

Causal chain analysis

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

Pollution (i.e. microbiological and chemical pollution) and Unsustainable exploitation of fish and other living resources (i.e. overexploitation) constitute the priority concerns of the Humboldt Current region because of their present and future environmental, economic, social and health impacts. These two concerns are affecting the productivity of coastal ecosystems and reduce the yield of the fisheries in a region that is highly dependant on its fishing industry. In this section the analysis of sectors involved in pollution and unsustainable exploitation of fish are analysed to evaluate the root causes of these problems.

Pollution

Immediate causes

The immediate causes of Pollution are microbiological and chemical pollution (Figure 14). Microbiological pollution stems mainly from

untreated wastewater. In Ecuador, 95% of the domestic wastewater is discharged without treatment; in Peru, 86%; and in Chile, 83%. (WHO/UNICEF/WSSCC 2001, Arauz & Campaña 1986 in CPPS/UNEP/IOC 1988).

Major sources of chemical pollution affecting aquatic environments 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.

Sectors

Urbanisation

Untreated domestic wastewater has been identified as the main cause of deterioration of the microbiological quality of water in the Humboldt Current region. This statement is based on the analysis of the level of coverage of the sanitation services and the different structures deployed to discharge wastewater (including submerged pipes, shore discharges etc.). It is estimated that around 1 360 million m³ per year of wastewater is discharged into the South East Pacific Ocean with a pollutant charge of 1.76 million tonnes per year of BOD₅ and 818 900 tonnes per year of COD. The pollutant discharge also includes 414 900 tonnes per year of suspended solids, 55 300 tonnes per year of nitrogen and 6 650 tonnes per year of phosphorus (Escobar 2002).

Major polluted areas of the region are located in coastal areas of Ecuador (Guayaquil, Santa Elena Peninsula, Bahía de Caráquez) and Peru (Lima, Callao, Chimbote) and are characterised by having high levels of total

