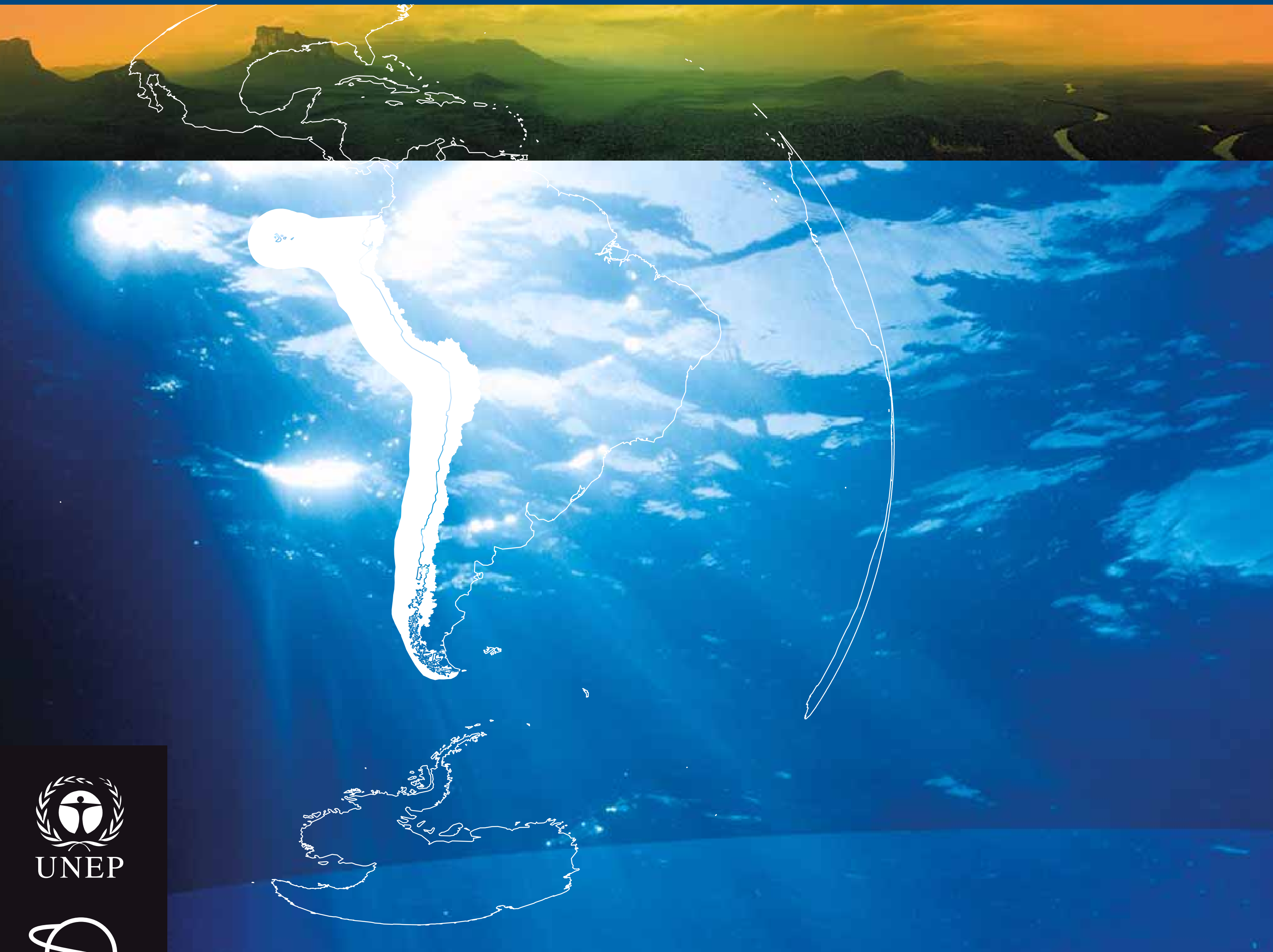
Global International Waters Assessment



Humboldt Current

GIWA Regional assessment 64

Permanent Commission for the South Pacific (CPPS)

UNEP

GEF

Högskolan Kalmar University

Global International Waters Assessment

Regional assessments

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Regional assessment 64
Humboldt Current

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Executive summary

The Humboldt Current region is located along western South America, stretching from the Ecuadorian-Colombian border (1° N) to the south of Chile (55° S). A feature of the continental area is the Andean Mountain range that extends along the entire region defining the catchment of the Humboldt Current region. The countries in the region include parts of Ecuador, Peru, Bolivia, Argentina and the whole of Chile. The impacts of the areas in Bolivia and Argentina on the Humboldt Current region are negligible and therefore these countries are excluded from the report. The region contains a variety of coastal ecosystems, including rainforests, reefs and mangroves within its tropical and subtropical zones, deserts along most of the coast of Peru and in the north of Chile, and extended coniferous woods, fjords and glaciers in the south of Chile. The marine area is characterised by a high productivity (>300 gC/m^2/year) and supports one of the most important fisheries of the world.

The total population in Chile, Ecuador and Peru reached 53.5 million in 2000, of which 74% is urban. In the Humboldt Current region the total population is estimated at 42 million (Landscan 2001). Drinking water and sanitation services vary from a moderate level of coverage in Ecuador and Peru to high levels in Chile. The most important socio-economic activities in the region are agriculture, fishing, aquaculture and mining, with the most industrialised areas located in Chile. An important feature of the regional economy is petroleum extraction.

The GIWA regional Task team selected Pollution and Unsustainable exploitation of fish and other living resources as the priority environmental concerns affecting the transboundary waters of the region. This decision was justified on account of their impacts on economic, social and health issues both at present and in the future. Therefore, the Causal chain analysis focused on these two problems. There is severe microbiological pollution of waters around the largest coastal cities of Ecuador and Peru. Chemical pollution from pesticides is evident in areas of intensive agriculture throughout the region, whereas high concentrations of heavy metals are found in the south of Peru and north of Chile where mining is a major industry. To a lesser degree, the environment of the region is also affected by other sources of pollution such as solid wastes, eutrophication and recurrent operational spills of hydrocarbons. Pollution is considered to affect the productivity of coastal areas, causing significant social and economic losses as well as affecting the health of both humans and ecosystems.

Overexploitation of fishing resources in the Humboldt Current ecosystem is the result of an over-dimensioned fishing effort. Both industrial and artisanal fleets have increased in size and have put the sustainability of fishing at risk. Most industrial fishing is directed towards small schooling fish such as anchovy, sardine and mackerel to supply fishmeal and cannery plants. Some of these species are considered highly or overexploited by the FAO. Although the fishing of these species is a major source of employment, final products are of low value. Other important fisheries such as tuna and shrimp occur in the more tropical parts of Ecuador and the north of Peru. Around 150 000 artisanal fishermen target mainly highly priced coastal resources such as shrimp, lobster, scallops, rock barnacle, and mussels. Some of these fisheries produce a high rate of by-catch and discards or cause habitat modification as a result of using destructive fishing practices. Aquaculture production has increased, although there are problems, for example in the case of shrimp farms in Ecuador and Peru where mortalities and low productivity have been results of pollution and poor management. Impacts of overfishing include the reduction of income and/or employment, reduction of economic returns, loss of fish resources, depletion of key species and changes in habitat and community structure.

The immediate causes of Pollution are microbiological and chemical pollution from untreated municipal and industrial wastewater.

Sectors associated with this pollution include urbanisation, industry and agriculture. The root causes identified include: 1) Demographic: concentration of population in coastal areas, migration and the development of informal settlements; 2) Technological: inappropriate treatment of wastewater; 3) Economic: lack of resources to increase the sanitation coverage and to maintain treatment systems, lack of mechanisms to promote private investments to reduce the pollution charge, and lack of resources for supervision and control; 4) Legal and institutional: overlapping responsibilities in institutions in charge of supervision and control, and limited promotion of the implementation of quality systems; and 5) Knowledge: inadequate understanding of the region's natural systems preventing an accurate determination of the carrying capacity of aquatic environments.

The most important immediate cause for Unsustainable exploitation of fish and other living resources is overexploitation and the increase in fishing effort. To a lesser degree the reduction in recruitment levels, changes in the distribution of the population and the reduction of fisheries habitat and nursery grounds are also of concern. Root causes include: 1) Economic: the increasing global demand for fisheries products, demand for key species to satisfy exigent markets, limited exigent markets for fisheries employing environmentally friendly methods, high profitability, and politics to foment exportable products; 2) Socio-cultural: demand for fisheries products to satisfy selective markets, and change in consumption habits; 3) Legal: insufficient application of the responsible fishing approach, lack of regional fisheries management, and insufficient application of modern management approaches; 4) Technological: insufficient use of technological advancements to assure sustainable fishing development; 5) Knowledge: limited application of the ecosystem approach, low investment in research, training, education and the dissemination of information, lack of sustainability indicators at the regional level and dispersed and fragmented information at the regional level concerning population characteristics; 6) Natural causes: increased effects of the El Niño Southern Oscillation (ENSO); 7) Governance: lack of incorporation of the regional ecosystem approach in government strategies, conflict among sectors, weak institutions responsible for enforcement of fisheries regulations, and insufficient adaptation to new criteria, concepts and trends in marine ecosystem management.

To mitigate pollution problems in the Humboldt Current region, two policy options were proposed: 1) Decentralise environmental management; and 2) Harmonise criteria and environmental quality standards and develop common indicator systems for environmental management. These two options were assessed considering their convenience, feasibility and acceptability. In the first case, a change in the national strategies of each country to face pollution from a centralised to a decentralised model is proposed, in which major responsibilities are assigned to local governments (i.e. municipalities). This will simplify the identification and selection of priorities at an early stage in project development leading to an ecosystem approach that includes the participation of local stakeholders. In the second case, it is intended that similar regulations and quality standards be set up at the regional level, taking advantage of existing regional cooperation mechanisms such as the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South Pacific, through which several agreements and protocols have already been developed.
Regarding the unsustainable exploitation of fish, three policy options were considered: 1) Rationalisation of fisheries; 2) Development of knowledge and indicators; and 3) Regulation of fishing effort. The aim of these measures is to develop a fisheries management system, especially for the region's migratory species, implementing the principles and practices of the "FAO Code of Conduct for Responsible Fisheries". For the sustainability of the fisheries in the region it is vital to develop research and indicators of regional change of the highly dynamic fish populations that are currently exploited. This will allow a better understanding of the ecological and physical variables driving the Humboldt Current fisheries.

