, there are significant differences between estimations of water availability in the Pacific Andean slope, with 2 000 m^3/inhabitant/year, and the Amazon Andean slope, with 70 000 m^3/inhabitant/year; which explain water shortages in some specific locations in both coastal and highland areas (Carrera de la Torre 1993).

In Peru, the climate drives the distribution pattern and availability of water. Water resources are scarce in the coastal Pacific slope (2 885 m^3/inhabitant/year), whereas the Amazon zone has an abundance of water (800 000 m^3/inhabitant/year). Additionally, the long dry spell lasting seven to nine months (May to December), has a negative effect on the water requirements of the country (CPPS 2001b).

In Chile, geographical and climatic characteristics have created independent basins between the Andes Mountains and the sea. Water resources are scarce in northern Chile but increase progressively southward (CPPS 2001b). Dams have been constructed to regulate surface water resources and the exploitation of groundwater resources is expanding (CPPS 2001b). In Chile, water is abstracted predominantly from surface resources and this is the reason why most of the rivers are "depleted" according to the authority responsible for regulating water use (FAO 2000a).

Pollution of existing supplies

Data from WHO/UNICEF/WSSCC (2001) show that 10.5 million inhabitants (20.4%) in the region do not have access to drinking water services. Another 5.2 million (10.2%) have "easy access" systems, which are considered a health risk especially for vulnerable populations. In total, 30.6% of the total population do not have access to safe water, either by WHO or national drinking water standards. This issue was considered to have a moderate impact in the region.

Changes in the water table

Information about groundwater is fragmented and variable between the countries in the region. For example, in Ecuador, there is no available information regarding changes in the water table, despite there having been increasing exploitation of aquifers. Since 2000, shrimp farmers of Ecuador have begun to construct farms inland using groundwater, as a strategy to avoid the white spot disease that affects the whole coastal environment. However, there are no estimates of the volume of water used or the impact on the water table. Some conflicts have arisen between neighbouring farmers because of a risk that saline groundwater will pollute land where rice, banana and other tropical fruits are traditionally cultured.

In Peru, the exploitable reserves of groundwater are estimated to be 2 740 million m^3, and the current exploited volume on the Pacific slope was estimated to be 1 508 million m^3 for human, cattle, agriculture and industrial consumption. This water is provided by 39 of 53 watersheds by means of 8 009 open tubular and mixed wells. In both the Atlantic and Titicaca Lake slopes underground reserves have not yet been determined but are deemed not to be significant. Studies carried out in the highlands estimated that the lagoons contain 3 028 million m^3 of water (CPPS 2001b).

In Chile, around 57% of the total water consumption comes from surface waters and 33% from groundwater (CPPS 2001b). Despite this large demand for groundwater, it is estimated that the drinking water service in Chile is guaranteed despite serious droughts because the companies that provide the service have access to several water supply sources (CPPS 2001b).

Socio-economic impacts

An estimated 15.7 million inhabitants in the region are exposed to health risks due to a lack of access to safe drinking water. Most of this population is from rural areas that migrated to marginal urban settlements causing an increased demand for freshwater and other services. Overpopulation is also causing the pollution of surface water bodies since settlements are generally located along watercourses into which people discharge their untreated wastewater (CPPS 2001b). Downstream communities, especially those located at the mouth of the rivers along the coast, are at great risk of contracting infectious diseases, as a consequence of their exposure to these polluted waters. The problem is compounded by industries that dump either poorly treated or untreated effluents into natural water bodies.

The deterioration in water quality is critical in some areas of Peru, due mainly to pollution from effluents produced by industry, particularly mining and metallurgy, which is affecting water supply sources and placing the health of the population at risk (CPPS 2001b). In addition to difficulties in controlling and monitoring water quality, particularly in the inland regions of the country, there is an indiscriminate use of raw sewage due the lack of water in coastal cities and the seasonality of rain in the Andean region (CPPS 2001b).

Conclusions and future outlook

Water shortages in the region can be attributed more to the lack of economic resources to increase the level of coverage than to a lack of water resources. The most vulnerable sectors are marginal settlements of large and median cities that are expanding at a higher rate than municipal services coverage, as well as rural populations where infrastructure is expensive due to a low population density. This problem is particularly evident in Ecuador and Peru.

Pollution

In the Humboldt Current region, pollution is considered a serious threat for the health both of humans, and of coastal and marine ecosystems. Most of the pollution problems are related to the deficient treatment of domestic and industrial wastewater, POPs used in agriculture and heavy metals from mine leachates (CPPS 2000a). Some countries in the region also suffer from endemic gastroenteric diseases related to poor quality drinking water and low sanitation standards. However, the situation is not homogeneous within the region, with conditions in Chile exceeding those in Ecuador and Peru.

Environmental impacts

Microbiological pollution

In Ecuador, 95% of the domestic wastewater is discharged without treatment (WHO/UNICEF/WSSCC 2001). The total discharge in Ecuador is estimated at 128 million m^3/year, 10.4% of the total discharge in the Humboldt Current region. The Gulf of Guayaquil receives around 75% of the domestic discharges (UNEP 1999). The Guayas, Daule and Babahoyo rivers have the highest levels of faecal coliforms in the South East Pacific and over 300 times the international water quality standards (CPPS 2000a). Tourist beaches near Guayaquil City such as Posorja, Data/El Arenal and Playas, the Santa Elena Peninsula and Bahia de Caraquez in the province of Manabi, also show high concentrations of faecal coliforms (Montaño 1993, CPPS 2000a) (Table 1 in Annex IV).

In Peru, 86% of domestic wastewater is untreated (Arauz & Campaña 1986 in CPPS/UNEP/IOC 1988). According to UNEP (1999), 435 million m^3/year of domestic wastewater is produced in Peru, 35.2% of the total discharge in the Humboldt Current region. Of this volume, 72.2% is discharged into the Callao and Miraflores bays, which explains the high values of coliforms reported in this area (Sánchez 1996). High concentrations of faecal coliforms are also reported at Agua Dulce, La Herradura, Bahía de Carquín/Huacho, Bahía Ferrol Chimbote, La Chira, Pampilla and Marbella (CPPS 2000a). Other coastal marine areas assessed on an annual or semi-annual basis are Huarmey, SupeParamonga and Cañete e Ilo; where levels of microbiological pollution moderately exceed the permissible limits of the Peruvian General Law of Waters (Table 2 in Annex IV).

Chile has the largest sanitation coverage in the region and has an increasing number of treatment plants (CPPS 2001b). Furthermore, there were almost 250 solid waste final disposal facilities in 2000 (INE/CONAMA 2002). However, WHO/UNICEF/WSSCC (2001) reported that 83.3% of the domestic wastewater is not treated. The total volume discharged in Chile is 627 million m^3/year, 54.4% of the total discharge in the Humboldt Current region (UNEP 1999). Wastes are mainly discharged into Maipo and Conception rivers (Cabrera 1994). CPPS (2001b) reported high concentrations of faecal coliforms at Antofagasta; historical data indicates that bacteria, viruses and parasites were associated with wastewater discharge (Table 3 in Annex IV). Diseases and mortality caused by pathogenic bacteria include typhoid and paratyphoid fever, and diarrhoeal child diseases. In 1999, the volume of industrial wastewater discharges was 49 million m^3 (INE/CONAMA 2002).

Eutrophication

Nutrient enrichment of coastal waters stems mostly from enrichment of rivers discharging into the coastal areas. It is estimated that around 81 000 tonnes per year of nitrogen and 7 100 tonnes per year of phosphorus enter the South East Pacific (Carrasco & Muñoz 1995). Agricultural run-off has a total input of 39 000 tonnes per year of nitrogen and 3 700 tonnes per year of phosphorus (CPPS 2000a). High values of nutrients have been found in areas with severe pollution and continuous discharges such as the Gulf of Guayaquil in Ecuador (Gutiérrez 1989), Callao, Ilo and Ite in Peru, and Valparaiso, Concepción, San Vicente and Bio Bio River in Chile (Zúñiga & Burgos 1996).

Because of the importance of the fishing sector in the region, residuals from fish canneries and fishmeal factories have been reported as one of the most significant sources of nutrient enrichment in coastal areas, especially in the north of Chile and in Chimbote, Paita and Pisco in Peru. The lack of appropriate technology for wastewater treatment precludes the recovery of solids and oils from effluents, creating azoic zones and eutrophication in closed areas such as El Ferrol, Chimbote, and Paracas, in Peru, where the weak circulation enhances negative effects (CPPS 2000a). High values of chlorophyll a and low levels of oxygen with a tendency to hypoxia are typically found surrounding these ports. The increase of organic wastes in the semi-enclosed bays of Peru has produced red tides (IMARPE 2003). Red tides are more frequent in spring and summer months and in several cases have caused the mortality of fish and invertebrates. In Chile, continental water bodies, mainly lakes and rivers, show increasing levels of eutrophication. Lakes such as Villarrica, Calafquen, Riñihue and Llanquihue already present mesotrophic states (Informe Pais 2002).

Aquaculture farms are another important source of nutrients in both continental and coastal waters.. The organic matter from these farms creates favourable conditions for various pathogens and subsequently causes mass mortalities amongst the species being reared with substantial economic losses. The production of cultured shrimp in Ecuador reached 160 000 tonnes in 1998 and the current production of cultured salmon in Chile is 80 000 tonnes.