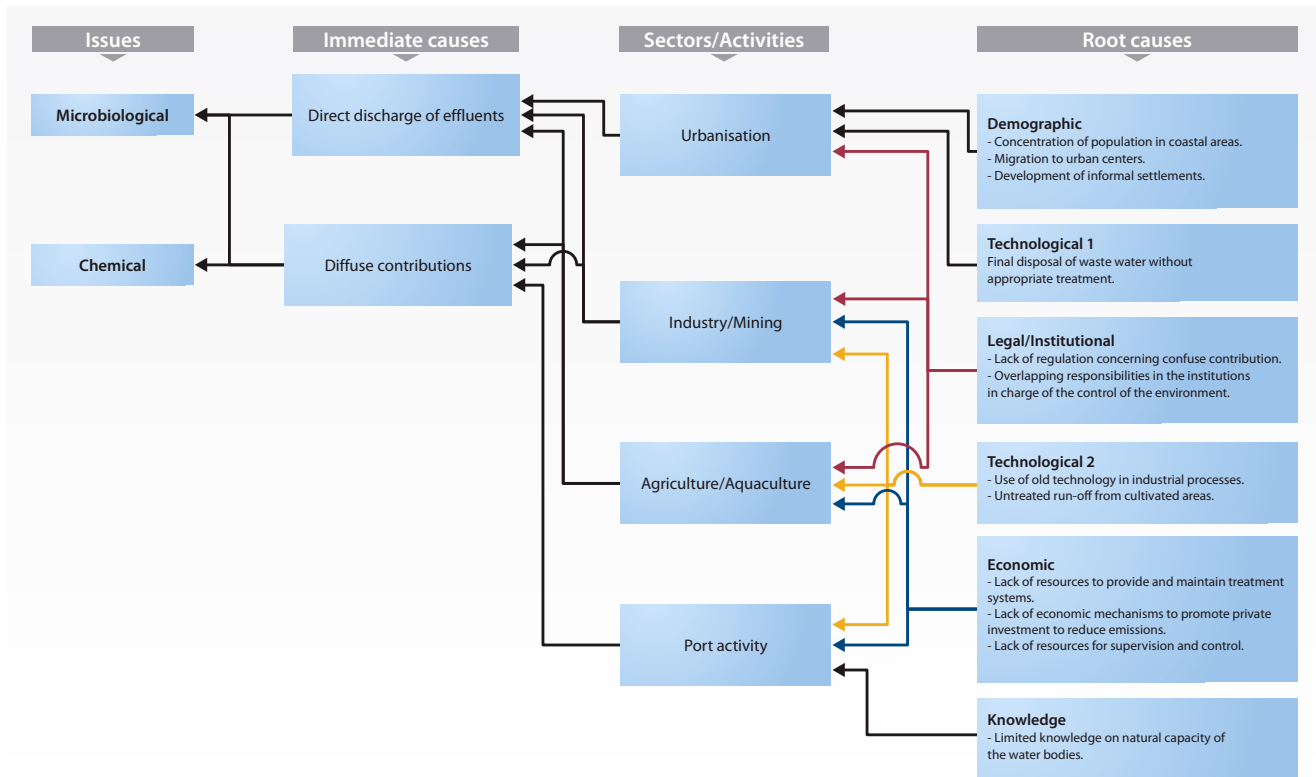


Figure 14 Causal chain diagram illustrating the causal links for Pollution in the Humboldt Current region.

and faecal coliforms and other pathogenic diseases of high risk for human health and the ecosystem, such as cholera, hepatitis, and several other gastrointestinal disorders. Higher infant morbidity and mortality rates found in these countries are related to the low coverage of both drinking water and sanitation services. Pathogens disseminate through water and, at least in the case of cholera, inflict serious transboundary impacts. Around 800 000 cases of cholera were reported in the region by OMS (2002) in the period 1991-2001. Cholera vibrión can survive a long time in faecal material in the soil and for several months in shellfish and fish. In 2001, Peruvian environmental health authorities closed the entire Paracas Bay zone for the culture of scallops due to the presence of the hepatitis A virus and established a surveillance system. The European Union prohibited the importation of scallops from Peru.

In Chile the issue of microbiological pollution is not as critical as in Ecuador and Peru. Despite the fact that 82% of the municipal wastewater discharged into the sea through rivers (Elqui, Aconcagua, Maipo, Mapocho, Bio Bio and Valdivia, among others) the average concentration reported in seawater during the period 1999-2003 did not surpass 2 500 faecal coliforms per 100 ml. The situation has improved in the past decade mainly due to the implementation of environmental management mechanisms and the installation of treatment systems by Chilean industries (Universidad de Chile 2002).

Industry and mining

Discharges through sewerage systems do not only contain domestic wastewater and other similar wastes from human activities such as commerce and services, but in many cases wastewater from industrial processes (CPPS 2000a). In fact, most of the industrial wastewater is discharged through municipal sewerage and transported by rivers to the ocean. The composition of these wastes is quite variable and depends on other factors such as the nature of the industrial activity, the technology used and raw matter quality. Thus, residuals may vary from those with high content of bio-degrading organic matter such as those produced by slaughterhouses, fishing plants or food industries to others with a higher proportion of chemicals such as tanneries and cellulose.

Mining activities constitute a source of chemical pollution due to the use of outdated methods and equipment and the inappropriate disposal of leachates. For example, the presence of mercury is characteristic in zones of artisanal mining in areas such as Zaruma and Portovelo in Ecuador and in the Peruvian Sierra. Furthermore, rivers transport large amounts of suspended sediment from dredging and monitors (water cannons) in gold mining to coastal areas (Escobar 2002). Variable concentrations of copper (Cu), lead (Pb), mercury (Hg), zinc (Zn), cadmium (Cd) and chromium (Cr) are found in the water, sediments and organisms of the region, with critical areas located in

the mining regions of northern and central Chile and southern Peru. Smoke, vapour and sulphuric gases from melting plants and refineries are sources of air pollution, particularly in Chile (CPPS 2000a).