Abbreviations and acronyms

BCCL Banco Central de Chile (Central Bank of Chile)
BCE Banco Central de Ecuador (Central Bank of Ecuador)
BCRP Banco Central de la Reserva de Perú (Central Bank of Peru)
BOD Biological Oxygen Demand
CAAM Comisión Asesora Ambiental, Ecuador (Environmental Advising Commission)
CEPAL Comisión Económica para Latinoamericana y el Caribe (Economic Commission for Latin America and the Caribbean ECLAC)
CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLIRSEN Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos (Ecuadorian Remote Sensing Centre)
CNA Cámara Nacional de Acuacultura, Ecuador (National Chamber of Aquaculture
CONAMA Comisión Nacional del Medio Ambiente, Chile (National Commission of the Environment)
CONPACSE Coordinated Programme on Marine Pollution, Monitoring and Control in the South-East Pacific
CPPS Comisión Permanente del Pacífico Sur (Permanent Commission for the South Pacific)
DIGEIM Dirección General de Intereses Marítimos, Ecuador (General Division of Maritime Affairs, Ecuador)
DDD Dichlorodiphenyldichloroethane
DDE Dichlorodiphenyldichloroethylene
DDT Dichlorodiphenyltrichloroethane
DGA Dirección General de Aguas, Chile (General Division of Water)
DIGMER Dirección General de la Marina Mercante y del Litoral, Ecuador (General Division of Marine Affairs, Ecuador)
DIRECTEMAR Dirección General del territorio Marítimo y Marina Mercante, Chile (General Division of the Maritime Territory and Marine Affairs, Chile)
EMAP Empresa Municipal de Agua Potable de Guayaquil, Ecuador (Municipal Freshwater Enterprise of Guayaquil)
ENSO El Niño Southern Oscillation
ERFEN Programme for the Regional Study of the El Niño phenomenon in the South East Pacific
ESPOL Escuela Politécnica del Litoral, Ecuador (Polytechnic School of the Littoral)
FAO Food and Agriculture Organization of the United Nations
GEF Global Environment Facility
GIWA Global International Waters Assessment
IATTC Inter American Tropical Tuna Commission
IFOP Instituto de Fomento Pesquero, Chile (Institute for the Development of Fishing)
IMARPE Instituto del Par de Perú (Peruvian Institute of Marine Research)
INE Instituto Nacional de Estadísticas, Chile (National Institute of Statistics)
INEI Instituto de Estadística e Informática, Perú (Peruvian Institute of Statistics and Information)
INOCAR Instituto Nacional Oceanográfico de la Armada, Ecuador (National Oceanographic Institute of the Navy)
INP Instituto Nacional de Pesca, Ecuador (National Institute of Fisheries)
INRENA Instituto Nacional de Recursos Naturales, Perú (National Institute of Natural Resources)
IOC Intergovernmental Oceanographic Commission
ISO International Standardization Organization
JICA Japan International Cooperation Agency
LAC Latin American Countries
MPN Most Probable Number
NAFTA North American Free Trade Agreement
ONUDI United Nations Industrial Development Organization UNIDO

OPS	Organización Panamericana de la Salud (The Pan American Health Organization)	TED	Turtle Excluding Device
PCB	Polychlorinated biphenyls	TSW	Tropical Subsurface Waters
PMRC	Programa Integrado de Manejo de Recursos Costeros, Ecuador (Integrated Coastal Resources Management Programme)	TV	Taura viruses
PNUMA	Programa de las Naciones Unidas para el Medio Ambiente (United Nations Environment Programme)	UNEP	United Nations Environment Programme
POP	Persistent Organic Pollutant	UNICEF	United Nations Children's Fund
PROSET	Regional Programme for the Protection of the South East Pacific from Land-based Activities	WHO	World Health Organization
SSW	Subtropical Surface Waters	WSSCC	Water Supply and Sanitation Collaborative Council
		WSSD	World Summit on Sustainable Development
		WSSV	White Spot Syndrome Virus
		WTO	World Tourism Organization
		WWF	World Wildlife Fund

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Regional definition

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA Assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the region

The Humboldt Current region (GIWA region 64) includes marine and terrestrial areas along the western coast of South America, from Ecuador's border with Colombia in the north, through Peru to the southern tip of Chile. The Galapagos archipelago, 1 000 km off Ecuador, is also included (Figure 1). Parts of Bolivia and Argentina fall within the boundaries of the Humboldt Current region but their impact is negligible on the region as a whole, and these countries are therefore excluded from the report. The area constitutes a unique and rich ecosystem with physical and ecological influences of the Humboldt Current reflected in its unique biota.

The Humboldt Current region's marine component is the world's largest upwelling area with a productivity of >300 gC/m^2/year. The primary and secondary productivity of this ecosystem supports some of the most important fisheries in the world. The upwelling is present all year around on the Peruvian coast, but only during the spring and summer in Chile. Around 19% of the world's catches are from Peruvian and Chilean waters (FAO 2002a). The species are mainly pelagic schooling fishes such as sardines, anchovies and mackerel. There are other important fishery resources as well as species of conservation interest such as sea turtles, birds and marine mammals.

Recurrent El Niño Southern Oscillation (ENSO) events cause the collapse of the upwelling system, producing changes in abundance and distribution of fishery resources. The result is a domino effect with major social and economic impacts. These events also lead to sequential changes provoking an alternation in the abundance of sardines and anchovies as the dominant species in the system. Such changes may have negative consequences for the fishing industry and the economy of the countries in the region.

Physical characteristics

Coastal area

Most of the regional geomorphology is determined by the Andean mountain range, which extends in a north-south direction through the whole region. In Chile, the Andes Mountains constitute the eastern border of the territory and, in some places, reach over 6 800 m (e.g. Ojos del Salado Mountain). The Andes Mountains run lengthways through Peru and Ecuador where three naturally well-defined continental regions are formed: the coastal or littoral region, the Andean or sierra region, and the Amazonian or eastern region (CPPS 2001b).

The Humboldt Current region covers a continental area of 2.3 million km^2, equivalent to 17% of South America (CPPS 2001a). Peru covers an area of 1.3 million km^2 (55%), Chile 756 600 km^2 (32%) and Ecuador 283 600 km^2 (12%). The coastline extends 8 409 km and includes a great variety of ecosystems, from tropical rainforest at the Equator to the perpetually ice-covered lands in the south of Chile.

The coast of Ecuador is 950 km long and is formed by a succession of alternating bays and capes. The coast is predominantly cliffed and fronted by beaches. Cliffs extend southward to around 2° S where the coast comprises a series of stepped marine terraces. In the south, the dominant feature of the coast is the Gulf of Guayaquil, an estuarine system with a shoreline fringed by dense stands of mangroves and mudflats (EMAP/DIGMER 1988, Arriaga & Vásconez 1991, Cucalón 1996). Ecuador has 79 drainage basins, 71 of which drain into the Pacific Ocean (Carrera de la Torre 1993, CAAM 1996). The insular region of Ecuador includes the Galapagos archipelago 1 000 km to the west off the mainland. The archipelago is made up by 19 islands between 1 and 4 500 km^2 and 42 islands of less than 1 km^2. The coastline of the 14 largest islands totals 1 400 km in length (Houvenaghel & Houvenaghel 1982).

The coast of Peru is arid and extends for 3 080 km. It includes 53 major valleys running in an east-west direction. Deserts located between these valleys comprise plains, hills and dry ravines. The dry coastal forest in the north extends from the border of Ecuador to the south of the Lambayeque Department. A mangrove area, small but unique in Peru, is located in the northern extremity of the Tumbes Department, whereas the ecosystem of the hills extends along the coastal side of the Andes Mountains (Jacinto & Cabrera 1998). Because of the hyper-aridity of the coast, the contribution of fluvial sediments and the formation of beaches are limited. Permanent rivers are few and most rivers reach the sea only on a seasonal basis. The shoreline is rocky and interspersed with confined beaches fronting river mouths. Between Chiclayo and Pisco there is a dense network of rivers reaching the sea, favouring the formation of coastal plains. However, south of Pisco there are few coastal plains and the shoreline is formed primarily by towering cliffs or small embayments with narrow beaches. Large sand dunes are found along the central coast of Peru. Shoreline displacement is evident in many locations of the Peruvian coast with raised shore platforms and beaches (CPPS/UNEP/IOC 1988, Soldi et al. 1988, Sánchez & Zevallos 1987).

Figure 1 Boundaries (right) and land use (left) of the Humboldt Current.
(Source: based on USGS 2002)

The northern two-thirds of the northern coast of Chile has characteristics similar to the Peruvian coast. The Andean range comes to the sea and small confined beaches or alluvial embayments interrupt the cliffed coast where infrequent streams lead down to the shoreline. 700 km of the northern zone correspond to a mega-cliff, where rocky coasts prevail for 580 km. Terraces appear along cliffed headlands fronting the foothills. From Arica to Coquimbo, the coast is narrow, open and cliffed, however, there are several shallow embayments suitable for ports (CPPS 2001b). In the central zone, coastal dunes develop in conjunction with beaches, especially north of the river outlets. Confined beaches prevail from Valparaiso to Valdivia. The main dune fields are located between 29 and 42° S (Morales 1995, Castro & Morales 1989 in CPPS 2001b). In the south, the coastal range comes down to the sea and provides only modest embayments. South of Puerto Montt the coastal configuration consists of broken glaciers, fjords, islands and channels (CPPS/UNEP/IOC 1988, Bore et al. 1988). The coastline has few inflexions, except in the southern part where it is separated into gulfs, islands, channels and fjords. Here the continental shelf is narrow, in places less than 10 km wide.

In the Humboldt Current region, Dinerstein et al. (1995), distinguished 11 ecoregions in two major ecosystems: the Northern Andean tropical rainforest in Ecuador and the southern South American temperate forest in Chile. Seven of these ecoregions are classified as Biodiversity Priority I: Mountain forest (Ecuador); West Ecuador rainforest (Ecuador); Ecuadorian dry forest (Ecuador); Tumbes/Piura dry forest (Ecuador, Peru); Chilean winter rainforest (Chile); Valdivia temperate forest (Chile, Argentina) and Chilean brushwood (Chile).

River basins

Since the Andes Mountains run parallel to the west coast of South America, short and rapidly flowing rivers are typical in coastal areas of the region. These rivers originate on the western slopes of the Andes Mountains and flow westwards to the Pacific Ocean. Only a few rivers, which flow across the northern and southern borders of Ecuador, are considered transboundary.

Ecuador has 31 hydrological systems with 79 basins. These systems originate in two Andean springs; one drains into the Pacific Ocean through 24 basins over an area of 123 240 km^2; the second, with seven basins, drains into the Amazon region covering 131 800 km^2. Ecuador shares drainage basins with Colombia to the north with the San Miguel Putumayo River Basin and with Peru in the south with the Catamayo-Chira and Puyango-Tumbes River Basins (CPPS 2001a). The total contribution of the Ecuadorian hydrological network, with a margin of error of 30%, is 110 km^3/year on the Pacific slope and 290 km^3/year on the Amazon slope. Seventy-nine rivers drain into the Pacific, most on a permanent basis, but some of them dry up in summer. These rivers carry most water between January and April and transport a high sediment load. In the north, the main rivers are Santiago and Esmeraldas. The Esmeraldas River Basin extends over 21 420 km^2 and around 2.5 million people (including the city of Quito) live and depend of its resources. The largest basin of Ecuador is the Guayas River in the central and southern part of the country with an area of 32 630 km^2 (Solorzano 1981, in CPPS 2001b). The total extraction of water resources in Ecuador was estimated to be 17 km^3 in 1997, of which 12.3% was for domestic use, 5.6% for industry and 82% for agriculture. Due to the high availability of water resources there is no competition among productive sectors (FAO 2000a). The potential of useable groundwater in the Pacific slope has been estimated at 10.4 km^3/ year. Groundwater exploitation in Ecuador is mainly for domestic and industrial uses (FAO 2000a).