Chemical pollution

Major sources of chemical pollution affecting the marine environment in the region include (UNEP 1999, CPPS 2000a, 2001b):

- Wastewater, which adds a variety of physical and chemical substances produced by industrial activities located in urban areas. Most of these wastes do not receive any treatment.
- Agriculture, which is the main source of pesticides through run-off and aerosols.
- Mine leachates and metallurgy.
- Oil spills, including maritime traffic and operational failures during loading and offloading.

Pesticides

Between 1990 and 1998 the countries in the region used an average of 15 500 tonnes of pesticide annually, including 6 670 tonnes of herbicides, 4 940 tonnes of insecticides and 3 900 tonnes of fungicides, bactericides and seed treatment pesticides (FAO 2002b) (Table 4). Highly toxic organophosphates and carbonates imported include Aldrin, Lindane, Mirex, and Heptachlor. Chile is the largest consumer of pesticides in the region, using 69.5%, followed by Peru with 18% and Ecuador with 12.5%.

Table 4 Annual comsumption of pesticides in the Humboldt Current region during the 1990s.

Country	Insecticides (tonnes/year)	Herbicides (tonnes/year)	Fungicides and others (tonnes/year)	Total (tonnes/year)
Ecuador	431.8	801	734.2	1 967
Peru	1 504	848.7	409.4	2 762.1
Chile	3 007.3	5 023.4	2 756.1	10 786.8

(Source: FAO 2002b).

In Ecuador, most agricultural activity is concentrated in the Guayas River basin. Products include banana, rice, sugar cane, vegetables. This area used 70% (equivalent to 3 200 tonnes active ingredients) of the total pesticides applied in the country (UNEP 1999). The banana sector alone consumes around 2 400 tonnes of insecticide-nematicide annually, including some restricted chemical products. The presence of DDE, DDD, DDT, x-BHC, Mirex, Toxapheno and Aldrin pesticides in waters and sediments of major rivers and estuaries has been reported (Table 4 in Annex IV). Concentrations of pesticides have also been found in organisms; Lindane has been detected in shrimps at concentrations of 4.17 µg/kg, 0.4'DDE in crabs at 1.25 to 3.56 µg/kg, Imazil in fish at 2.48 µg/kg and Dieldrin in clams at 0.69 µg/kg (INOCAR 2002b). Intriago et al. (1994, in CAAM 1996) reported concentrations of Calixin and Tilt of 0.018 µg/l in water and 0.8 µg/kg in sediments of shrimp ponds. These fungicides are frequently used to control the "black sigatoka" fungus disease affecting banana plantations.

In Peru, around 548 chemical products with a synthetic and biological origin are used in pest and weed control, mainly phosphates and chlorinates (UNEP 1999). Concentrations of pesticides in water and sediments along the coast are shown in Table 5 in Annex IV. Residuals of DDT and its metabolite DDE were also found in the River shrimp (*Cryphiops caementarius*) (DDTs < 5.8 ng/g). Fish such as Mullet (*Mugil cephalus*) and the Croaker (*Menticirrhus elongates*) had concentrations of Aroclor 1254 of 28.96 ng/g, and, in lower concentration, Aroclor 1260 (maximum 11.81 ng/g in *M. elongatus*); whereas DDTs were present in all its forms in all tested species (Cabello and Sánchez 2003).

Chile imported 243 types of pesticides with a total value of 67.7 million USD in 1993. In 1998, import of pesticides increased by almost 50% to 100 million USD and the types of pesticide increased to 1 100, although decreased in 2001 to 437 (INE/CONAMA 2002). The most used insecticides are organophosphates (64%) and chlorinated hydrocarbons (32%) (UNEP 1999). The most used fungicides are the carbonates (58%), and mercury compounds (11%). At Iquique, organoclorines and phosphates such as Dipteryx, Malathion, Folidol, Afalon are used in agriculture. The presence of DDT, DDE and Lindane has been reported in Concepcion Bay, the Gulf of San Vicente and the Gulf of Arauco and DDT traces were detected in samples from the Bio Bio River. The highest level of DDT has been found in the Gulf of Arauco, of DDE in the Gulf of San Vicente, and Lindane in Concepción Bay (Table 6 in Annex IV) (CPPS/UNEP/IOC 1988). Pesticides recorded in southern and central Chile between 1980 and 1996 include DDT, DDE and variable concentrations of Aldrin and Lindane (CPPS 2000a). Aldrin, Lindane, DDT and DDE have been found in samples of molluscs (*Perumytilus purpuratus* and *Aulacomya ater*) in coastal areas of Burca, Lirquen and Concepcion Bay between 1985 and 88 (Chuecas et al. 1989). Despite the potential danger of POPs to the reproductive and immunology systems of marine fauna, no studies have been undertaken to assess the impact of these substances on local biota.

Heavy metals

Regional assessments on heavy metals in coastal waters, sediment and organisms of the region show that concentrations of copper (Cu), lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg) and chromium (Cr) are related to municipal wastewater discharges and mining run-off (CPPS/UNEP/IOC 1988, CPPS 2000a). The most widely distributed heavy metal in the region is copper (Tables 7-11 and 14-18 in Annex IV). Concentrations between 3.1 and 4.8 ppb have been found in waters of the region. In general terms, Chile has the widest distribution and the highest concentrations of this heavy metal in its coastal environment. In Peru, the contamination by copper is concentrated in the southern part of the country (Rimac Basin and Callao Bay), and in the central zone

(Chimbote area to the north). In Ecuador, the highest concentration of copper is found in the Gulf of Guayaquil. Regarding concentrations of copper in sediments, the highest have been reported in the Rimac River, Peru (109-3 200 mg/kg) and two Chilean cities Antofagasta (5 790 mg/kg) and Coquimbo (4 520 mg/kg) (for ref. see Annex IV).

Concentrations of lead were reported near the main urban centres throughout the region. The highest concentrations of lead in water were found in the Gulf of Guayaquil (74.0 mg/l), the Rimac River (30.1 µg/l), and Valparaiso Bay (9.5 mg/l). High concentrations of lead in sediments were found in the Gulf of Guayaquil, Ecuador (12-218 mg/kg), Callao (388 mg/kg) and Paracas (269 mg/kg) (Table 12 in Annex IV), Peru, and three sites in Chile: Antofagasta (2 718 mg/kg), Iquique (270 mg/kg) and Arica (269 mg/kg) (for ref. see Annex VI).

Cadmium is another heavy metal with high concentrations in the region. In the Gulf of Guayaquil, Ecuador, concentrations ranged between 14.5 and <50 mg/l (Table 13 in Annex IV). Other areas with high concentrations were found in Chile between Valparaiso (0.32 ppb) and Punta Arenas (10.1 mg/l).

High concentrations of zinc are present in several sites along the northern and central coasts of Chile, from Iquique (91.0 mg/l) to Talcahuano (68.6 mg/l). The highest concentrations were found at Playa Ancha (139 mg/l). The maximum concentrations of zinc in sediments were found in the Gulf of Guayaquil (556 mg/kg), Ecuador, the Rimac River, Peru (1 000 mg/kg) and Antofagasta in Chile (10 775 mg/kg) (for ref. see Annex IV).

The highest concentrations of mercury were found in Peru and Chile. Paracas Bay in Peru had the highest concentration (1.4 µg/l), while in Chile, the maximum concentrations were recorded at San Vicente (1.78 µg/l) and in other specific localities: Burca, 1.1 µg/l; Tome, 1.56 µg/l; Lirquen, 1.15 µg/l; Andalien, 1.16 µg/l. Chile also showed a wide distribution of chromium from Arica (56.4 µg/l) to Castro (59.5 µg/l) (for ref. see Annex IV).

The presence of heavy metals in organisms (molluscs) was found in the north of Chile and south of Peru with a distribution pattern similar to that of heavy metals in sediments. In general, these sites coincide with coastal areas that host mining activities that discharge washed products into the sea. Other metals such as lead and cadmium show a wider distribution, and their highest concentrations in organisms are found in sites with mining-metallurgic activities. Studies of heavy metals in organisms have been carried out in 27 species of molluscs, 35 species of fish and seven species of crustaceans (CPPS 2000a).

Suspended solids

Sedimentation affects almost 60% of the region's coast. The lack of integrated basin management, deforestation, inadequate agricultural practices and overgrazing, are factors contributing to increasing erosion, especially in the highlands. During the rainy season, large quantities of suspended solids are deposited in coastal areas. This is especially evident in the Gulf of Guayaquil, where the Secchi depth in the inner estuary is 1-3 m and in the outer estuary 3-13 m. The annual rate of sediment discharge from this area was estimated to be 2.5 million tonnes. Critical areas identified in the region include (Ayón 1981, Teves 1989, Morales and Castro 1989).

- Ecuador: Bahía de Caráquez, San Jacinto, San Clemente, Montañita, La Libertad, and Posorja.
- Peru: Lima Bay, El Ferrol Bay, Chimbote, Delicias Beach in Trujillo and from Pisco to the Chilean border.
- Chile: developments in the dune zone, which are changing the coastal morphology in the central-south coast of Chile (Loncura, Quintero Bay).

In Peru from Pisco to Lima, there are high rates of coastal sedimentation, except at Miraflores Bay where erosive processes occur.