Agriculture and aquaculture

Several farming activities including agriculture, livestock and particularly aquaculture are responsible for the introduction of large amounts of organic matter to the water bodies, increasing the risk of pathogen development, with subsequent affects on production. In 2000, Chilean aquaculture produced 342 million tonnes of salmon and trout, producing residuals equivalent to domestic wastes of around 10 million people. Pollution of estuarine waters has favoured the presence of several pathogens that affected shrimp farms in Ecuador during the 1990s with considerable economic losses (CAN 2002). The use of polluted water for agriculture irrigation has been identified as a problem in several areas and related to cases of hepatitis, intestinal infections and malaria (Carrera de la Torre 1993).

Farming activities are also responsible for the introduction of fertilisers, pesticides, antibiotics and sediments into coastal waters through run-off. Farming uses around 70% of the water resources of the region and has been identified as one of the main sources of diffuse pollution of freshwater, estuaries and coastal areas (Escobar 2002). Large-scale pesticide use has introduced considerable amounts of chemicals in rivers and coastal waters in the centre of Chile, the south of Peru and the Gulf of Guayaquil in Ecuador (CPPS 2000a). Between 1990 and 1998 an annual average of 15 500 tonnes of pesticides were used in the region; the majority of pesticides are organophosphates (64%) and chlorinated hydrocarbons (32%) (UNEP 1999). Besides introducing chemical contaminants to sediments, surface and groundwater resources, agricultural run-off causes erosion and soil loss (Escobar 2002).

Port activity

Activities developed by the maritime sector are a source of chemical pollution, such as hydrocarbons and heavy metals, around the major ports in the region. Operational failures during the loading and unloading of diesel and the pumping of bunker and cesspool waters release hydrocarbon residuals into the seawater. Chemical spills, such as sulphuric acid and phenol, have been reported in Chile (DIRECTEMAR 2003). Other sources of pollution include the maintenance of vessels in dry docks, dredging and waste reception facilities.

Root causes

Pollution is a significant problem for the Humboldt Current region as a consequence of the development of human activities in the coastal areas. Although important headway has been made in the

assessment of the level of environmental pollution, and to a lesser degree the impact on the biota and human health, an analysis of the root causes shows that the problems originate from social, economic and cultural aspects. Rectifying these problems will require not only political measures, but also large economic resources from both the government and private sectors in the fields of sanitation infrastructure, environmental education and health assistance.

Demographic

Like the rest of South America, the Humboldt Current region shows a strong trend towards urbanisation. Between 1990 and 2000, the urban population of the region increased from 69% to 74% on average (WHO/ UNICEF/WSSCC 2001). The population growth rate in the region (1.2-1.6%) has however decreased steadily during the past three decades. The concentration of the poor population along the coastal margins and the proliferation of settlements around urbanised centres are major root causes of pollution in the region. In the majority of the countries, migration to urban centres is due to the decline in the agricultural sector, low rates of productivity, limited profitability in production, violence and insecurity and the indiscriminate access to urban lands (CPPS 2001b). In general, the coastal population grows at a higher rate than non-coastal areas. These new and mainly informal settlements create a permanent demand for sanitation, healthcare and other services that countries in the region have not been able to satisfy.

Technological

The lack of appropriate treatment or final disposal management of wastewater and other residuals is considered the second most important root cause of the Pollution concern. The municipalities provide most of these services in the region but generally do not employ new technologies for waste management or recycling. In general, a low coverage of both solid waste collection and wastewater treatment characterise the region, although the situation of Chile is much better than Ecuador and Peru. Recycling of solid wastes is not customary but is limited to a small number of municipalities. Hazardous wastes are not always disposed of properly. Operational deficiencies in the drinking water network produce losses as a result of wastage and unreported consumption.

Several industries use low-cost but inefficient technologies for industrial processes. For example, the industries of mining, petrochemicals and even fishmeal and canneries do not always install filters or treatment plants for their effluents. The agricultural sector uses around 70% of the water resources and is one of main diffuse sources of water pollution of coastal and estuarine waters through run-off, since effluents do not usually receive any treatment when leaving the farms (Escobar 2002).

Hundreds of different pesticides and other substances are applied to increase crop production. As a consequence, POPs are found in the water of rivers and estuaries and in sediments throughout the region, with severe impacts on marine biota (UNEP 1999).