Peru has three major hydrological systems that correspond to the slope basins, Pacific, Amazon and Titicaca Lake. There are 106 drainage basins carrying both surface and groundwater. In terms of total water resources, there is an abundance of available surface water and this constitutes a major potential. Nevertheless, water availability varies greatly over time for climatic reasons. There is consequently a shortage of water resources on the Pacific and Titicaca Lake slopes and an abundance on the Amazonian slope. An important feature of coastal Peruvian rivers is their temporary pattern with unstable flows. There is a short three- to five-month period of abundance (December through to May) followed by a long dry period with low water levels lasting seven to nine months (May through to December). This has a negative effect on the country's water requirements. Snowmelt and rainfall in the Andes Mountains also produce river discharges on the Pacific slope with an average flow of 1 161 m^3/s. Rivers with the greatest average flow are the Santa, Tumbes and Chira. The rivers running into the Titicaca have an average flow of 222 m^3/s; the main rivers are the Ramis and Ilave. Only part of the basin belongs to Peru since it is shared with Bolivia.

Chile is characterised by a hydrological system of transverse valleys running east-west. Rivers start both in the Andes Mountains and in the coastal mountain range. In the north, rivers are short with low discharges; most of them do not reach the sea. The largest drainage basin of Chile is the 440 km-long Loa River with a drainage basin covering 34 000 km^2 (INE/CONAMA 2002). Due to convective rains in the highlands during summer, some rivers acquire an alluvial character, with an estimated surface run-off of 30 400 m^3/s (CPPS 2001b). The most important rivers in the transverse valleys are the Copiapó, Huasco, Elqui and Limarí. They originate in the Andean sector and have permanent discharges due to the rains and snowmelt from the high mountains. Maximum discharges are in December. In the central-southern region, rivers have a seasonal pattern, with the highest discharges occurring during the winter. The main rivers of this region are the Maule, Itata, Bio Bio and Imperial. The Bio Bio River forms a drainage basin of 24 000 km^2 along its 380 km waterway (INE/CONAMA 2002). Rivers in the south have larger discharges as a result of heavy rainfall and the regulatory action of temporary lakes formed by the rivers' discharges. The main rivers are the Toltén, Valdivia, Bueno and Maullín. In the Patagonian region, rivers run shorter courses which discharge to fjords forming numerous channels and transforming the western section into countless islands at the southernmost part of Chile (CPPS 2001b). The main Patagonian rivers include the Palaena, Cisnes, Aisén, Baker and Pascua. The Baker River forms another important basin covering 27 680 km^2, of which 21 480 km^2 are in Chile (INE/CONAMA 2002).

Marine area

The South East Pacific Ocean is affected by the Equatorial current and its derivatives, the North and South Equatorial Currents, as well as the Humboldt, Coastal Humboldt (or Coastal Peru) Current and the Colombia Current. The Humboldt Current originates at 40 to 45º S from the Antarctic Circumpolar Current that meets the South American coast at about 50° S (Figure 2). It is cold and rich in nutrients and characterised by numerous gyres that create distinctive local counter-currents and upwellings. These waters support highly productive fisheries off Peru and Chile. The Humboldt Current flows northward along the coast of Chile and Peru, losing significance at 5° S where it meets the Equatorial Front and veers off towards the west, becoming the westward South Equatorial Current (Gallardo 1984, CPPS/UNEP/IOC 1988, Soldi et al. 1988).

Figure 2 Marine currents in the Southeast Pacific.
(Source: Redrawn from CPPS 2000b)

In the north of the region, Tropical Surface Waters (TSW) are predominant, characterised by temperatures above 25°C and salinity below 33.5‰, as a result of excessive rainfall over evaporation. South of 4° S, Subtropical Surface Waters (SSW) are found. These are characterised by having a salinity over 35‰, in response to the excess of evaporation over rainfall. Towards the west, this water has temperatures up to 28°C due to a strong insolation, whereas to the east in the sector of the Humboldt Current, this water is modified by the horizontal mixing of cold upwelling waters with temperatures between 15 and 19°C and a salinity of 35‰ or slightly lower (Wyrtki 1966, Stevenson & Taft 1971, Enfield 1975).

Oceanographic conditions are dramatically altered during El Niño events. This is caused by large-scale changes in the ocean-atmosphere interaction. During the El Niño, warm eastward-flowing waters from the Equator dominate the Humboldt Current causing changes such as the increase of water temperature by up to 2 to 3°C, sea-level rises up to 40 to 50 cm and a reduction in the availability of surface nutrients. Such changes have devastating consequences for pelagic fisheries off Chile, Peru and Ecuador, and for the marine fauna that relies on these normally highly productive areas (Stevenson 1981, Cucalón 1986, Arcos 1987). The El Niño event has also been associated with coral bleaching, mortality and changes in the abundance and distribution of seabirds, marine mammals and sea turtles (Stevenson 1981, Glynn & Wellington 1983, Gallardo 1984, Robinson & Del Pino 1984, Cucalón 1986, 1996, Arcos 1987, CPPS/UNEP/IOC 1988, Soldi et al. 1988, f

Marine biodiversity

The marine area of the Humboldt Current falls within the following biogeographical categories: Western Inter-tropical (Ecuador-northern Peru), Western Sub-tropical (northern Peru-central Chile), Western Temperate (southern Chile, 45° S approximately), Sub-Polar and Polar Archipelagic (coastal). There are three coastal faunal provinces within the Humboldt Current region: Panamanian (Ecuador), Peru-Chile (southern Ecuador to Chile) and Magellan (southern Chile). The most important coastal ecosystems are:

Coral reefs

Coral formations have their southern limit distribution in Ecuador around 1° 30' S. They are present in the Galapagos Islands and Machalilla National Park (mainland) (Glynn & Wellington 1983, CPPS/UNEP/IOC 1988). The presence of hermatypic (reef-building) corals has been reported in areas around Pascua Island in Chile. There are 13 hermatypic and 32 ahermatypic (non-reef-building) coral species in Galapagos, 30% of them endemic. The eastern Pacific coral reefs are neither extensive nor diverse, having an intermittent occurrence and little development (Glynn & Wellington 1983).

Mangroves

Mangrove ecosystems are intermittent along the northern coast of Ecuador (CayapasMataje estuary) and are the predominant community in the Gulf of Guayaquil (Hurtado 1995a,b). The southern distribution limit is San Pedro, Peru (Acero et al. 1995). There are five mangrove areas in the region; three of them are included in the category "High Threat" (Dinerstein et al. 1995). The main mangrove species found in the region are: *Rhizophora mangle* (red); *Rhizophora harrisonii* (rusty), *Conocarpus erectus* (button), *Laguncularia racemosa* (white); *Avicennia nitida*, *Avicennia germinans* and *Pelliciera rhizophorae* (black) (Schwartz 1982).

Wetlands

Wetlands are found throughout the region. In Ecuador, 32 inland wetlands have been inventoried. The most important are: the Ciudad Laguna in the province of Esmeraldas (North Ecuador); La Segua in the province of Manabi (central Ecuador); and 16 others in the southern provinces of Guayas and El Oro (South Ecuador) (Briones et al. 1997, 2001a,b). There are also important wetlands in Peru such as the Tumbes Mangrove National Sanctuary; Virrillá estuary, Piura; Balsar of Huanchaco, La Libertad; La Albufera of Playa Chica, Lima; Marshes of Villa, Lima; Paracas National Reserve, Ica; Mejía Lagoons National Sanctuary, Arequipa; and Lagoons of Ite, Tacna (Jacinto & Cabrera 1998). In Chile, coastal marshes are located around 40 to 43° S within estuaries and behind sandy areas. There are salt marshes in the Gulf of Ancud, where the presence of halophytes has been reported. It is estimated that 30% of the wetlands have been drained or otherwise disturbed, although the degree of disturbance varies (CPPS 2000a).

Islands

The Galapagos Archipelago is located 1 000 km off the coast of Ecuador and is one of the most important natural areas in the region. Other protected islands in mainland Ecuador are La Plata Island (Machalilla National Park) and Santa Clara Island in the Gulf of Guayaquil. The Churute Mangrove Reserve embraces and protects several islands and small islands of the Guayas River Delta (Hurtado 1995b). The Cayapas-Mataje Mangrove Ecologic Reserve protects some small islands of the Mataje River Delta in the north of Ecuador. In Peru, there are 25 guano islands protected by the Fishing Ministry (Acero et al. 1995, Jacinto & Cabrera 1998). Important islands are Lobos de Tierra and Lobos de Afuera, Canape, Santa, San Lorenzo, Chincha, Sangalla and Isla Vieja as well as hundreds of smaller islands (CPPS 2000a). In Chile, there are hundreds of small islands and rocks in the southernmost part forming several archipelagos (Chiloé, Guaitecas, Guayaneco, Alcalufes) characterised by fjords, channels and islands, many of which are included in the National System for Protected Areas (Benoit & Zúñiga 1995). The most important oceanic islands include Pascua Island, Sala and Gomez Island and the Juan Fernandez archipelago.

Beaches, dunes and cliffs

Ecuador has 423 km of cliffed coast between 10 and 50 m in height and 1 256 km of open coast with more than 100 sandy beaches. In Peru more representative sandy beaches are located in the Paracas National Reserve, Pisco and in several islands (Jacinto & Cabrera 1998). Chile has 7 000 km of coastline of which 700 km in the northern zone correspond to a mega-cliff. Between 21 and 33° S, cliffs and shallow rocky coasts prevail. There are a few beaches, especially at Coquimbo-La Serena, Longotoma-Concón, Chile Central, and Arauco-Chiloé. Most of them are embayments located over shallow rocky platforms between promontories (CPPS 2000a).

Estuaries and inlets

Estuaries are best represented in Ecuador. The Guayas River estuary is the largest along the west coast of South America. The Cañar and Jubones rivers also discharge to the Gulf of Guayaquil, whereas in the north of Ecuador, the Santiago, Esmeraldas and Muisne rivers form their own estuaries.