Solid wastes

A total of 2.3 million tonnes of solid wastes are produced every day in the Humboldt Current region. Between 0.5 and 1% of them are discharged on beaches and a lower proportion goes directly into the ocean (Carrasco and Muñoz 1995, Sánchez and Orozco 1997, Carrera de la Torre 1996, Delgado and Laguna 1995, Calero et al. 1996, Escobar 1996, Gutiérrez 1996, CPPS 2000a). The composition of solid wastes is organic matter (40-65%), paper and cardboard (10-20%), plastics (3-15%), metals (1.5-3%), glass (2-3%) and others (2-8%) (CPPS 2000a).

The recollection of solid wastes is considered inadequate in Ecuador and Peru, where urban coverage is 70% and 75% respectively (Figure 6) (CAAM 1996, Alegre et al. 2001). In contrast, the coverage in Chile is 99% (CONAMA 2002). Regarding the final disposal of solid wastes, around 70% of the solid waste volume produced by the urban population in Ecuador is disposed in controlled dumping areas (Figure 6), 14% is discharged into gorges, open fields or rivers within urban perimeters or nearby areas, 2.8% burned and 4% buried (CAAM 1996). In Peru, 64.6% of the generated solid wastes in Lima are disposed appropriately; the rest is left in open areas and constitutes a source of disease. Industrial, hospital and other dangerous wastes are not disposed of separately (Calderón 2001). In Chile, the final disposal is in dumps and more than 80% in sanitary landfills. In most of the region's cities, municipalities directly carry out the solid waste collection and management, but in

Figure 6 Families foraging a waste dump outside Guayaquil, Equador.
(Photo: CORBIS)

Chile the solid waste management is controlled by private enterprises. It is estimated that around 80% of the cities with over 50 000 habitants have privatised garbage collection services (CONAMA 2000).

Thermal pollution

There are several sources of land-based thermal pollution in the region but their environmental impact has not been documented. One case has been reported of sea turtles "trapped" in abnormally warm waters near thermoelectric plants in the north of Chile.

Radionuclide pollution

The levels and distribution of radionuclides in coastal waters, organisms and at various different sampling sites in the Humboldt Current region have been investigated by several scientists (CPPS 2000a, 2001c for a review). From these studies it is concluded that levels of Cs-137 are mostly below the limit of detection and its presence in some samples is attributed to residuals from tropospheric and stratospheric fall-out following atmospheric nuclear tests carried out in past decades. Radiological measurements in fish, crustaceans and molluscs between 1988 and 1995 in Chile demonstrated the absence of radioactive contamination. Similarly, values obtained for Cs-137 and K-40 between 1993 and 1996 by the Peruvian Institute of Nuclear Energy in samples of water and coastal sediments were below the minimal detectable concentrations (CPPS 2000a).

Spills

Data from the 1980s indicates that 17 oil terminals and nine coastal refineries were established in the region, which represents a potential risk of spillage due to transport and operational failures. During a 15-year period (before 1981), 448 accidental oil spills involving a total of

1 430 m^3 were reported (Vergara and Pizarro 1981). In general, low concentrations of hydrocarbons have been reported in the marine waters of the Humboldt Current region; except where oil activity and maritime traffic are concentrated.

In Ecuador, spills related to operational failures were reported in several ports, especially at Guayaquil City. Concentrations of hydrocarbons in surface waters are low, with the highest values reported during 1987-1994 (0.2-5.15 µg/l) (Table 1 in Annex VII). In January 2001 an accident in the Galapagos Islands received worldwide attention due to the environmental sensitivity of the area. The tanker *Jessica* ran aground at Puerto Baquerizo, San Cristobal Island, carrying 360 m^3 of bunker oil and 730 m^3 of diesel.

In Peru, major spills have occurred in Lima, specifically at Conchan where there is a refinery with the same name, and occasionally at Ventanilla where there is another refinery called La Pampilla. There are 12 fuel containers of various capacities; the largest are located at Eten, Salaverry, Chimbote, Supe, Callao, Pisco, Mollendo, San Nicolás and Ilo. In these areas there is a continual risk of oil spill. The largest spills occurred in 1990 (22 300 m^3 of kerosene) and in 1995 (more than 70 000 m^3 of crude oil) (CPPS 2000a). Elevated concentrations of hydrocarbons in water and sediments were reported in Talara, Callao, Ilo and Ite between 1985 and 1996, the highest concentration was found at Chimbote with 0.55-18.43 µg/l (Tables 22 and 21 in Annex IV) (Jacinto and Cabello 1996).

In Chile, oil pollution is reported mainly in the coastal region at Puerto Quintero, San Vicente and Punta Arenas. Historically, Antofagasta and Tocopilla are highly polluted due to the spillage of hydrocarbons (CPPS 2000a). INE/CONAMA (2002) reported 17 spills of hydrocarbons in Chile during 2000, including a large spill of 450 m^3 of diesel at Caleta Cifuncho. Concentrations of hydrocarbons of 0.25-2.08 µg/l were reported in coastal waters during the period 1985-1988. Data for sediments in the period 1985-1995 showed that 83% of the samples had concentrations between 0.11 and 2.00 µg/g (Tables 4 and 5 in Annex VII). The maximum concentration was between 0.36 and 25 µg/g (Ramorino 1994 in CPPS 2000a). Large spills occurred during the 1970s, but smaller spills, particularly of diesel, occurred at a rate of 13 per year between 1990 and 2002 (DIRECTEMAR 2003).

Socio-economic impacts

Pollution and its socio-economic consequences are matters of increasing concern in the Humboldt Current region because of the potential impacts on the quality of life of its inhabitants. Domestic wastewater discharged in the region was estimated at 846 400 m^3 and the domestic contaminant charge at 222 400 tonnes of BOD_5 per year in 1990 (CPPS 2000a). A high proportion of this wastewater, as well as industrial and commercial effluents, are collected in sewage systems, but most receive no sanitation treatment before being disposed of in water bodies. As a consequence, these water bodies contain a mixture of chemical and biological pollutants that affect public health when the water is used for agriculture, aquaculture, recreation and human consumption. Untreated wastewater in the countries of the region is more than 83% of the total wastewater produced, which is the cause of the high concentration of faecal coliforms found. In general, Chile is best prepared to face the problems associated with domestic wastewater management. Nevertheless, available information shows that waters receiving treatment are not equivalent to the level of coverage.

Untreated domestic wastewater discharged into coastal waters is a primary source of contamination with pathogenic and chemical agents. It poses a major health risk, especially for immersion activities and for consumers of seafood products. Exposure to bacteria, viruses, parasites, fungi and a variety of other harmful substances can occur in the coastal environment through water intake, water inhalation as mist or dew, consumption of seafood, and dermal contact with waters and sand. The inadequate sanitation conditions prevailing in the region are responsible for the high rates of child mortality and morbidity in Ecuador and Peru, the countries with lowest sanitation coverage. Infant mortality was estimated at 44 deaths per 1 000 live births in both countries (OPS 2001). In Peru, the main cause of death among infants under the age of one was transmissible diseases, especially intestinal diseases (25.1%). Diarrhoea is the main cause of morbidity, especially in children under five years old in Ecuador.

The lack of basic sanitation, as well as poverty and poor diet, was responsible for the 1991 cholera outbreak in the region. The first cases were recorded in Chancay, a small fishing village close to Lima, the outbreak expanding rapidly along the coast from Ecuador to Chile. An explanation for the simultaneous appearance of cholera in the countries of the region is that zooplankton in the ballast water of oil carriers transported the vibrion. Cholera has a historic association with the sea; the largest pandemics have occurred on the coastlines of the world (Colwell 1996). Cholera vibrion can survive a long time in faecal material and in the soil. In shellfish it may survive for up to two months and on the surface of fishes or in their intestines for 40 days. Contagion is possible through bathing in seawater or consumption of contaminated shellfish (Piatkin & Krivoshein 1981).

The OPS (2001) reported 797 929 cases of cholera in the region during the period 1991-2001; 88% of them during the first two years. The most affected countries were Ecuador with 11.8% of reported cases and

Peru with 88%. In Chile only 76 cases were reported during the 1990s crisis. Besides the better sanitation conditions in Chile, warmer waters in Peru and Ecuador provide more suitable ecological conditions for microorganism development and transmission. Since 1993, the incidence of cholera has steadily decreased, except for an increase of 45 472 cases associated with the El Niño event of 1997-1998 (Figure 7).

Other impacts of microbiological contamination reported in Peru include conjunctivitis, which is associated with polluted beaches (Echegaray 1986, in CPPS/UNEP/IOC 1988) and diarrhoea, intestinal fevers, hepatitis and parasitism linked to the clandestine use of polluted water for agricultural purposes (Sánchez 1996). In Ecuador, Arauz and Campaña (1986, in CPPS/UNEP/IOC 1998) reviewed historical data about the presence of hepatitis A, intestinal infections and malaria and identified a possible link with faecal contamination.