Economic

Countries of the region do not have sufficient economic resources to provide and maintain the treatment plants in order to improve the current sanitation conditions because tariff rates are subsidised or the ‘polluter pays’ principle is not taken into account. Neither do they have economic mechanisms to promote investment in clean technology by industries in order to reduce emissions into the environment. Governments or municipalities do not provide sufficient resources to establish efficient mechanisms of supervision and control of industrial emissions, except in the case of Chile where industries operate under a self-regulation regime.

Legal and institutional

The obsolescence of laws is a common problem in the region. Responsibilities are not always well defined among different national and local institutions in charge of the control of the environment and their assignments frequently overlap. Inappropriate municipal

regulations and weak sanctions are also common. There is a lack of regulations concerning diffuse contributions and therefore no institution is responsible for their control. There is also limited promotion and support of the implementation of quality systems acknowledged worldwide, for example, ISO clean production and organic production.

Knowledge

There is limited knowledge on the natural capacity of the water bodies to deal effectively with the amount of organic and chemical charge, which the countries of the region are introducing into coastal ecosystems.

Unsustainable exploitation of fish and other living resources

Immediate causes

Overexploitation of fish

Overexploitation of fish is an important immediate cause since the South East Pacific Ocean is one of the major fishing zones of the world (Figure 15). However, total catches in the Humboldt Current region