Socio-economic characteristics

Population

In 2000 the three countries Chile, Ecuador and Peru had a total population of 53.3 million, and it was estimated that 42 million of these live within the boundaries of the Humboldt Current region (CEPAL 2001, Landscan 2001) (Table 1, Figure 3). It is estimated that there will be 65.6 million people living in the three countries in 2015. Around 28% of the region's population lives within 100 km of the coast. In 1999, 74% of the coastal population lived in 56 urban centres, 22 of which are coastal cities with more than 100 000 inhabitants (CPPS 2001b). During the last two decades the population density in urban centres has increased considerably.

Table 1 Population characteristics in the Humboldt Current region.

Country	Population below NPL* (%)	Income <1 USD/day (%)	Illiteration rate (%)	HDI index**	Overall mortality rate (%)	Infant mortality rate (%)
Chile	21	4.2	3	0.826	0.57	1.04
Equador	35	20.2	4.8	0.722	0.58	4.48
Peru	49	15.5	5.4	0.737	0.62	4.30

*Note: * National Poverty Line. ** Human Development Index.*

(Source: CPPS 2001b, CEPAL 2001)

Figure 3 Population density in the Humboldt Current region.
(Source ORNL 2003)

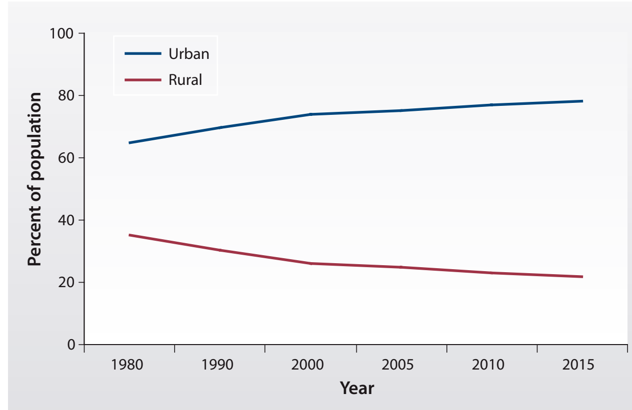

Figure 4 Population growth in the Humboldt Current region 1980-2015.
(Source: CPPS 2000a)

In 1980, 65% of the population was urban, which in 2000 rose to 74% but with differences between the countries, with Chile having the highest percentage of urban inhabitants at 86%. This tendency is not expected to change substantially in the near future. Figure 4 shows the proportion of urban and rural populations since 1980 and the projection up to 2015. Migration from rural areas has created large marginal settlements around the cities without infrastructure and services. Most of these new settlements are located in sites exposed to external dangers such as floods and landslides, as well as internal hazards such as health risks, pollution and poor quality housing, affecting the quality of life and increasing social gaps (CPPS 2001b).

The growth of marginal settlements is a major environmental problem exacerbated by an unsustainable development model and a lack of employment opportunities in rural areas. Consequently, almost 80% of the poor population reside in slums, particularly in coastal cities. In some cities, the marginal population is larger than the formal urban one. In Guayaquil, Ecuador, during the 1990s, marginal settlements housed one third of its urban population. In Peru, 1 045 new settlements (young towns) containing almost 67% of the total poor population were established in coastal areas during the 1980s (Céspedes 1990). 55% of the Peruvian population was considered poor in 2001 (INEI-ENHIV 2004). Chile had 67 coastal communities with 12% of people living below the level of extreme poverty in 1990 (Canales et al. 1990, CPPS 2000a, 2001b).

The International Poverty Line Data shows that in 1996, Ecuador had the highest number of inhabitants with incomes less than 1 USD/day (20.2%), Chile the lowest with 4.2% (1994), and Peru 15.5% (1996) (CPPS 2001b). The statistics of illiteracy in 1998 were: Chile 3% of the population, Ecuador 4.8% and Peru 5.4% (CPPS 2001b). The Human

Development Index (HDI) confirms that Chile has a higher human development standard than Peru and Ecuador (Table 1) (CPPS 2001b). The infant mortality rate of Ecuador is the highest within the Humboldt Current region and is above the Latin American average of 32 (Table 1). Infant mortality is closely linked to diarrhoeal diseases caused by environmental pollution produced by untreated discharges of municipal wastewater (CPPS 2001b).

Drinking water and sanitation service

In the Humboldt Current region, only Chile has access to drinking water and sanitation services above the Latin American average of 91% coverage of drinking water and 81% coverage of sanitation services, while Peru and Ecuador are below LAC standard (Table 2) (CPPS 2001b).

Around 30 million people have sanitation services in the three countries and 10 million have on-site solutions resulting in 13 million inhabitants lacking access to sanitation services (WHO/UNICEF/WSSCC 2001). The lack of appropriate wastewater treatment and the low coverage of drinking water service in Peru and Ecuador have been related with gastroenteric disorders such as gastroenteritis, typhoid, hepatitis A and a cholera epidemic during the early 1990s. Extreme environmental conditions such as floods during El Niño years contributed to the problem carrying the pathogens agents with the water. The sanitation service coverage improved during the 1990s, and most so in Peru where coverage increased with 76%. The increases were more modest in Chile with 12% and Ecuador 4% (WHO/UNICEF/WSSCC 2001).

In Ecuador, 42% of the total population has sanitation services and 16% have on-site treatment and the situation in Peru is similar with 53 and 21% respectively. In Chile the situation is far better with sanitation services reaching 77% of the population while 16% rely on onsite treatment (WHO/UNICEF/WSSCC 2001). The situation varies between urban and rural populations in all three countries. The coverage of sanitation services are always much lower in rural than in urban areas (Table 2).

Table 2 Water supply and sanitation coverage in the Humboldt Current region 2000.

Country	Water supply coverage (%)			Sanitation coverage (%)		
	Urban	Rural	Total	Urban	Rural	Total
Chile	99	66	94	98	93	97
Equador	81	51	71	70	37	59
Peru	87	51	77	90	40	76

(Source: WHO/UNICEF/WSSCC 2000)

Economy

The economy of the region is primarily based on agriculture, fisheries, coastal industry, oil-related industry, ports and maritime transport (CPPS 2001b).

Agriculture

Agricultural is one of the main economic activities in the region. In 1999 agriculture made up 12.9% of the GDP in Ecuador, 8.7% in Peru and 6.3% in Chile. Ecuador and Peru are above the LAC average of 7.5% (CPPS 2001b). Arable land in 1998 totalled 7.2 million ha: 51.4% in Peru, 22.2% in Ecuador and 26.4% in Chile. Agricultural inputs are high, especially fertiliser and pesticides, required particularly for plantations of rice, banana, cotton, sugar cane and potatoes. Data on fertilisers used for agriculture showed an incremental tendency during the period 1996-1998. A total of 809 000 tonnes of fertilisers were used in 1998. Chile has the highest percentage of fertiliser consumption at 55.1%, Peru 23.6% and Ecuador 21.3%.

Fisheries

FAO ranked the South East Pacific area as having the second highest fishing production in the world, after the Northwest Pacific. The three countries included in the Humboldt Current region produce 99.5% of the total catches of the South East Pacific. During the period 1988-1992, catches averaged 14.2 million tonnes, 22% of the total world production. FAO (1997) reported that 60% of demersal stocks and 70% of pelagic species in the region were either fully exploited or overexploited. However, the total production between 1995 and 1999 in the South East Pacific averaged 14.5 million tonnes per year, practically the same average as that between 1988-1992, despite a catch reduction of 42% in 1998 due to the 1997-1998 El Niño event (Figure 5).

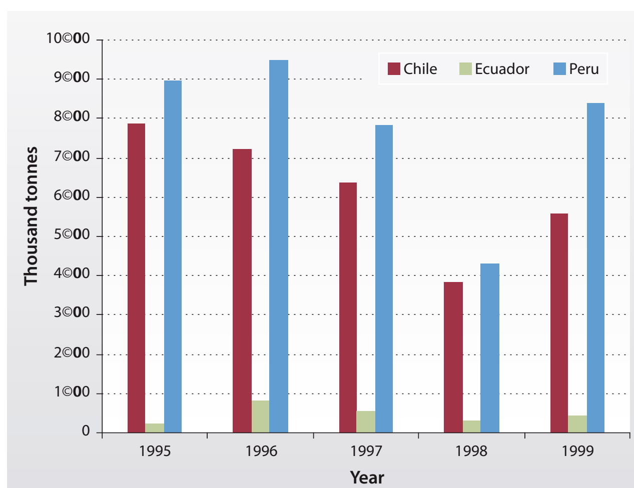

Figure 5 Landings in the Southeast Pacific during the period 1995-1999.
(Source: GIWA Task Team)

In Ecuador, fishing and aquaculture products were the second largest export item in 1998 (1.2 billion USD), even higher than petroleum (920 million USD) (Hurtado et al. 2000). In 2001, the value of fishing products decreased to 660 million USD; 53% lower than in 1998 and 22.7% lower than the average exported in the 1990s (820 million USD). The decrease was mainly noticed in the shrimp production due to the white spot disease, which affected aquaculture farms. Despite this dramatic decrease, fishing and aquaculture products represented 21% of the total exportations 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 the total export 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. According to the National Institute of Fishing (INP 1999) the fishing sector plays an important social and economic role in the country since thousands of people depend on it directly and indirectly.

In Peru, the statistics of the Central Reserve Bank (BCRP 2002) for the period 1992-2001 show that fishing exports are second only after mining, contributing more than agriculture, petroleum and industrial products. Fishing exports represented 16.8% of the total, with an annual average of 944 million USD, and contributing 0.57% to the GDP. During 2001, fishing exports reached 1.1 billion USD or 16% of the total exportations, 19% more than the average recorded between 1991 and 2001, and contributing to 0.49% of the GDP. It is estimated that more than 80 000 people worked in fishing and aquaculture during 1999 in both extraction and processing activities, which represents 0.9% of the urban working population in Peru (FAO 2002c).

In Chile, fishing and aquaculture export, between 1996 and 2001, produced an income of 986 million USD per year, which represents 5.6% of the total Chilean exports (BCCL 2002). Fishing products is the third most important item after fruits (7.5%) and cellulose, paper and others (6.3%). In 2001, landings reached 4.6 million tonnes: 4.2 million tonnes of fish (89%); 300 000 tonnes of algae (6.4%), 134 000 tonnes of molluscs (3%), 26 000 tonnes of crustaceans (0.5%), and 48 000 tonnes of other species (1%) (National Board of Fisheries 2004). Fishing exports in 2001 were 1 billion USD or 5.5% of the total exports, and 2.5% more than fishing exports between 1996 and 2001. Fisheries contribute 1.4% to the GDP in Chile.