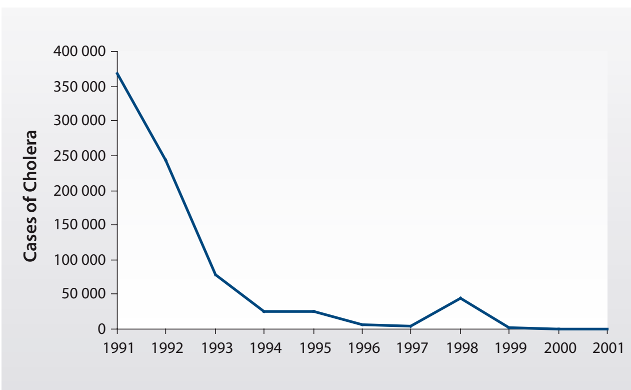

Figure 7 Number of cholera cases in the Humboldt Current region between 1991 and 2001.
(Source: OMS 2002)

Pathogens are affecting activities that require high quality water such as aquaculture. INOCAR (2001a) found concentrations of 1 000 MPN/100ml total coliforms and 450 MPN/100ml faecal coliforms in the wastewater of shrimp farms in the Gulf of Guayaquil, Ecuador. In Peru the presence in 2001 of hepatitis A at Paracas Bay resulted in the closure of the culture area of scallops because the European market stopped importation of this product.

Data on heavy metal pollution presented in this report (Annex VI) show that concentrations at some sites in the region exceeded international regulations by several times. The concentration of trace metals increased due to the proliferation of industrial and domestic effluents, endangering the coastal and estuarine ecosystems. However, the long-term effects of such chronic concentrations below the toxicity level are unknown. Human exposure to even low concentrations of toxic chemical pollutants in coastal waters would invoke serious long-term impacts on health. Copper and cadmium are considered highly dangerous for marine ecosystems and pose risks for human health when contaminated seafood is ingested (Zúñiga 1998).

Cadmium in the water originates from the manufacture and extraction of zinc, soldering based on silver, metal baths, copper refining, lead processing, fossil combustibles, municipal effluents, lubricants, phosphate fertilisers, pigments, volcanic eruptions, etc. Copper is associated with mining, proximity to industrial zones, antifouling painting, non-ferric metal recycling, fertilisers, fungicides, wood preservers etc. (OPS/OMS 1987, Zuñiga 1998). In Chile there are 421 processing plants for copper, of which 5% discharge directly into coastal waters (Escobar 2002). Problems with eutrophication have been reported only in salmon farms in the south of Chile, where harmful algal blooms induced by agricultural run-off have resulted in severe economic losses (Clement & Lambeye 1994 in CPPS 2001b).

Conclusions and future outlook

If the current population rate is maintained, it is estimated that, for the year 2020, discharges will increase by 95% and BOD_5 by 80% (calculated from UNEP 1999, CEPAL 2001, WHO/UNICEF/WSSCC 2001). This will necessitate significant investment in sewage systems and treatment plants to deal appropriately with such a volume of discharges. At the same time, it is necessary to obtain information concerning the amount of organic matter entering the rivers and the sea, the natural depuration capacity of receptor bodies, the ecology of pathogen microorganisms in wastewater and the effect of seawater on them. It is also important to study the epidemiology of these pathogens, the possible vectors and reservoirs, in order to determine whether or not they represent a potential regional problem. The expected increase of wastewater production will be a problem in the future because sanitary coverage is increasing at a slow rate in parts of the region.

Due to the lack of knowledge of the threshold limits of marine ecosystems that are chronically affected by metals, it is important to determine the tendencies of metal concentrations and their geographic distribution. Elevated concentrations shown in this report are not necessarily representative of the entire region since the monitoring effort was concentrated in known industrial and overpopulated areas. The implementation of a systematic research effort is necessary in the region in order to assess the impact of heavy metals and persistent organic pollutants on the biota and the ecosystem over the long-term.

Habitat and community modification

Coastal biodiversity is being affected by contamination from municipal wastewater and other human activities that require land such as new towns, port facilities, aquaculture and agriculture. The increasing demand for natural resources to satisfy human needs such as housing, wood, fish and shellfish, are stressing the ecosystems beyond their capacity. Natural communities, especially those found close to large cities are more susceptible to eutrophication because of the discharge of high levels of nitrates and phosphates. In these areas changes in the composition and spatial distribution of marine organisms have been reported over the last two decades; key species for both the fishing industry and for the ecosystem have disappeared from the Gulf of Guayaquil, Ecuador (Solorzano 1981, in CPPS 2001b), the mouth of Rimac River in Lima-Callao, Peru (Guillen 1981) and at San Vicente, Conception Bay and the Bio Bio River mouth in Chile (Castilla 1983).

During the 1980s and 1990s, aquaculture along the coast of Ecuador and northern Peru constituted a new anthropogenic incursion of an important and fragile ecosystem, destroying important mangrove areas with devastating consequences. The governments of the countries have adopted and implemented stringent sanctions in order to halt the destruction of mangrove areas for the rearing of penaeid shrimps.

Environmental impacts

Loss of ecosystems

Clearance of mangrove forests is probably the most evident example of ecosystem loss in the region. Mangroves are highly productive ecosystems with a high biodiversity. Located in tropical and sub-tropical coastal regions, they play an important role in protecting the coast from erosion and storms, and provide nourishment for the most important commercial species. They also provide wood and food for coastal communities and have some capacity to cleanse wastewater produced upstream. Due to the ecological and social importance of mangroves, loss of ecosystems was scored as having a moderate impact.

Major losses of mangrove have been recorded in Ecuador, where mangrove forests extended for over 193 000 ha in 1980 before the shrimp farming boom. Facilities were built on low-lying saline lands along estuaries, islands and river mouths, including mangrove areas. Between 1980 and 1990 the annual mangrove loss rate was 1.4% and during the 1990s, 1.1%. In 2000 mangrove areas totalled 147 000 ha, with a total loss of 24%. Almost one third of the 150 000 ha of shrimp ponds in the country were built in mangrove areas. The major losses of mangrove occurred during the period 1969-1995 in three estuaries on the northern central coastline: Chone estuary (90% loss); Cojimies estuary (70% loss) and Muisne (79% loss) (Hurtado et al. 2000). These mangrove areas are now considered critical and endangered (Dinerstein et al. 1995). Mangroves in Peru, much less abundant than in Ecuador, were lost at similar rates as a result of the construction of shrimp farms and extraction of different aquatic biological resources (INRENA 1995, Sánchez & Orozco 1997).

In Chile some dune formations have been destabilised due to the elimination of vegetation cover, as a result of land reclamation including marginal settlements (Castro & Morales 1989). Urbanisation and agricultural activities were also factors in causing a loss of wetlands and coastal habitats in the region.

Modification of ecosystems

A moderate impact score was assigned to the issue because of the environmental impacts of mine discharges. On the Chañaral shore, in the north of Chile, 150 million tonnes of mining run-off was discharged into the bay in 1983-1984. This resulted in the reduction of the depth of the bay, a geomorphological deterioration and the total disappearance of macrofauna on sandy shores and rocky benthos (Castilla 1983). Copper concentrations of 16 630 ppm were recorded in soft ocean floor sediments (Castilla & Nealler 1978, Castilla 1983).

In the south of Peru, Toquepala and Cuajone mines have been discharging 90 000 tonnes per day of mining waste into the Locumba River at Inglesa Beach, Ite, over 33 years. This material was distributed along the beach, modifying the bottom and the habitat of marine organisms. The discharge of mining waste into the lowest 20 km of the Locumba River has also been documented.

In Ecuador, mollusc and crustacean habitats were lost in the Guayas and Chone rivers due to the destruction of mangrove forests to construct shrimp ponds. In the past decade closed seasons have been enforced to protect depleted stocks of clams (*Anadara tuberculosa* and *Anadara similis*), shrimps (*Litopenaeus* sp.) and the Mangrove crab (*Ucides occidentalis*) (GIWA Task team members pers. comm.).

Socio-economic impacts

Economic impacts due to loss or modification of ecosystems have not been well documented in the region. The sector most affected by mangrove ecosystem loss is the artisanal fishery, because the mangrove is the habitat of commercial fishes, molluscs and crustaceans. Shrimp aquaculture has also been affected due to the reduction in the mangroves capacity to cleanse water, the increase of coastal erosion and the loss of nursery grounds for shrimps, among other factors. The economic cost of replacing the loss of the mangroves water treatment function is estimated at 1 billion USD in Ecuador alone (Hurtado et al. 2000).

There are no available estimates for other habitat losses. Other modifications to ecosystems associated with mining activities have been documented, but socio-economic information is not available. Health impacts associated with the loss or modification of ecosystems have not been identified in the region. Social and community impacts include the reduction in the capacity of the region's ecosystems to meet basic human needs, lost employment opportunities, conflicts between the users, and inter-generational inequity. The rural population is affected directly but a chain of social impacts is expected.

Conclusions and future outlook

Certain human activities have caused serious impacts on the fragile coastal ecosystems of the region. These may have been avoided if basic ecological studies had been undertaken to assess the vulnerability of such communities to human activities. Besides pollution, already reviewed in the preceding section, the environmental impacts of other activities such as the construction of dams, port facilities and infrastructure on the coasts of the region were not considered. Inadequately planned and constructed infrastructure has obstructed river courses, drained wetlands and increased beach erosion.

The destruction of mangrove forests in order to construct shrimp ponds, was halted only following the outbreak of the white spot disease in 1999, which caused mass mortalities and a collapse of the industry. Although the virus was the etiological agent affecting the stocks, the most probable root cause was the poor management of soils and water during the previous two decades, which had caused disequilibrium in the ecosystem, allowing optimal conditions for the incubation of the virus and other pathogens. Today the industry is recovering and it is unlikely that former mangrove destruction activities will be resumed after the damage caused by the disease.