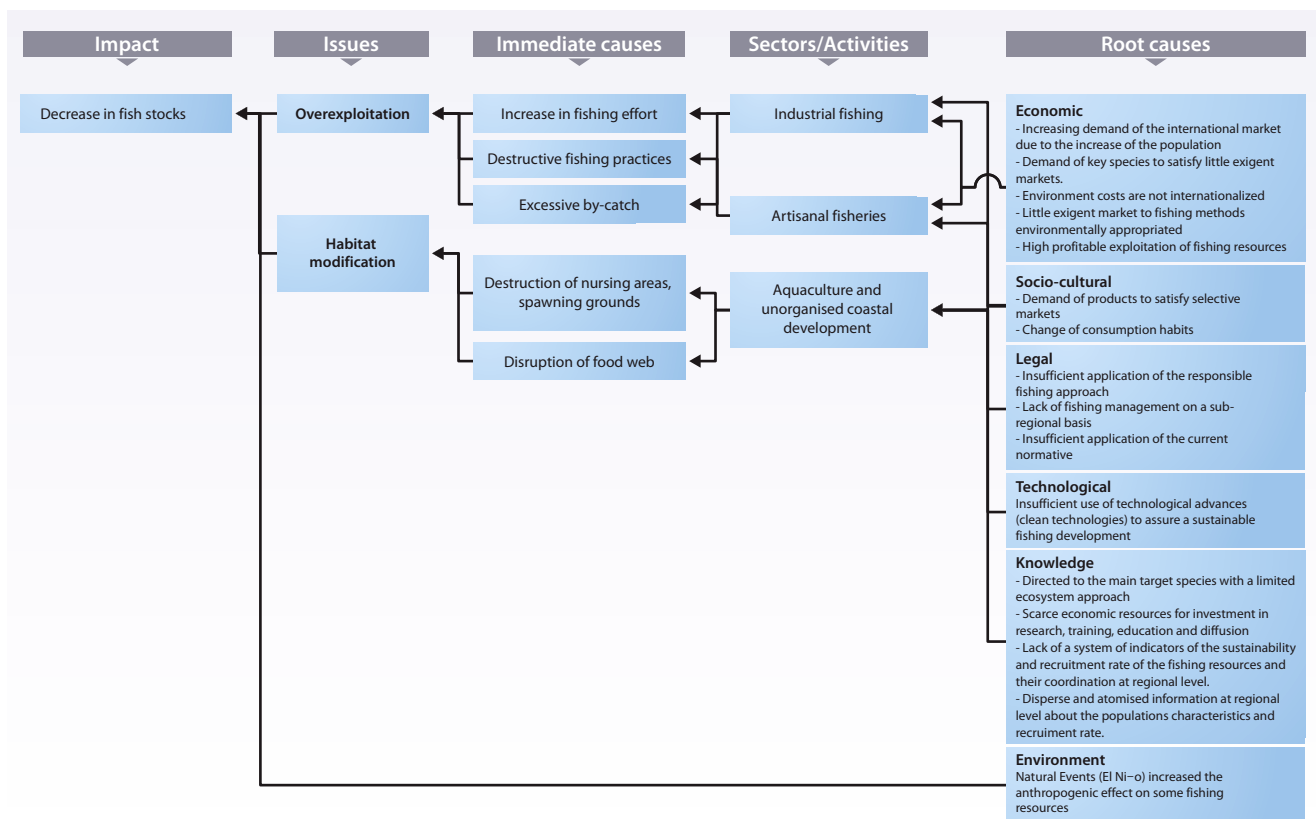


Figure 15 Causal chain diagram illustrating the causal links for Unsustainable exploitation of fish and other living resources.

have decreased in the last decade since reaching their highest levels during the 1970s and 1980s. This has been attributed to high levels of exploitation and extreme environmental variations (Csirke et al. 1996). The regional economy is highly dependant on fishing resources for food, labour and export revenue.

Loss of habitat and nursing sites

Another form of overexploitation is the destruction of mangrove areas for aquaculture ponds and urban development in Ecuador and northern Peru. Such activities are destroying important nursing areas for commercial species and decreasing the availability of resources for other trophic levels, thus altering the whole food chain. This ecosystem disruption could produce changes in the distribution of fishing resources, cause a net loss in productivity, threaten local and regional food security, reduce profits received from fishing activities, provoke conflict among fishermen, increase unemployment and hinder economic opportunities.

Destructive fishing practices

The use of non-selective fishing gear is a problem that extends throughout the region and is more common in artisanal than in industrial fisheries. The use of fine-meshed nets for shrimp post-larvae capture during the 1990s is a typical case of an unmanageable fishery, because it was widely spread along the coast of Ecuador and the north of Peru (Gaibor et al. 1992). Small-meshed purse-seines in Peru are used to catch sexually immature specimens. The impact of such fishing practices on coastal and estuarine resources is unknown, but they could be affecting the recruitment level of several commercial species. It is likely that the use of non-selective fishing gear is responsible for the low catches of traditionally abundant species. To a lesser degree, the use of poisonous substances or explosives is an ancestral fishing practice in Ecuador and Peru but largely under-reported.

The use of trawling nets to catch shrimps in Ecuador has altered the composition of benthic communities, produces large amounts of discards, decreases the variety of habitats and reduces the biodiversity of aquatic systems. The effect of this fishery on other bio-resources, apart from marine turtles, has not been assessed.

By-catch

Marine mammals, turtles and birds are present in the by-catch of almost every fishery in the region. The impacts of other aspects of by-catch, such as the capture of immature individuals or the partial use of the catch as in the case of shark fins, are underestimated. The Ecuadorian shrimp trawling fleet produce significant amounts of discards that surpass what is actually utilised in shrimp production and also alters

benthic biota by disturbing the seabed (Little & Herrera 1991, Coello 1996). The overdevelopment of the fleet, and recently the presence of the white spot disease virus, is affecting the fishery. Since discards do not need to be reported to the authorities, the problem remains concealed in most fisheries.

Fishing practices and non-selective gear for species or sizes are responsible for the high by-catch rate. Management techniques to address this issue include the use of technical (improved fishing selectivity), administrative (regulations) and economic measures.

Sectors

Industrial capture fisheries

Small pelagic fishes such as anchovy, sardine and mackerels, are the focus of an over-dimensioned purse-seine fleet composed of approximately 2 000 vessels (CPPS 2000b). Some of the species, such as anchovy and sardine, have been targeted for around 50 years and stocks have reached critical levels to which the fishing effort responded by moving towards other, more abundant species to continue supplying the fishmeal and cannery industries in the region (IMARPE 2002a). In some cases the industrial fishery sector shows a disproportionate growth of its fishing and processing infrastructure with respect to the actual fisheries resources. The most important species that support this large-scale fishery are under severe pressure and at their limit in terms of exploitation, as shown in Table 7.

Table 7 The level of exploitation of the four most important schooling fishes in the South East Pacific.