Aquaculture

Aquaculture provides employment in the coastal areas of the region and important socio-economic benefits. Shrimp farming represented almost 80% of the total value for 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. In 1995, around 146 000 ha were dedicated to this activity in the country (CLIRSEN 1996). In 1992, this sector included 1 567 farms, 343 hatcheries, 95 packing plants, 26 factories for shrimp food, hundreds of enterprises providing supplies and services, and employed 68 000 people (Coello 1996). 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 including molluscs and algae are also harvested (FAO 2000c). In 1998 this sector produced 361 400 tonnes for human consumption or raw material, generating until August a total of 535 million USD, 46.5% of the fishing exports in that year (FAO 2000c). The aquaculture sector generated more than 67 000 jobs in 1998, rising to 95 000 people if indirect activities are considered (FAO 2000c). According to the National Service of Fishing, aquaculture production grew from 105 300 tonnes in 1991 to 631 600 tonnes in 2001.

In Peru, aquaculture is just beginning and focuses on shrimps, trout and scallops. The activity has grown in recent years reaching a production of 8 700 tonnes per year: 4 300 tonnes of shrimp, 2 600 tonnes of scallops, 1 600 tonnes of trout and 200 tonnes of other species (FAO 2000a).

Tourism

According to the World Tourism Organisation, 3.5 million tourists visit the region every year and 48% stay on or near the coast (WTO 1997). During the past decade tourism in Ecuador increased by 7% annually (Ecuadorian Ministry of Tourism 2000). The Galapagos National Park reported a total of 77 590 tourists in 2001, which represented one third of the income generated by the receptive tourism sector in the country (430 million USD) (NATURA/WWF 2002). This region possesses a high diversity of natural environments and ecotourism is a growing activity (CPPS 2001b).

Mining

Chile and Peru are among the largest producers of copper and silver in the world. Chile produces around 4.6 million tonnes of copper annually and accounts for 19% of global copper production and 11% of refined copper. Chile has one of the largest copper reserves in the world with estimates surpassing 200 million tonnes, 34% of the global known reserves (Astorga 2002). There were 427 mines and around 800 mining residual deposits in 1999 (UNEP 1999). Mining industries are located at Antofagasta, Santiago and Valparaiso. Mining in Chile contributed 9.6% to the GDP in 1990 and 11% in 2000 (INE/CONAMA 2002).

Peru contributes 3.1% to global copper and 1.7% of refined copper production. Silver production totalled 1 820 tonnes in 1994 (CEPAL 1996). According to the Peruvian Ministry of Energy and Mining, 24 companies with 30 mines were in operation in 1995 (UNEP 1999). The contribution of mining to GDP was 2.4% in 1990 and 1.9% in 1994 (CPPS 2001b). In Ecuador gold mining is concentrated in the south of the country, in the provinces of Azuay and El Oro, with a total production of around 10 tonnes. In Ecuador, mining has contributed 0.8% to GDP since 1988 (CAAM 1996).

Industry

The region is moving toward industrialisation. Chile ranks as the most industrialised country in the South East Pacific; in 2002 industry accounted for approximately 19.3% of the GDP (INE/CONAMA 2002). The food industry is the most important, followed by textile, chemical, wood pulp, paper, etc. In Chile there are around 311 industrial facilities, with the highest concentration at Talcahuano. Wood pulp, paper and chemical sub-product industries are concentrated at Conception, and the food industry is located at Antofagasta, Santiago and Valparaiso (CPPS 2000a). Chile exported 8.2 billion USD of industrial products in 2000 (INE/CONAMA 2002). In Peru, most industries (65%) are concentrated in Lima (1 025 industrial facilities). In Ecuador, industries are concentrated along the coast, especially in the province of Guayas, and include wheat flour, fish canneries, vegetable oil, beer and soft beverages, textile, paper, and steel. Packing plants comprise 33%, canneries 29%, vegetable oil refineries 6%, mills 4% and foundries 4% (CAMM 1996).

Oil

Both Chile and Peru have offshore oil production. Pipelines are found along the coast of the three countries. There are refineries and a significant amount of oil traffic in the region (CPPS 2001b). On the Ecuadorian coast, the oil infrastructure is concentrated in La Libertad, where two refineries process 6 400 m^3 per day, and Esmeraldas with a capacity of 17 500 m^3 per day. There is also an offshore platform for gas extraction in the Gulf of Guayaquil. In Peru, oil production is carried out on the northwestern continental platform and oil is processed in two refineries at La Pampilla and Conchan (UNEP 1999). In Chile, offshore platforms are located in the south (Punta Arenas) and in the Magellan Strait (CPPS 2000a).

Ports and maritime transport

There are over 22 ports along the South East Pacific coastline with a gross registered tonnage for cargo ships equivalent to 23.5% of the total for the LAC (CPPS 2000a). Peru has 18 marine terminals with more than 10 000 tonnes of capacity; the most important are Callao, Chimbote and Salaverry (CPPS 2000a). Ecuador has four ports; the most important is at Guayaquil, which handled 3.9 million tonnes (67% of the total loading) in 1993. It is expected the loading will increase to 6.5 million tonnes by 2010 (JICA 1995). The Chilean ports of Valparaiso and Concepcion receive almost 20% of the total loading (CPPS 2000a).

Regional conventions

Countries of the region have developed regional mechanisms of cooperation, including regulations and protocols to deal with pollution from land-based sources, hydrocarbon spills and exploitation of fishing resources (CPPS 2003b). In 2002, countries of the region signed the Galapagos Agreement for the management of marine resources on the high seas of the South East Pacific, which establishes a legal framework for the exploitation and conservation of living resources beyond the 200 nautical miles of national jurisdiction. It is expected that these regional instruments will facilitate the management of transboundary issues such as those considered in this analysis. For more information on regional conventions, protocols and projects see Annex III.

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.

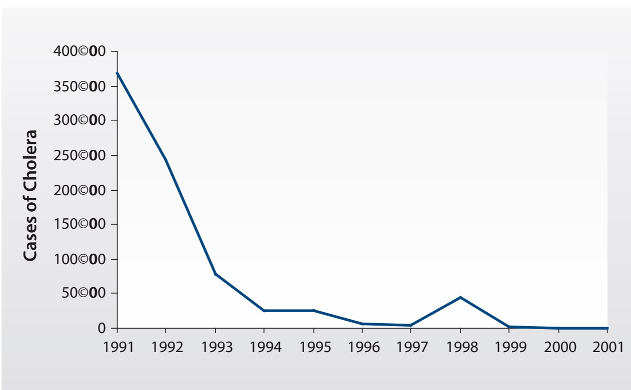

Figure 7 Number of cholera cases in the Humboldt Current region between 1991 and 2001.
(Source: OMS 2002)

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

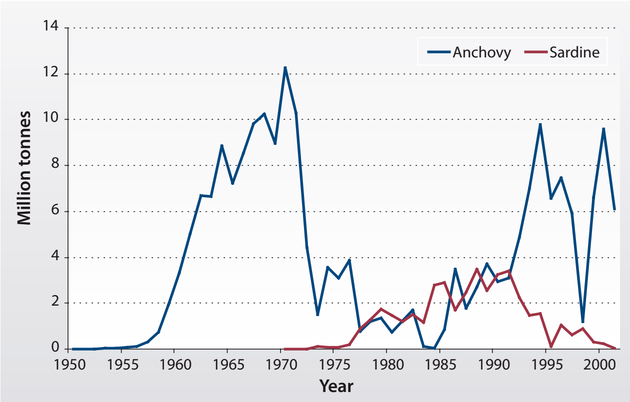

Figure 8 Peruvian catches of sardine and anchovy between 1950 and 2001.
(Source: GIWA Task team 2004)

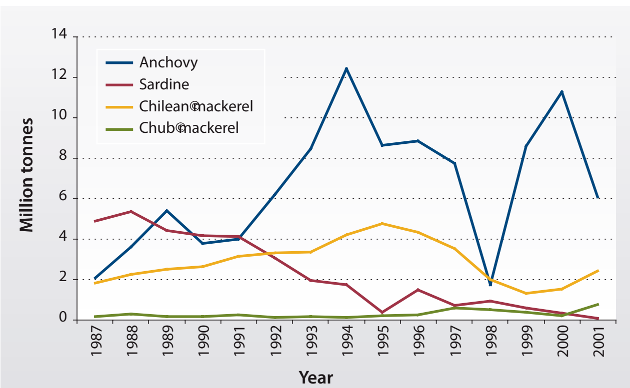

Figure 9 Catches of the small pelagic fish in the Southeast Pacific between 1987 and 2001.
(Source: GIWA Task team 2004)

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

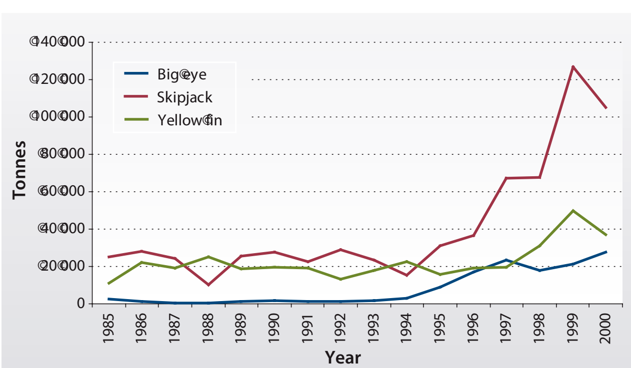

Figure 10 Catches of tuna by the Ecuadorian purse-seine fleet.
(Source: GIWA Task team 2004)

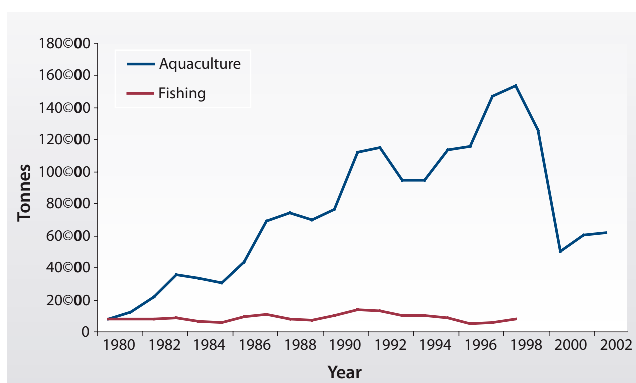

Figure 11 Total shrimp production in Ecuador.
(Source: GIWA TAsk team 2004)

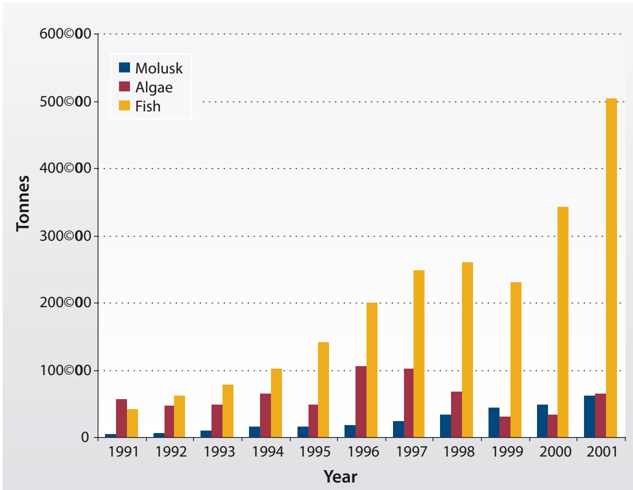

Figure 12 Aquaculture production in Chile.
(Source: GIWA Task team 2004)

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.