All of the countries in the region are now enforcing environmental standards to minimise the impacts of human activities. The exigency of environmental impact assessments in the planning of public infrastructure developments, as well as an increase of the public environmental conscience is favouring the adoption of environmentally friendly methods and technologies in order to limit the impacts of human activities on the region's ecosystems.

IMPACT Unsustainable exploitation of fish and other living resources

For more than 50 years the Humboldt Current region has been one of the most important fishing areas in the world. In 2000, catches from Peru and Chile accounted for 15 million tonnes, around 19% of global fishing production (FAO 2002a). The most fished species are the Peruvian anchovy *Engraulis ringens*, South American sardine (*Sardinops sagax*), Chilean jack mackerel (*Trachurus murphyi*) and the Chub mackerel (*Scomber japonicus*). The Peruvian anchovy accounts for the largest proportion of fisheries production by a large margin. However, changing environmental conditions are causing annual fluctuations and long-term changes in both fish abundance and distribution; and subsequently the total production of commercial species. For example, in Peru, the most commercially important fish species in the 1960s was the anchovy, a combination of the anchovy and sardine and, to a lesser extent, the Chilean jack mackerel and Chub mackerel in the 1980s, and the anchovy again in the 1990s. During the past five years the Peruvian fishing industry has been sustained to 90% by anchovy and sardine for the production of fishmeal (IMARPE 2002a)

Other important resources include several species of pelagic fishes such as tuna, shark and billfishes as well as demersal species including croakers and hake. Invertebrates include the Humboldt Current giant squid (*Dosidicus gigas*) and a great variety of tropical and temperate molluscs, crustaceans and echinoderms.

Environmental impacts

Overexploitation

Small pelagic fishery

Catches of the Peruvian anchovy peaked at 13.1 million tonnes in 1970 after which production declined from 1.7 million tonnes in 1973 to 94 000 tonnes in 1984 (Figure 8). Catches of other pelagic species such as the South American sardine, Chilean jack mackerel, and the Chub mackerel increased after the collapse of the Peruvian anchovy in 1973. This increase occurred simultaneously in other countries of the Humboldt Current region. The presence of other small pelagic fishes allowed the fish meal and oil industry to sustain production from the mid-1970s to the mid-1980s, although a small proportion of the sardine catches was canned. After this period, the stocks recovered, reaching 11.9 million tonnes in 1994, which decreased again to 1.7 million tonnes in 1998 due to the effect of the El Niño event of 1997-1998 (Figures 8 and 9).

The Peruvian anchovy is strongly dependant on environmental conditions and it is now known that in the long-term the species pass

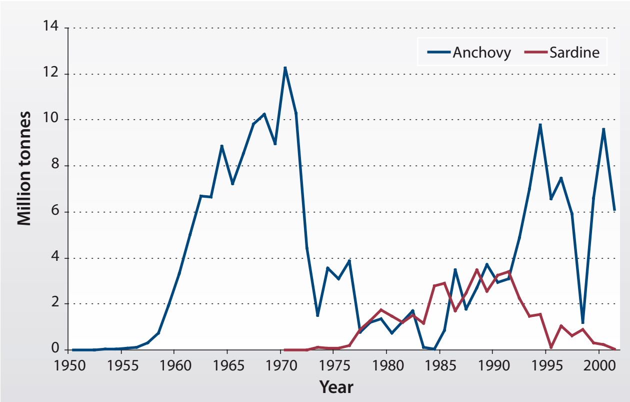

Figure 8 Peruvian catches of sardine and anchovy between 1950 and 2001.
(Source: GIWA Task team 2004)

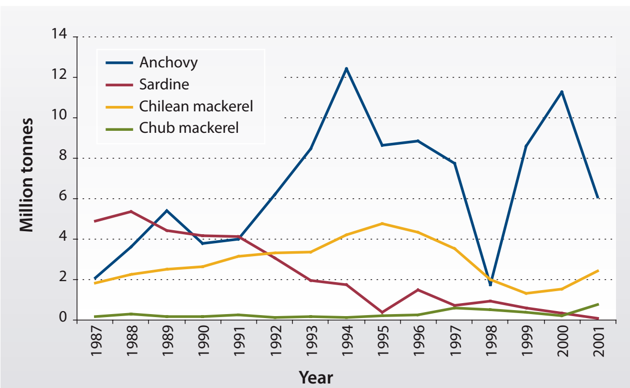

Figure 9 Catches of the small pelagic fish in the Southeast Pacific between 1987 and 2001.
(Source: GIWA Task team 2004)

through different stages of "equilibrium" and "population regimes". Because of its natural variability and poor resilience to intensive fishing effort, the FAO (1997) recommended adopting specific monitoring and control measures to prevent overfishing. Peru set a limited fishing quota during the second half of 1997 to maintain the biomass above 4 to 5 million tonnes in order to withstand the consequences of El Niño. Since 1999 landings of the Peruvian anchovy have increased again, reaching 10.8 million tonnes in 2000 and remaining constant through 2002. Several management measures are being taken by Peruvian authorities for this fishery, including quotas and closed seasons during the reproduction periods in February-March and August-September.

The South American sardine is the second largest contributor to small pelagic production after the Peruvian anchovy. As previously mentioned, the population of the South American sardine started to grow after the El Niño event of 1972-1973 and its consolidation in the system was assisted by the collapse of anchovy stocks. Catches grew almost exponentially during the 1970s reaching 3.3 million tonnes per year in 1979. After the El Niño of 1982-1983, landings continued increasing, reaching more than 3.5 million tonnes per year. Part of the anchovy fleet focused on the South American sardine to supply canning plants. In 1991, catches began a steady decrease to a low of approximately 100 000 tonnes per year (Figures 8 and 9). A population analysis of this species indicated that since 1986 there has been a steady reduction in recruitment (Csirke et al. 1996). By 1994 the South American sardine biomass (aged 3+ years) was around 2 million tonnes for the Peruvian north-central stock, whereas it was more than 10 million tonnes in 1987. An increase in the biomass of the South American sardine was observed during the El Niño event of 1997-1998, especially of immature fish (1 and 2 years) in 1998. However, the absence of anchovy made the fishing effort focus on other available pelagic resources, the most important being the South American sardine. After this period, its availability decreased and a declining trend continues. The decline of this species occurred in all the countries of the region. Peru has implemented quotas and similar closed seasons as for the anchovy.

The Chilean jack mackerel is another species with notorious changes in abundance and distribution. It is the main species of the Chilean fishing industry (Subsecretaría de Pesca de Chile 1998). There are no data on landings before 1970 since annual catches were barely over 30 000 tonnes per year. However, in the early 1970s this species began to appear consistently as by-catch in local artisanal and industrial fisheries. Chilean, Peruvian and the former Soviet fishing fleets began targeting it by the mid-1970s and 1980s. Catches increased to almost 5 million tonnes in 1995 (Figure 9). Because of its transboundary regime and the possible existence of subpopulation units, it has not been possible to make an assessment of its real level of exploitation. FAO (1997) characterised this resource as moderately and strongly exploited in the South East Pacific, which indicates that the fishery is operating at, or close to, its optimal yield level. From 1996, catches continued to decrease to 1.5 million tonnes in 2000. It is expected that this tendency will continue in the near future.

Catches in the region of Chub Mackerel before 1970 were between 10 000 and 30 000 tonnes per year. They rapidly increased to 836 000 tonnes in 1978. Between 1988 and 1994 the maximum catch was 402 000 tonnes in 1990 and then decreased to 79 000 tonnes in 1994 (Figure 9). Landings increased again by the end of the 1990s. Mackerel species have been used for human consumption, fishmeal and oil production. However, in 2002, the Peruvian government issued a decree declaring that these species can be used only for direct human consumption.

Other important small pelagic resources in the region include the Araucanian herring *(Strongomera benticki)*, the Pacific thread herring *(Opisthonema* spp.*)* and the Eastern Pacific bonito *(Sarda chilensis).*

Purse-seine tuna fishery

Ecuador has the largest tuna fleet in the tropical Eastern Pacific. Statistics for the period 1990-2000 show an increasing trend in catch volumes (Figure 10). The most important species is the Oceanic skipjack (*Katsuwonus pelamis*) accounting for 62% of the catches in 2000, and also the Yellow fin tuna (*Thunnus albacares*) (22%) and Big eye (*T. obesus*) (16%) (CPPS 2003a). The health of the tuna purse-seine fishery is better than other fisheries in Ecuador, and catches peaked in 1999 at 198 000 tonnes. This unique fishery is under a regional management framework and monitored for its sustainability through the Inter American Tropical Tuna Commission (IATTC).

Demersal fishery

The primary species in the demersal fishing include the South Pacific hake (*Merluccius gayi*) and, more recently, the Patagonian grenadier (*Macruronus magellanicus*) and the Patagonian hake (*Merluccius polylepis*). Catches of these and other demersal fish such as sciaenids, eels and several other coastal species peaked in 1988 with 550 000 tonnes. Total catches then decreased, to 320 000 tonnes in 1993, and increased to 415 000 tonnes in 1994. In Peru, a closure of the South Pacific hake fishery lasted until 1994. The fishery was closed again in September 2002. In this case, overfishing resulted from intensive fishing effort and environmental conditions in combination (IMARPE 2002b). Demersal resources show a variable degree of exploitation. However, there are indications that the availability and abundance of some species are decreasing compared to past decades.