Species		Exploitation level
Common name	Scientific name	
Anchovy	<i>Engraulis ringens</i>	Full-exploited in its whole distribution range
Sardine	<i>Sardinops sagax</i>	High-exploited in its whole distribution range and absent of several areas
Chilean jack mackerel	<i>Trachurus murphyi</i>	Between mid and highly exploited with the risk of overexploitation
Chub mackerel	<i>Scomber japonicus</i>	Moderately exploited

(Source: FAO 1997)

The tuna purse-seine fishery in the northern part of the region is another important oceanic fishery that is being exploited to its limits. This fishery is under the international management regime of the Inter American Tropical Tuna Commission (IATTC) that has led to the establishment of several regulations such as dolphin mortality limits and has recently established closed seasons to maintain the sustainability of tuna stocks. Nowadays Ecuador has one of the largest tuna fleets in the Eastern Tropical Pacific. Illegal tuna fishing inside the Galapagos Marine reserve (40 nautical miles around the archipelago) is a recurrent source of conflict with the tourism and artisanal fishing sector.

The most important commercial species in the region are as follows: Chub mackerel, Pacific thread herring, sardine, Pacific anchovy, shrimp and tuna in Ecuador; Chilean jack mackerel, anchovy, sardine, hakes, swordfish and the Rock barnacle in Chile; anchovy, sardine, Chilean jack mackerel, Chub mackerel and scallops in Peru. Management measures for these resources include access regulations, total allowable catch, fleet capacity, closed seasons, minimum size, zoning, fishing techniques, equipment and fishing systems (Zuzunaga 2002). In 1992, Peru and Chile established an agreement for joint research of sardine and anchovy stocks whose results are evaluated in periodic workshops.

Artisanal capture fisheries

Most of the coastal demersal species are under similar levels of pressure in the Humboldt Current region. Over the decades, artisanal fishermen have exploited marine resources under a free access regime, with associated economic activities (e.g. transportation, commercialisation) (CPPS 1999). For this reason, these fisheries are not as well monitored as the industrial fisheries, but the reduction of landings is evident throughout the entire region. The causes of this decline include depleted stocks, destruction of habitat by pollution and other human activities such as tourism, port facilities, urban development and aquaculture, among others. Artisanal fisheries also have an over-dimensioned fishing fleet with around 45 000 boats and 150 000 people dedicated to the activity (CPPS 2000b). Closed seasons have been implemented in the region to protect high valued coastal species including shrimps, crabs and lobsters in Ecuador, the Rock barnacle in Chile and the South Pacific hake in Peru.

Aquaculture

Aquaculture provides employment in the coastal areas of the region and important socioeconomic benefits. Shrimp farming represented almost 80% of the total value of regional aquaculture production (CPPS 2001b). Other cultured resources include algae, crustaceans, molluscs, fish and some invertebrates.

In Ecuador, the shrimp industry constituted the third most important economic activity during the 1990s. After 2000, the productivity of this sector decreased, exports dropped from an average of 720 million USD between 1994 and 1998, to 283 million USD in the period 2000-2001 (BCE 2002). In Chile, aquaculture increased at a rate of 18.4% between 1994 and 1998. Today it represents one of the most dynamic and important sectors of the country. The salmon fishery is the most important (79%), but other species such as molluscs and algae are also harvested (FAO 2000c). In Peru, aquaculture is just beginning, and focuses on shrimps, trout and scallops.

Root causes

The unsustainable exploitation of fish is a concern of extreme importance for the region since fisheries are one of the most important economic activities and sources of employment. Unfortunately, fishing resources have not always been managed using a precautionary and ecosystem approach, and this has resulted in the decline of the main commercial stocks. The over-dimensioned effort is the direct cause of overfishing, as well as other economic, environmental and institutional causes. An alternative management regime is necessary to reverse the effects of the root causes of this concern in order to attain a sustainable level of exploitation.

Economic

The increasing demand of fishing products to satisfy local and international markets either for human consumption or to supply livestock feed is a major cause of the unsustainable use of the Humboldt Current region's fisheries resources. The environmental costs of this exploitation are not fully understood and some species considered vital for the ecosystem are used as raw material of low industrial value. Except for a few cases such as tuna and shrimps, the majority of industrialised products do not have an exigent market demanding production or processes that are environmentally friendly. Another aspect of this root cause is the profitability of some export products, for example, of lobster, scallop, and sea cucumber, among others. Besides fetching high prices, some additional pressure is generated through policies to encourage the export of these products.