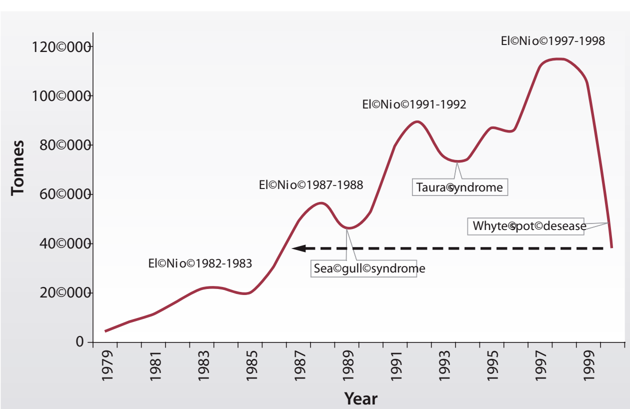

Figure 13 Decreased shrimp production as a result of pathogens. *(Source: CNA 2002)*

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).

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)

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).

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.

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 m^3 per year of wastewater is discharged into the South East Pacific Ocean with a pollutant charge of 1.76 million tonnes per year of BOD_5 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

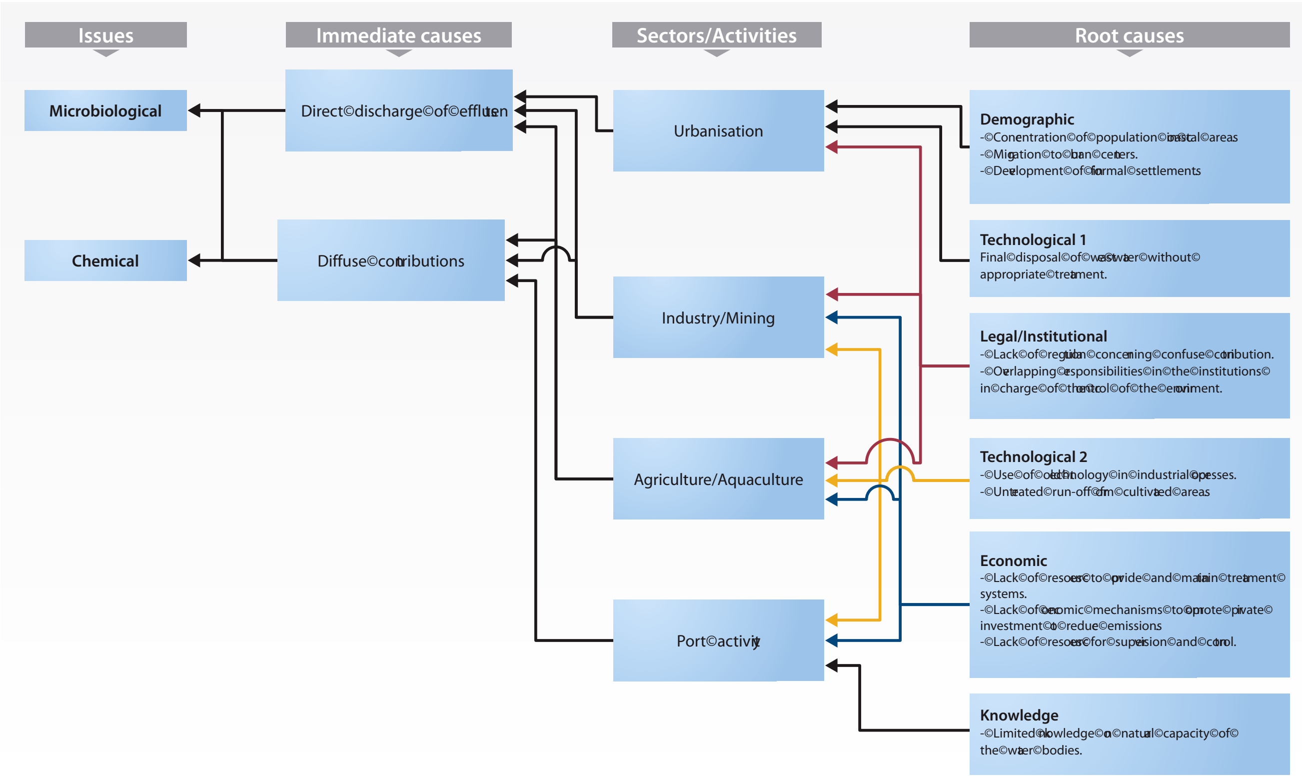

Figure 14 Causal chain diagram illustrating the causal links for Pollution in the Humboldt Current region.

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 vibrion 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

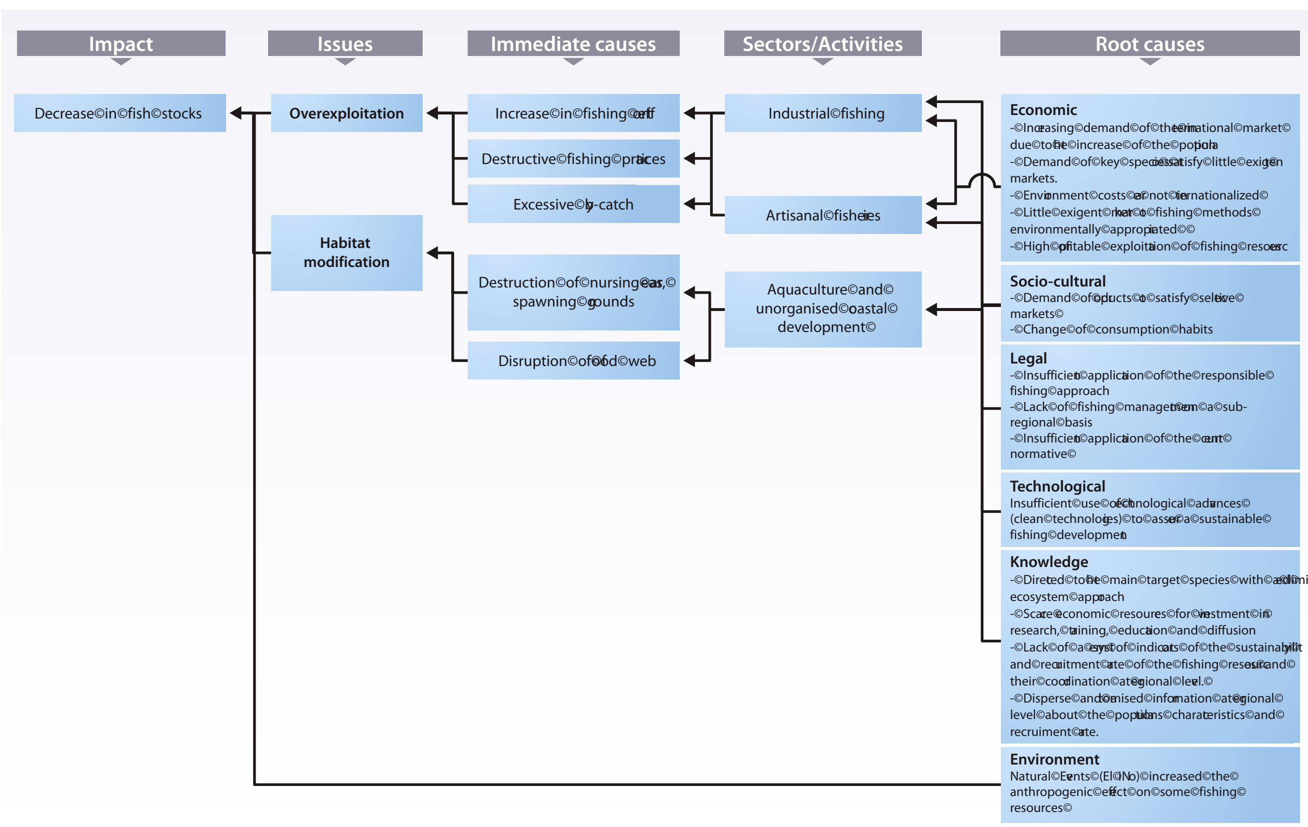

Figure 15 Causal chain diagram illustrating the causal links for Unsustainable exploitation of fish and other living resources.

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	*Engraulis ringens*	Full-exploited in its whole distribution range
Sardine	*Sardinops sagax*	High-exploited in its whole distribution range and absent of several areas
Chilean jack mackerel	*Trachurus murphyi*	Between mid and highly exploited with the risk of overexploitation
Chub mackerel	*Scomber japonicus*	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 counties 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.

Policy options

This section aims to identify feasible policy options that target key components identified in the Causal chain analysis in order to minimise future impacts on the transboundary aquatic environment. Recommended policy options were identified through a pragmatic process that evaluated a wide range of potential policy options proposed by regional experts and key political actors according to a number of criteria that were appropriate for the institutional context, such as political and social acceptability, costs and benefits and capacity for implementation. The policy options presented in the report require additional detailed analysis that is beyond the scope of the GIWA and, as a consequence, they are not formal recommendations to governments but rather contributions to broader policy processes in the region.

Pollution and Unsustainable exploitation of fish have been identified as the major environmental concerns of the region. In the causal chain analysis the sectors/activities and the root causes of these problems were identified. In the case of pollution, microbiological and chemical pollution are the most severe issues causing a deterioration in the environmental quality of the region, although their severity differs between the countries. Regarding the unsustainable exploitation of fish, overexploitation was considered the most relevant issue due to the importance of the fisheries for the regional economy and because of the shared nature of the main fish stocks.

Pollution

GIWA experts selected pollution as the first priority environmental concern of the region because its impact on economic, social and health issues. Microbiological pollution was the most relevant immediate cause because a high proportion of domestic effluents (80-95%) are discharged into natural water bodies without treatment (CPPS 2000a, WHO/UNICEF/WSSCC 2001). The region is characterised by low sanitation coverage with around 13 million people without access to this service (WHO/UNICEF/WSSCC 2001). Concentrations of faecal coliforms in waters around the major urban centres in Ecuador and Peru exceed current standards. These inadequate sanitation conditions favour the presence of endemic gastroenteric diseases such as typhoid, cholera and hepatitis. Other sources of microbiological pollution include the effluents from slaughterhouses and food processing plants, as well as the discharge of solid wastes. Extreme climatic events such as the El Niño exacerbate sanitation problems by increasing rainfall and flooding and damaging the sanitation infrastructure.

The root causes of microbiological pollution include:

- Demographic – Overpopulation, migration from rural areas, dynamic and unplanned human settlements and intense use of land.
- Technological – Lack of appropriate technologies for wastewater treatment.
- Economic – Subsidised tariffs, lack of resources for supervision and control, insufficient promotion of private investment, among others.
- Legal and institutional – Overlapping responsibilities, lack of a basin approach to hydrological resource management.