Giant squid fishery

The most important fishery of the Giant squid (*Dosidicus gigas*) occurs along the coast of Peru. Catches increased significantly from 10 000 tonnes in 1989 to at least 200 000 tonnes in 1994. Catches have fluctuated in the past decade. Its wide distribution indicates that the population has two or three sub-populations available for exploitation. The level of exploitation may be considered as under-exploited to fully exploited. Environmental conditions play an important role in giant squid availability. There is no national fleet specialised in optimising catches. In the past years authorised foreign vessels in Peru and Ecuador and part of the artisanal fleet have been involved in its exploitation. In 2002 the biomass of giant squid was estimated to be at least 800 000 tonnes.

Shrimp trawling fishery

This is carried out only in Ecuador by a fleet of 197 vessels (Subsecretaría de Pesca de Ecuador 1997). The shrimp production can be correlated with thermal anomalies; positive during El Niño and negative during La Niña. During the El Niño years of 1982-1983, and 1987, catches surpassed 8 000 tonnes and in 1992 were over 13 500 tonnes (Figure 11). However, during the El Niño of 1997-1998 catches were below the average of the 1990s and even the 1980s. In general, since 1992 there has been a decreasing trend in wild shrimp catches. Coello (1996) characterised this fishery as overexploited by the mid-1990s, indicating that it surpassed the annual maximum production predicted and recommended effort, estimated at 1 500-1 800 tonnes, by two to four times. This fishery is also responsible for large amounts of discards (Little & Herrera 1991).

Aquaculture

The major aquacultures in the region are white shrimp farming in Ecuador and the north of Peru and the culture of salmonids, and to a lower degree the farming of molluscs and algae in open areas in the south of Chile. The Ecuadorian shrimp culture started in the 1970s, reaching its highest production levels of 154 000 tonnes in 1998 (Figure 11). The activity extended over 180 000 ha of saline and mangrove areas with land ponds. During the 1990s farms experienced several epidemics, but it was the white spot disease that led to the collapse of the industry in 2000 when production decreased to 50 000 tonnes. In contrast, aquaculture production in Chile has been steadily increasing since the 1980s. In 2001 the aquaculture production

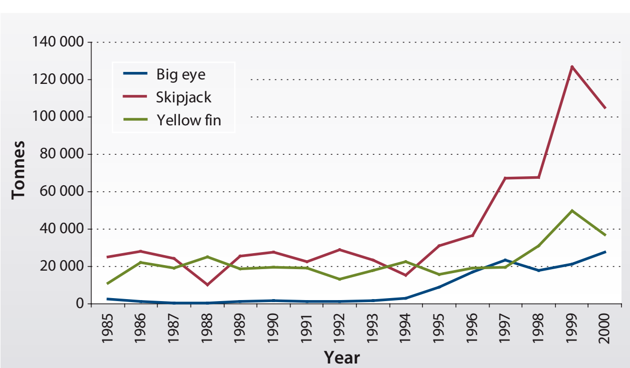

Figure 10 Catches of tuna by the Ecuadorian purse-seine fleet.
(Source: GIWA Task team 2004)

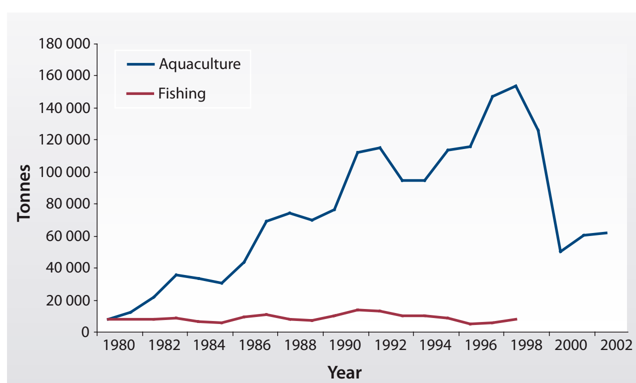

Figure 11 Total shrimp production in Ecuador.
(Source: GIWA TAsk team 2004)

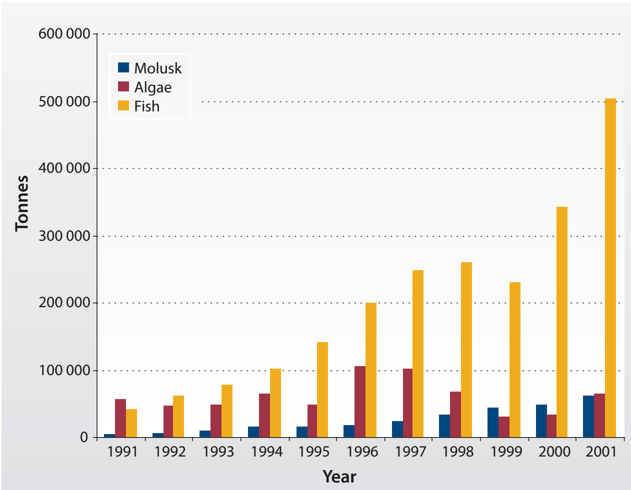

Figure 12 Aquaculture production in Chile.
(Source: GIWA Task team 2004)

reached 631 600 tonnes, an increase of 600% with respect to 1991, with 1 770 aquaculture facilities (CPPS 2003a) (Figure 12).

Artisanal fishing

Artisanal fishing production is an important contributor to the region's economy. There are 280 landing sites in Chile, 138 in Ecuador and 182 in Peru. It is estimated that there are around 150 000 artisanal fishermen and around 50 000 fishing boats in the region (CPPS 1999). Artisanal fishermen in Ecuador target large pelagic species such as shark, tuna, billfish and dolphin fish, as well as coastal, reef and estuarine fish (sciaenids, gerrids, etc.) and invertebrates (shrimp, clams and crabs). Peruvian fishermen target mainly demersal fishes such as hake, croakers, coastal fishes and invertebrates (scallops, clams) and the Giant squid. Chilean artisanal fisheries target hake and the Patagonian grenadier and a great variety of coastal fish and invertebrates (scallops, sea urchin, mussels, clams, oysters). Most of the artisanal catches are for local consumption.

Excessive by-catch and discards

The South East Pacific area was identified as being fourth place in terms of discards among the world's fishing zones, with 2.6 million tonnes (Alverson et al. 1996). Although the Peruvian anchovy and the South American sardine fisheries have very low by-catch rates (1-3%), the shear size of fishing volume generates several hundred thousand tonnes of discards. There are no official reports in the region on discards in industrial fisheries since purse-seine vessels are not obligated to keep records, except for the tuna fleet, whose fishery is under the control of the Inter American Tropical Tuna Commission (IATTC).

The shrimp-trawling fishery has an extremely high rate of discards. Little and Herrera (1991) estimated that between March and November 1991 the trawling catch in Ecuador was 15 700 tonnes, of which 11 700 tonnes (75%) were discards. Coello (1996) also referred to the underutilisation of shrimp trawling by-catch and noted the impacts on other demersal resources. Kameya et al. (1991) reported that the high rate of discards in the shrimp-trawling fishery in the north of Peru included 219 species: 124 of fish, 75 molluscs and 20 crustaceans. Sea turtles in particular (*Lepidochelys olivacea*) have been exploited and by-caught during the last three decades. Little and Herrera (1991) estimated sea turtle by-catch between 8 178 tonnes and 11 064 tonnes per year. International pressure obliged Ecuadorian authorities to enforce the use of Turtle Excluding Devices (TEDs) on shrimp trawlers by the end of the 1990s.

The mortality of thousands of small cetaceans every year in gill nets and other artisanal gear has been documented in Ecuador (Félix and Samaniego 1994), Peru (Read et al. 1988, Van Waerebeek & Reyes 1994) and Chile (Lescrauwaet & Gibbons 1994). The mortality of cetaceans in the Peruvian purse-seine fishery was estimated to be 0-0.13/task (Bello 2001). The most affected species in Ecuador and Peru is the Common dolphin (*Delphinus* sp.). Some management measures have been implemented in the region to reduce interactions of the South American sea lion (*Otaria flavescens*) with fisheries. Marine bird mortalities occur at a rate of one to two birds per 1 000 hooks in Peruvian waters (Jahncke et al. 2001).

In Peru, there were also significant discards from the hake fishery by the mid-1990s, accounting for 20% of the total volume. Later, when a market developed for small-sized species, discards decreased significantly (IMARPE 2002a).

Destructive fishing practices

The use of destructive fishing practices in the region is under-reported. In Ecuador the shrimp trawling fishery operates 15-22 days every month, 10 months of the year (Coello 1996), which implies a constant mobilisation, suspension and mixing of marine sediment in areas where such activity is conducted. There is no information, however, about the impact of this fishery on benthic communities. Another negative aspect of the shrimp industry in Ecuador was the shrimp post-larvae fishery carried out on beaches and in estuaries using fine-meshed nets that produce 80% by-catch: larvae and juvenile fishes (8.3%), non-commercial penaeids (10.5%), commercial penaeids (18.5%) and other crustaceans (62.7%) (Gaibor et al. 1992). The impact on the wild populations of both shrimps and non-target benthic species of fish, crustaceans and molluscs is unknown in the region.

In Peru a depletion of fishing resources and changes in the composition and abundance of species in coastal areas has been observed. This is attributed to the deterioration of coastal ecosystems due to the trawling fishery employing non-selective fishing gear and the use of purse-seine nets with a fine mesh that catch juveniles. Also, industrial vessels invade the fishing areas assigned to the artisanal fisheries and provoke conflicts. Authorities in Peru have started to investigate the use of explosives in both industrial and artisanal fisheries, since this practice is increasing (IMARPE 2002a).