Socio-cultural

The increasing demand for some species, or parts of them, for example, sea cucumber, shark fins and even sea lion testes, to satisfy selective markets is a cause of concern. Some of these species have restrictions or trading is prohibited under the CITES Convention, creating an illegal market due to their high prices. There is also an increasing demand for low-fat products for health reasons and consequently an increase in fish and shellfish consumption.

Legal and institutional

Since most of the fisheries in the region are under a free access regime, fisheries management institutions are not fully aware of the need to apply a responsible fishing approach as recommended by the FAO (1995b). Fishers do not always adhere to the current national regulations, disrespecting restricted areas, mesh size and even closed seasons. Furthermore, fisheries management strategies are not adequately coordinated between the countries of the region despite an understanding of the shared nature of fish stocks.

Technological

Regional institutions have not sufficiently incorporated technological advances to allow a more accurate assessment of fishing resources and to assure their sustainable exploitation. There is also a low investment in research and technology for the development of new fisheries. Furthermore, fleets in the region are highly specialised in small pelagic fishes and it is unlikely that they will be willing to modify vessels or acquire expensive technology to develop new fisheries in the near future.

Knowledge

The research effort in the region is directed mainly towards the more profitable species or those that directly supply industrial plants but with a limited ecosystem approach. A common problem for the countries in the region is the scarcity of economic resources for investment in research, training, education and dissemination. Economic restrictions have limited regional coordination, thus impeding the development of sustainability indicator systems for fish resources (i.e. level of recruitment). Although advances in the field of oceanography and climatic characterisation in the region have been achieved by regional programmes such as the Regional Study of El Niño Phenomenon (ERFEN) (see Annex III) and the annual joint regional oceanographic cruises coordinated by the Permanent Commission of the South Pacific (CPPS), information on population characteristics of exploited species on a regional basis is sparse and fragmented.

Governance

Countries in the region have failed to adopt modern criteria, concepts and trends regarding marine ecosystem management. There is a lack of regional policies and strategies. Conflicts of interest among different fishing sub-sectors also make it difficult to integrate policies. Institutions responsible for managing the fisheries are often weak because they lack resources and institutional capacity.

Natural causes

Extreme environmental events such as El Niño have exacerbated anthropogenic impacts on some fishing resources. Current knowledge

is not sufficient to allow predictions of the intensity and extent of the impacts of such events on the highly dynamic populations exploited in the South East Pacific Ocean. Therefore, a coordinated effort among science, government and industrial sectors is required during these periods to develop strategies that adopt a precautionary approach to fisheries in order to mitigate the impacts of El Niño.

Conclusions

The main root causes of the two priority concerns in the Humboldt Current region are associated with demographic, economic and socio-cultural aspects. The scarcity of economic resources limits the ability of the countries in the region to improve the level of coverage of basic services such as sanitation, wastewater treatment and freshwater supply in line with population growth. In the case of fisheries, economic restrictions delay the development of research and technologies to exploit natural resources on a sustainable basis. These major problems will continue to affect the region as long as the countries are unable to find alternatives for their current economic models.

Other institutional and governance weaknesses complicate coordination or impede private sector investment in public services and delay solutions. They also impede the application of policies and strategies for the exploitation of fishing resources based on an ecosystem approach at the regional level. To date, each country has been managing fishing stocks separately. The importance of regional management of transboundary fish stocks such as Jack mackerel, anchovy, sardine, Giant squid and swordfish has been demonstrated through modelling analyses (Zuzunaga 2002). However, in the region, there is a cooperative attitude that would facilitate the implementation of fishing management measures as well as favouring the exchange and joint evaluation of fishing and oceanographic data. In this context it is important to note that the valuable collaboration of countries such as the United Kingdom, United States, and Germany, among others which, through their specialised institutions, have maintained an important presence in the South East Pacific Ocean. This collaboration is complemented by the permanent support from FAO.