Chemical pollution was considered as the second most relevant issue. The immediate causes are mainly related to industrial wastewater, the use of pesticides and other agro-chemicals (FAO 2002b, UNEP 1999). POPs such as DDT and its metabolites, Aldrin, and Lindane are present in water and sediments throughout the region (CPPS 2000a). Mining discharges are another important source of chemical pollution since Chile and Peru are major copper and gold producers. Several heavy metals such as copper, zinc, lead, cadmium, mercury and chromium have been found in concentrations exceeding national regulations in coastal waters and sediments around mining areas and industrial centres.

The root causes of chemical pollution include:

- Demographic – Concentration of the population in coastal areas, migration and development of informal settlements.
- Technological – Obsolete technology, inappropriate wastewater and solid waste treatment.
- Economic – High cost of treatment systems, lack of promotion of private investment.
- Legal and institutional – Obsolete laws, inappropriate municipal regulations, overlapping responsibilities of institutions in charge of the supervision and control, weak sanctions.
- Knowledge – Unknown carrying capacity of the ecosystem, ignorance about the effects of chemical pollution.

Construction of options

Environmental pollution in the Humboldt Current region is linked with failures in public administration, a lack of education and poverty. It is therefore necessary that the region adopts the principles established at international forums such as the World Summit on Sustainable Development (United Nations 2002) which proposes "the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, linking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes, and reducing resource degradation, pollution and waste". Regarding pollution, the WSSD Plan of Implementation also proposes the adoption and implementation of policies and measures to apply the 'polluter pays' principle described in the Rio Declaration on Environment and Development (United Nations 1992) and the "increase of investment in cleaner production and eco-efficiency in all countries through, *inter alia*, incentives and support schemes and policies directed at establishing appropriate regulatory, financial and legal frameworks".

The governments of the Humboldt Current region have adopted legal mechanisms and several programmes to address pollution issues such as (see Annex III):

- The Convention for the protection of the Marine Environment and Coastal Areas in the South East Pacific.
- The Agreement on Regional Cooperation in Combating Pollution in the South East Pacific by Hydrocarbons and Other Harmful Substances in Cases of Emergency.
- The Protocol for the Protection of the South East Pacific from Radioactive Pollution.
- The Protocol to Prohibit Transboundary Movements of Hazardous Wastes and their Disposal to the South East Pacific.
- The Coordinated Regional Programme for Research.
- Surveillance and Control of Marine Pollution of the South East Pacific (CONPACSE).
- Regional Programme for the Protection of the South East Pacific from Land-based Activities (PROSET).

The Permanent Commission for the South Pacific (CPPS) has coordinated these agreements, protocols and programmes in the region since 1981 through the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South Pacific. The selection of policy options most appropriate in addressing pollution in the region should take into consideration and strengthen these regional mechanisms.

Decentralise environmental management:
Policy option addressing the root causes Demographic, Legal and Institutional, and Knowledge.

In the countries of the region, the creation of policies and strategies for pollution control has had a high degree of centralisation. Legal regulations and the sharing of responsibilities involve the participation of several authorities without legal or institutional mechanisms to assure an integral approach to the problem, and excluding the involvement of local stakeholders in the decision-making process (CPPS 2000a, 2001b). Therefore, social problems caused by pollution and environmental degradation will continue until local stakeholders are able to participate actively in finding appropriate solutions. The WSSD declaration appeals to the participation of stakeholders and encourages partnerships to support the implementation of Agenda 21 at the local and regional levels.

Generally, regional governments have shown interest in the establishment of decentralised management strategies, policies and conceptual frameworks, as well as in defining specific projects to address problems with an ecosystem management approach. However, the implementation of these processes is still problematic. Operative mechanisms require coordination in order to evaluate policies and strategies at national and regional levels, and the creation of operative institutions to implement environmental management projects at local levels (i.e. municipalities). This policy requires the corroboration of local governments in order to delegate responsibilities, create policies and establish mechanisms of control according to specific requirements. The participation of multiple stakeholders in this process is fundamental. Local governments may also use the experiences of other municipalities or from neighbouring countries through well-established regional mechanisms of cooperation, such as the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South East Pacific (CPPS/UNEP 1983).

Convenience

The creation of a unified institutional mechanism, with defined national policies and strategies, and an additional mechanism at the local level, will allow the simple identification and selection of themes and priority problems for environmental management. Furthermore, it will allow the formation of projects, which include the participation of different stakeholders directly related to pollution problems. The integrated approach and institutional cooperation will also provide better possibilities for effective pollution management.

A greater understanding of the pollution problem will promote a more effective use of natural and human resources and the progressive improvement of the environmental situation. The inefficient control of pollution through sectored actions has necessitated the implementation of policies that assure institutional integration to reduce, and finally halt, the growing pollution problems in the region.

Feasibility

Countries in the region have considerable national experience in developing institutional mechanisms for regional cooperation. For example, the governments of the region established the Permanent Commission for the South Pacific (CPPS) and its Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South East Pacific (CPPS/UNEP 1983). The Commission may be able to assist in the design and implementation of regional policies, in collaboration with their respective national components, to guarantee a system for the mitigation and control of pollution in the region.

The main objective of the Plan of Action is to protect the coastal and marine areas to safeguard the health and well-being of current and future generations through the active cooperation of its members. For this purpose, the Plan of Action coordinates national institutions that conform to an operative network for the benefit of the South East Pacific. The Major sources of pollution in the South East Pacific were identified during the coordinated implementation of programmes such as CONPACSE and PROSET (CPPS 2000a, 2001b). Through the same mechanism, countries of the Humboldt Current region should identify potential donors and international assistance programmes to obtain economic resources in order to develop both the initial designing phase and the execution of the proposed policy.

Acceptability

For a long time, the local governments of the Humboldt Current region have claimed that they should be given responsibility for addressing their own local social and environmental problems. Therefore, municipalities and other forms of local administration would be willing to assume such responsibilities as long as the national government assign the necessary funds. However, the main obstacle for decentralisation is opposition by the traditional bureaucracy, who fear a subsequent loss of power and influence. The creation of local institutions with sufficient operational capacity to deal with pollution problems would require the reorganisation of the institutions currently in charge of pollution control leading to further opposition from the central bureaucracy.

The majority of local stakeholders would be willing to adopt a new approach to tackling pollution since they will be the beneficiaries of a healthy environment. However, polluters, such as industries, could oppose stronger regulations, and therefore local institutions should be strengthened and given greater legislative powers by the national Government and the Congress whose responsibility it would be to provide a new legal framework. This framework should take into consideration the necessity to improve the efficiency and level of coverage of sanitation and freshwater services and to include modern concepts of management, such as the privatisation and self-regulation approach for industrial wastewater.

Harmonise criteria and environmental quality standards and develop common indicator systems for environmental management:
Policy option addressing the root causes Technological, Economic, and Knowledge.

The countries of the Humboldt Current region have developed their own criteria and environmental standards for the control of effluents discharged into water bodies, air and soil. There is therefore no regional coordination of national regulations. An important step towards reducing pollution levels will be a study of the characteristics and efficiency of the current standards and actions taken in these countries, identifying opportunities to initiate a process of harmonisation of regulations and to define mechanisms of evaluation and control of the results obtained both at national and regional levels. It will be necessary to identify appropriate indicators to evaluate the achievements obtained as a result of the implementation of such regulations to adequately support the process of control and mitigation of the more important pollution issues in the region. This could be achieved through the organisation of regional workshops coordinated by the Plan of Action of the South East Pacific under the auspices of the programmes CONPACSE and PROSET, which are concerned with the mitigation of the pollution concern. The governments of the region demonstrated their commitment to resolving the pollution issues by ratifying the Convention for the Protection of the Marine Environment and Coastal Areas of the South East Pacific also known as the Lima Convention (CPPS 1981) and also by adopting international agreements such as the WSSD (United Nations 2002) and UNCED (United Nations 1992).

Convenience

This policy aims to establish regional regulations and standards, in order to mitigate and control pollution in the region. Particular importance should be given to sanitation criteria for wastewater discharges, both domestic and industrial, and their treatment, identified as the major cause of pollution and environmental degradation (CPPS 2000a). Chile has the highest standards in the region regarding the control of water pollution. This significant achievement may be the result of the harmonisation of environmental criteria and the establishment of guidelines for appropriate legal frameworks that include the new principles of wastewater management, such as the 'polluter pays' principle.

Feasibility

The experience and advances of the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South East Pacific include institutional cooperative structures in each country of the region, containing structural elements and operative facilities necessary for the implementation of this policy. Unfortunately, countries of the region have not been able to take advantage of this regional mechanism to promote a healthier environment. Countries have not taken the initiative to establish environmental regulations at the regional level like countries that are members of economic blocks such as the European Community (EC) or the North American Free Trade Agreement (NAFTA). The adoption of such regional standards will be necessary in the short-term if the Humboldt Current region is to progress.

Acceptability

As previously noted, the governments of the Humboldt Current region have signed agreements and protocols that aim to foster cooperation in combating pollution and develop regulations and operative mechanisms to reduce and control pollution in the South East Pacific (Annex III). These mechanisms include a variety of issues related to pollution, from wastewater to radioactive contamination. There is consequently a tendency among the countries to accept regional compromises regarding pollution. The next step is to implement practical actions in order to harmonise criteria, create regional standards of environmental quality and establish a common system of indicators. The WSSD declaration pledged to focus and give priority attention to conditions that threaten sustainable development, including environmental degradation.

Conclusions

Two policy options were selected to address the GIWA concern Pollution in the Humboldt Current region regarding convenience, feasibility and acceptability: *Decentralise environmental management* and *Harmonise criteria and environmental quality standards and develop common indicator systems for environmental management.* The first policy attempts to devolve environmental management to local governments and to promote the active participation of local stakeholders in the decision-making process. This policy requires the strengthening of local governments through the creation of an appropriate legal framework in order that local governments assume such responsibilities. Decentralisation of environmental management is considered the most convenient way to address pollution problems, although it requires the political will of each country to adopt such administrative changes and to assign the necessary economic resources for its implementation.

The second policy demands the active participation of governments and technical institutions to develop common standards and environmental regulations for the Humboldt Current region. Countries of the region have developed several regional mechanisms of cooperation to deal with pollution problems such as the Plan of Action for the protection of the Marine Environment and Coastal Areas of the South Pacific (CPPS/PNUMA 1983) (see Annex III) and specific programmes to assess the impact of land-based sources of pollution (CONPACSE and PROSET). Unfortunately, countries have not been able to take full advantage of such mechanisms for the benefit of their populations. Ecuador and Peru could benefit from the experience of Chile, a country with higher environmental standards and lower levels of pollution.