Decreased viability of stock through pollution and disease

Diseases caused by bacteria, fungus and viruses in cultured shrimp (*Litopenaeus vannamei*) in Ecuador and Peru are periodically reported. Productivity has decreased as a result of mass mortalities and reduced growth rates. Figure 13 shows the reduction in the productivity of shrimp ponds in Ecuador and its relationship with the presence of pathogens. According to Jiménez (1996), between 1989 and 2000 three periods of low productivity occurred: in 1989, the seagull syndrome, associated with bacteria (*Vibrio* sp.); in 1992, Taura syndrome (associated with pollution by two fungicides used in banana agro-industry and a virus (TV); and in 1999, the white spot disease (WSSV). Annual losses of 600 million USD have been reported as a result of these diseases (CNA 2002). Moreover, the presence of the white spot virus in several marine organisms has been reported, indicating that wild shrimp populations are also at risk. This could explain the drop of wild shrimp catches in Ecuador after 2000.

Impact on the biological and genetic diversity

Introductions of alien species with culture purposes or through ballast waters has been a matter of concern in the region because of their ecological implications (CPPS 2003c). Around 400 species including fish, reptiles, crustaceans, plankton, among others, have been introduced either on purpose or accidentally in the countries of the region.

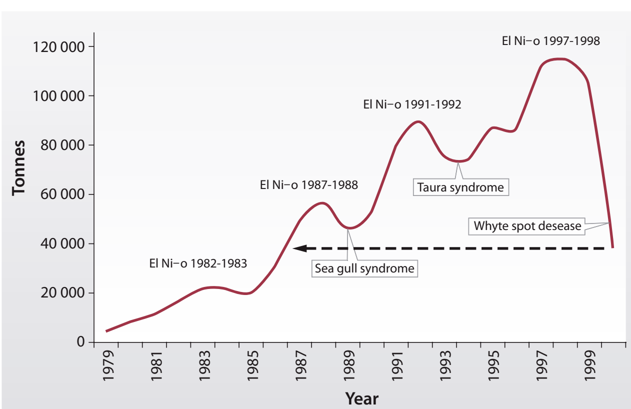

Figure 13 Decreased shrimp production as a result of pathogens.
(Source: CNA 2002)

In Ecuador, the better-documented case is the Tilapia, an African and Middle Eastern species, acquired in Brazil, and today a species commonly found in Ecuadorian rivers. Its presence in the Chone River wetlands has provoked the displacement of the local species Chame (*Dormitator latifrons*) (Coello 1996). Another alien species is the Bullfrog (*Rana catesbiana*), a North American species brought to Ecuador from Brazil. Alien species used for culture purposes in Ecuador include the Bullfrog, the mollusc *Argopecten circularis*, Paloma pompano (*Trachinotus paitensis*), Brine shrimp (*Artemia salina*), the zooplankton *Brachionus plicatilis* and the diatom *Dunaliella tertioleta* (Jiménez 2000). Although the magnitude of the impact on native populations is unknown, an indirect affect could also occur due to the introduction of pathogens of diverse types such as intra-cellular bacteria, protozoan, bacteria and virus (Jiménez 2000). It is estimated that at least 15 alien species have been introduced in Ecuador.

In Peru, alien species in the coastal marine environment have little significance in relation to alien species in continental waters. Cánepa et al. (1998) reported 32 species, 14 in the coastal marine environment (11 micro algae and three fish and molluscs) and 18 in the continental environment (16 fishes and two crustaceans); seven of them failed to adapt to the continental environment, and one fish species *Prochilodus argenteus* is maintained in quarantine. Three species were intentionally introduced for culture purposes, one accidentally and seven in other ways. The alien oyster *Crassostrea gigas*, besides competing for space and food, could affect native species such as *C. columbiensis* and *C. corteziensis* because of its larger size and high egg production (5 070 million) with the risk of forming hybrids and causing negative effects in the genetics of local populations (Canepa et al. 1998). The Argentine pejerrey (*Basilichthys bonariensis*), because of its feeding habits, high fecundity (70 000 eggs) and ethology, is seriously affecting local populations, putting several of them in danger. The Rainbow trout (*Oncorhynchus mikiss*), due to its carnivorous nature, has put the native species Ictia suche (*Trichomicterus rivulatus*) at risk.

In Chile, Báez et al. (1998) reported 332 alien species for economic, recreational or ornamental purposes as well as for experiments and demonstrations: 14 micro algae, two macro algae, three cnidarians, six molluscs, 11 crustaceans, four echinoderms, 287 fish, one amphibian, and four reptiles. 43 of these species were introduced in the marine environment. Alien species introduced include algae *Porphyra* spp., *Spirulina* spp.; molluscs *Pecten maximus, Crassostrea gigas, Haliotis rufescens*; crustaceans *Litopenaeus vannamei*; and several species of fish *Coregonus* sp., *Salvelinus* sp. and *Salmo* sp., among others.

Socio-economic impacts

The fishing sector plays an important social and economic role in the Humboldt Current region since thousands of people depend on it directly or indirectly. For local economies, fisheries are one of the most important export products, accounting for a major proportion of the GDP.

In Ecuador, fishing and aquaculture products were the second largest export in 1998 (1 200 million USD), even higher than petroleum (920 million USD) (Hurtado et al. 2000). After 1999, these products decreased to 660 million USD in 2001; 53% lower than in 1998 and 23% lower than the average exported in the 1990s (820 million USD). The reduction was mainly in shrimp production because of white spot virus disease, which had previously been affecting the cultures. Despite this dramatic decrease, fishing and aquaculture products represented 21% of the total export during the 1990s and 14% in 2001 (BCE 2002), indicating that they are still an important sector of the Ecuadorian economy. In the period 1980-2001, 12.1% of exports corresponded to shrimp (cultured and wild), 3.7% to industrialised fishing products (fish meal, canned and others), 0.8% to tuna, and 0.6% to other fishes.

In Peru, the statistics of the Central Reserve Bank (BCRP 2002) for the period 1992-2001 show that exports from fishing are second after mining, but more than agriculture, petroleum and industry products. Fishing represented 16.8% of the total exports with an annual average of 944 million USD, contributing 0.57% to the GDP. During 2001 fishing exports reached 1 123 million USD or 16% of total exports, 19% more than the average recorded between 1991 and 2001, and contributing 0.49% to the GDP. It is estimated that during 1999 more than 80 000 people worked in fishing and aquaculture in both extraction and processing activities, which represents 0.9% of the urban working population in Peru (FAO 2000b).

In Chile, fishing and aquaculture exports between 1996 and 2001 produced an average annual income of 986 million USD, which represents 5.6% of total Chilean exports (BCCL 2002). Fishing products are the third most important export after fruits (7.5%) and cellulose, paper and others (6.3%). In 2001, landings reached 4.66 million tonnes, of which 4.15 million tonnes were of fish (89%); 299 800 tonnes of algae (6.4%); 138 400 tonnes of molluscs (3%); 26 100 tonnes of crustaceans (0.5%); and 48 200 tonnes of other species (1%). Fishing exports in 2001 totalled 1 010 million USD or 5.5% of the total, and 2.5% more than obtained in the period 1996-2001. Fisheries in Chile contribute 1.4% to the GDP.

Losses from overfishing have been identified in some sectors. For example, the white spot disease produced losses estimated at 270 million USD in 2000, 59% less than the total export of 1999 (CNA 2002). There is no available information about the social impacts but it is evident that serious repercussions were derived from such a drastic reduction when more than 50% of the farms ceased operating, also affecting many related activities.

For decades artisanal fishermen have exploited marine resources under a free access regime, which is known to have negative long-term consequences for both resources and the associated economic activities (CPPS 1999). Such a regime would be the cause of alterations in coastal resources and ecosystems. Overfishing of coastal resources has often ended through the establishment of closed seasons for formerly important products. However, the economic impacts of such a policy are not always significant because the artisanal fishing sector is highly versatile and has found other alternative resources. Furthermore, the artisanal fisheries products are mainly consumed locally and generally commercialised directly on the beach, making it difficult to monitor catches. In Ecuador the clams *Anadara tuberculosa* and *A. similes* and the crab *Ucides occidentalis* are considered overexploited based upon reductions in their market price, however their fishing potential, fishing effort and level of exploitation remains unknown (Coello 1996). In Chile the first sign of crisis for the artisanal sector produced a long closed season for the most important benthic resource of the coastal zone, the Rock barnacle (named Loco) (*Concholephas concholephas*), in operation for three years between 1989 and 1992. The establishment of a second closed season for the South Pacific hake in Peruvian waters is another example of a response to the overexploitation of coastal resources.

Conclusions and future outlook

Most of the pelagic and coastal fisheries resources in the South East Pacific are fully or overexploited (FAO 1997). The decline of some fisheries is caused by several factors including: overdevelopment of the fishing effort (fleet, number of fishermen); critical habitat modification, especially estuaries and mangroves in the coastal environment and the continental shelf in the oceanic environment; pollution from land-based sources; environmental forces; and the lack of integrated fishing management policies with an ecosystem approach. It is evident that the sustainability of fisheries in the region is strongly dependent on future management measures to bring the fisheries under appropriate control.

The Peruvian anchovy, the South American sardine and the Chilean mackerel provide striking examples of the relationship between environmental conditions and resource availability. Overfishing produces a synergistic effect inflicting further damage to the ecosystem and causing important socio-economic impacts for the coastal populations of the region, especially during El Niño events. The fragility of the Humboldt Current ecosystem to environmental forces has become increasingly evident as scientific knowledge of this highly complex ecosystem increases.

IMPACT Global change

Environmental impacts

Changes in the hydrological cycle and ocean circulation

It is expected that extreme natural events, such as El Niño, will increase in frequency and intensity as a result of global change. The El Niño Southern Oscillation (ENSO) is a global ocean-atmospheric anomaly event responsible for significant climate, oceanic, biological and ecological changes. The countries of the region particularly affected by El Niño are Ecuador and Peru.

An example of the negative effects of flooding is the Daule River in Ecuador, which increased its flow from 50 to 1 200 m^3/s. Rain and subsequent flooding covered and destroyed 185 000 ha of agricultural land. The risk for human health increased, roads were destroyed and the life quality of both rural and urban populations deteriorated. In the ocean, environmental changes impacted the small pelagic fish fisheries. In 1983, a 50% reduction of the total catch was recorded.

Sea-level change

Since approximately 20% of the population in the region lives in cities next to the sea, the issue of sea-level change is of primary concern. There is evidence that the sea in at least one place in southern Chile has been rising steadily for decades (CPPS/PNUMA 1997). Besides flooding, the sea-level rise will compromise productive activities such as trading ports. In addition, agriculture, coastal springs and wetlands will be affected by saltwater intrusion and the disposal of domestic and industrial wastes will be obstructed. Because the region is located on a seismic area, vertical movements of tectonic plates may either mask or increase the problems.

An increase of the sea level by more than one centimetre could mean a coastline retreat of between 50 cm and 1 m in low lands, especially affecting estuaries and tourist beaches. The forecast increase by 2025 will erode the northern beaches of Chile (Teves et al. 1992). Extrapolating the sea-level rise at a rate of 10 cm per each 0.5°C increase will produce an average increase in Chile between 20 and 80 cm in the next 100 years, affecting most of the 4 000 km long coast. The sea-level rise will exacerbate damage caused by floods and increase the height of waves. Changes in several coastal processes such as littoral currents, wave breaking points and arrival direction, and the movement of sediments along beaches will change the sediment balance. Similar events could affect estuarine channels, causing variations in the water volume exchange in each tidal cycle (CPPS 2000a).

Expected impacts on biological components of the region caused by the rises in sea level and temperature, evaluated by the GIWA Task team and coordinated by CPPS, include:

- Changes in the composition of phytoplankton with lower values in cell counts and the dominance of diatoms constrained in a narrow coastal strip.
- Changes in the abundance of oceanic species in the coastal plankton.
- Presence of tropical species in the oceanic nekton.

These changes will seriously impact pelagic fisheries in the region, causing the disorganisation of schools, changes in abundance and distribution patterns, and affect the reproduction and survival of eggs and larvae. Furthermore they will result in a decreasing biomass and the creation of ecological gaps together with an alteration of the prey/predator balance. Some species will experience an extension of their distribution range, and the whole ecosystem will be subject to noticeable eutrophication.

The warming of the equatorial areas might cause the movement of the benthic and pelagic fauna toward more temperate waters. In Chile, the increase of upwelling and its southward expansion is expected, with a consequent increase of the pelagic fishery, invasion of tropical species and probable changes in the food web (Aguilera et al. 1992). In Peru, global warming will produce similar effects as those produced during strong El Niño events. The anchovy, the main fishing resource, will move southwards or downwards to colder waters. The sardine, although more resilient, may do the same. The Chilean jack mackerel and the Chub mackerel would migrate nearer to the coast, becoming more accessible for fishing. The effect on these species is in general negative, with a tendency of reduction of size in the native species and an increase of tropical ichthyofaunal diversity. The native benthic ichthyofauna will also be negatively impacted.

Increased UV-B radiation as a result of ozone depletion

The increase of radiation may have serious effects on cattle farming and human populations, especially in the southern areas of Chile where this has been reported. There is no evidence of such impacts in Ecuador or Peru.

Socio-economic impacts

Extraordinary ENSO events are the only issues so far documented in the region from a socio-economic perspective. In Ecuador, the ENSO of 1982-1983 provoked an economic impact of 165 million USD (CEPAL 1983). The social sector (including houses destroyed or damaged, environmental damage, health, and education) was 13.1 million USD. The transport sector lost 75.7 million USD, including destroyed and damaged bridges, roads, urban infrastructure, and railroads. Agricultural, livestock and fisheries sectors lost 41.9 million USD. Industry, including infrastructure, lost 25.2 million USD. Other sectors reported losses of 8.8 million USD.

The ENSO event of 1997-1998 caused a loss of 533 million USD in Ecuador and 3.5 billion USD in Peru. The main sectors affected were agriculture and transport in Ecuador and agriculture, fishing, mining, industry and commerce in Peru (Tables 5 and 6).

The effects of climate change on the socio-economic system in Chile will be more significant in the more crowded districts located from the central toward the south-central areas, that will suffer flooding and the effect of waves. 50% of the artisanal fishermen in the south-central regions would be especially affected because of the change in distribution of targeted species, which will produce a migration of the fisher population and a change in the labour structure due to employment substitution. In coastal areas the occlusion of draining systems is expected, provoking sanitation problems in the future (CPPS 2000a).

In Peru, global warming and the rise in the sea level will affect coastal settlements of Lima located between Punta Chorrillos, Villa and Chimbote City, involving thousands of fishers. The same will occur in small coastal villages in the northwest such as Zorritos, Cabo Blanco, Matacaballo, Parachique and the village of San Andrés in the Pisco zone. Freshwater caption will be affected as well as the coastal recreational infrastructure. Losses of beach area at Ventanilla are estimated at 7 million m^3. Between Callao and La Punta, basic infrastructure of both maritime transport and fishing will be lost (CPPS 2000a).

Table 5 Estimated monetary losses caused by the 1997-1998 El Niño in Ecuador.

Sector	Monetary losses (million USD)
Agriculture	167
Shrimp	68
Finfish fishery	6
Agro-industry	16
Transport infrastructure	204
Energy	19
Tourism	88
Urban infrastructure	3
Housing	36
Sanitation	36
Education	20

(Source: CPPS 2000a)

Table 6 Estimated monetary losses caused by the 1997-1998 El Niño in Peru.

Sector	Monetary loss (million USD)
Housing, education and health	485
Water supply, sanitation and transport	955
Agriculture, fishing, mining, industry and commerce	1 600
Public infrastructure, prevention and emergency activities	433

(Source: CPPS 2000a)

In the future, health and social and community impacts are expected to increase due to sporadic extreme events that will cause damage to human life and property, increased costs of emergency response, unemployment and income loss, and migration among others.

Conclusions and future outlook

Global change, as in other areas of the world, will have a strong effect in the Humboldt Current region. Forecast impacts, especially those on coastal areas, suggest enormous economic losses to infrastructure and the collapse of public services. A rise in sea level and UV-B radiation are the main threatening features of the Global change concern because of their direct effect on the population regarding health and economic aspects. Impacts on the biodiversity and therefore on ecosystem stability could render the region more susceptible to overexploitation of marine resources. Consequently, poverty and general social problems in the region will increase. There are few remaining alternatives for countries facing this problem since the majority of causes of global changes originate in the more industrialised regions of the world.

Priority concerns

The ranking of concerns according to the GIWA overall scores gave the following order of priority:

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

The Task team did however consider that this ranking was not adequately describing the situation in the Humboldt Current region and therefore changed priorities for the Causal chain and Policy option analyses. Pollution and Unsustainable exploitation of fish and other living resources were prioritised because of impacts on socio-economic issues and other concerns.

Among the Pollution issues, microbiological pollution was considered the most important because of the large amount of domestic wastewater discharged without treatment. The potential health risk is a matter of permanent concern. Chemical pollution was ranked in second place for similar considerations; industrial effluents are discharged without appropriate treatment. Suspended solids were not considered as a major issue despite the low level of sanitation coverage in the region. Spills ranked low because the level of marine contamination is negligible and because the impacts on sensitive areas have been minimal. Eutrophication received an underestimated score considering the amount of fertiliser imported to the region. Thermal and radionuclides have no evident impacts at present. Both urban and rural populations are affected by domestic and industrial pollution, although marginal urban settlements are particularly vulnerable to biological and chemical contamination. Prevention and mitigation measures are necessary to implement in the short-term to reduce the levels of microbiological pollution, their health impact and their economic cost. The lack of institutional capacity in local governments to adopt stronger environmental standards and the scarcity of funds are the principal obstacles to implement remediation measures.

Unsustainable exploitation of fish and other living resources was considered as the second priority concern. Overexploitation was considered the most severe environmental issue with high economic and social impacts because of the importance of the fishing sector to the regional economy. The fishing industry is a major source of direct and indirect employment for the coastal population. A collapse of the fisheries would affect other related sectors producing a domino effect in the economy of the Humboldt Current region. The vulnerability of the Humboldt Current ecosystem to environmental forces, especially to the El Niño event, has obligated the adoption of management strategies with regional approaches to avoid the collapse of the industry.