Unsustainable exploitation of fish and other living resources

The second priority environmental concern was the Unsustainable exploitation of fish and other living resources. Overexploitation was considered to have a severe impact in the region due to the steady reduction in landings of small pelagic fish and changes in abundance and the composition of species, most of which are considered highly or fully exploited (i.e. Anchoveta (*Engraulis ringens),* South American pilchard (*Sardinops sagax*), Inca shad (*Trachurus murphyi*), Chub mackerel (*Scomber japonicus*), Pacific thread herring (*Opisthonema* spp.), Araucanian herring (*Strangomera benticki*) (FAO 1997). Demersal species (South Pacific hake (*Merluccius gayi*), Southern hake (*M. polylepis*), Patagonian grenaider (*Macruronus magellanicus*)) and several invertebrates are similarly exploited and some are considered overexploited (including sea urchin, clams, scallops, crabs and other crustaceans). The reduction in fishing resources has caused serious economic and social consequences, especially in artisanal communities that are highly dependent on marine resources (CPPS 2003b). Destructive fishing practices, excessive by-catch and discards, which have an impact on the biological and genetic diversity, were considered to have a slight impact.

Figure 16 Fishermen pull their catch onto their boat off the coast of Peru.
(Photo: CORBIS)

The immediate causes of overexploitation include: an increase in fishing effort by both artisanal and industrial fleets; a decrease in the recruitment level of commercial species, particularly of small pelagic schooling fish; a change in the distribution of fish populations, either due to habitat destruction or natural climatic variability; and the use of non-selective fishing gear which produces high rates of by-catch and discards.

The root causes of the unsustainable exploitation of fish include:

- Economic – Increasing demand for fisheries products, demand for specific species of high value, inadequate evaluation of environmental costs.
- Socio-cultural – Demand for products to satisfy selective markets, change in consumption patterns.
- Legal and institutional – Weak application of the responsible approach to fisheries, insufficient application of the current management normative, lack of regional management approach, conflicts among sub-sectors, weakness of institutions responsible for fisheries management.
- Technological – Limited adoption of cleaner technologies.
- Knowledge – Research focused mainly on the exploited species rather than applying the ecosystem approach, insufficient and fragmented information.
- Governance – Lack of policies and strategies with an ecosystem approach at the regional level, conflicts among stakeholders, weak control and enforcement.
- Natural processes – Natural events have increased anthropogenic impacts on some fishing resources.

Construction of options

Based on the Causal chain analysis, three policy options were developed according to the criteria of efficiency, equity, political feasibility and capacity of implementation at the regional level:

1. Rationalisation of fishing production
2. Development of knowledge and indicators
3. Regulation of fishing effort

The chosen policies are in concordance with chapter 17 of Agenda 21 and paragraph 31 of WSSD regarding the conservation and management of the oceans. These policies attempt to maintain the productivity and biodiversity of the South East Pacific Ocean in the long-term through the sustainable management of its resources. The policies also help to implement the ecosystem approach to fisheries, eliminate destructive fishing practices and facilitate the diffusion and exchange of knowledge between the countries of the region.

The policies also promote the regional management of transboundary fishing resources as proposed by Zuzunaga (2002) through coordination and cooperation between the countries. These policies should be implemented through well-established regional mechanisms such as the Permanent Commission for the South Pacific (CPPS), which has been coordinating technical cooperation in the region regarding coastal and marine issues for the past 50 years. Progression in this direction by the South East Pacific countries was demonstrated through the signing of the Galapagos Agreement in 2000, which includes the conservation and management of living resources beyond the countries' jurisdiction (see Annex III).

Rationalise fishing production

Policy option addressing the root causes Economic, and Socio-cultural.

Since most of the fishing production from the South East Pacific Ocean is used as raw material for fishmeal, this policy attempts to promote the rationalisation of fishing production according to the following aspects: 1) opportunities and market conditions; 2) possibilities of diversifying exploitation and producing added-value products; 3) necessity to internationalise environmental protection costs; 4) maintain the base of exploited resources; and 5) ensure equity and benefits for society.

These aspects demand that economic studies identify opportunities and markets be developed both for new fishing products and for new processed products. The key objective of this policy is to maintain fishing productivity in the South East Pacific and increase incomes through the sustainable management of fishing production. This policy agrees with the Code of Conduct for Responsible Fisheries (FAO 1995) that establishes, in paragraph 11, the necessity that countries cooperate to facilitate the production of value-added products in developing countries. This is also part of the identification and selection of good management practices for the region.

Development of knowledge and indicators

Policy option addressing the root causes Knowledge, and Natural causes.

A second priority was given to the development of knowledge and indicators of change that occur in the exploited populations to allow policy makers to make informed decisions in the management of the fisheries. The policy requires the development of research, the exchange of information and the implementation of measures at a regional level.

Countries of the Humboldt Current region have been actively cooperating in fishing research under the coordination of the CPPS through its Coordination Commission of Scientific Research. Scientific programmes conducted jointly by countries of the region include the following: the Regional Study of the El Niño Phenomenon (ERFEN); the Joint Regional Cruises Programme; and the Integrated Management of the Large Marine Ecosystem of the Humboldt Current (see Annex III). Part of this cooperation includes training programmes in themes such as hydro-acoustic assessments of resources, and marine biodiversity, among others. Furthermore, countries should increase cooperation to develop baseline studies to establish indicators, especially for transboundary resources, to develop regulations at the regional level to ensure their conservation and management as stipulated in the FAO Code of Conduct. The highly variable oceanographic conditions of the region and the presence of extreme events such as the El Niño and La Niña have important consequences for the fisheries in the region (Csirke et al 1996), which demand highly dynamic management in which all the countries exploiting the same resources participate in the decision-making process. As mentioned earlier, the advantages of such a regional approach for the main fisheries of the South East Pacific have been demonstrated through modelling analysis (Zuzunaga 2002).

Regulation of fishing effort

Policy option addressing the root causes Legal, Governance, and Technological.

The third priority was given to the regulation of fishing effort. However, caution should be taken when issuing measures to regulate fishing effort since environmental conditions also play an important role in the availability and distribution of fishing resources. Csirke et al. (1996) stated that due to the changes in abundance of the Peruvian anchovy as a result of natural variability, a dynamic management system should be adopted that takes into account the fluctuations in its population regime.

Countries in the region are currently implementing measures aimed at reducing fishing effort. For example, Ecuador imposes annual closed seasons for shrimp trawling fishing, as well as for some invertebrates, such as clams and crabs. Peru has imposed closed seasons and quotas for anchovy, sardine, mackerel and hake, and Chile has closed seasons for some coastal invertebrates. However, no measures other than those for the tuna fishing fleet in the Eastern Tropical Pacific by the Inter-American Tropical Tuna Commission (IATTC) have been taken with a regional approach. The industrial fishing sector has shown in several cases a disproportionate increase in fishing effort compared with the potential of the fishing resource (IMARPE 2002a). The FAO Code of Conduct also calls upon governments to prevent or eliminate excess fishing capacity as a means of ensuring the effectiveness of conservation and management measures. An alternative to reducing fishing effort is to change fishing gear to exploit new fisheries, especially in deeper waters. Promoting investment in new technology capable of catching under-exploited resources should be included in the strategy to redistribute fishing effort.

The regulation of fishing effort at the regional level could be implemented based on advances in knowledge regarding the fisheries. This process may be facilitated through the participation of CPPS as part of the implementation of existing mechanisms of regional cooperation, such as the Galapagos Agreement.

Conclusions

Three policy options were developed to address the issue of overexploitation of fishing resources according to the criteria of efficiency, equity, political feasibility and capacity of implementation at the regional level: *Rationalisation of fishing production*, *Development of knowledge and indicators* and *Regulation of fishing effort*.

The first option attempts to maximise the benefits for the counties by taking into account market opportunities, diversifying products and internationalising environmental costs, but maintaining the current basis of exploitation. The second option requires the development of knowledge of the exploited population in order to adopt sustainable fishing management practices. For this purpose the region has developed regional mechanisms of cooperation such as the Regional Study of the El Niño Phenomenon (ERFEN), the Joint Regional Cruises Programme and the Integrated Management of the Large Marine Ecosystem of the Humboldt Current (see Annex III). The ultimate aim is joint management of shared fish stocks in the region. The third policy aims to regulate fishing effort to achieve sustainable fishing management, but takes into account that some resources in the Humboldt Current ecosystem show a high susceptibility to environmental fluctuations. Countries are currently adopting restrictive measures such as closed seasons and quotas for some stocks. However, an alternative to reducing fishing effort on depleted stocks is to develop new fisheries and to promote investment in new technology.

Conclusions and recommendations

Pollution and Unsustainable exploitation of fish and other living resources were selected as the two priority concerns in the Humboldt Current region. The environmental and socio-economic impacts have common causes regarding social, cultural and economic issues such as poverty, migration to urban centres, a lack of economic resources to invest in technology and a lack of knowledge, which delay the adoption of integrated management policies that are based upon a regional approach. The region has legally binding mechanisms for regional cooperation. The most important is the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South Pacific, whose Executive Secretariat is the Permanent Commission for the South Pacific (CPPS), as well as with several complementary instruments such as protocols and agreements that have not been fully implemented at the regional level.

Pollution

There is detailed information in the region about the level of microbiological and chemical aquatic pollution. This information demonstrates that, although pollution has similar causes and levels of intensity in the three countries and there are still local problems associated with the major urban and industrial centres, it is not a transboundary issue. This is essentially due to the nature of rivers, the main carriers of pollution, which originate in the western slope of the Andean mountain range. In general, rivers are short with low discharges and in most cases seasonal. Unfortunately, there are few assessments on the current impacts of pollution on the coastal and marine biota of the South East Pacific Ocean. Studies need to determine the potential changes in the communities and ecosystems of the region if the current levels of pollution continue.

Although the root causes of pollution identified in this analysis are present in all three countries, it is evident that there are differences in the level of coverage of basic services and the effectiveness of environmental management (WHO/UNICEF/WSSCC 2001). In this sense, the policy options proposed for the region must take into account these intra-regional differences. Chile has the highest environmental standards, with legal mechanisms that have allowed the privatisation of public services, and have incorporated the concept of self-regulation for industrial wastewater discharges. These mechanisms are not yet fully implemented in Ecuador and Peru, resulting in significantly higher rates of gastroenteric diseases and infant morbidity in these countries.

The harmonisation of criteria and environmental standards between the countries of the region is a policy option proposed to improve the environmental conditions of the region. The adoption by Ecuador and Peru of environmental standards similar to those used in Chile and the modernisation of environmental regulations to encourage private investment in sanitation and drinking water supply could be a mid-term objective. To facilitate this transition process the creation of decentralised entities for environmental management has been proposed. The basic idea is to reduce the decision-making power of centralist governments and assign responsibilities to municipalities or local governments, which will operate through a consultative process with local stakeholders, to identify local priority problems and provide integrated solutions. However, in the case of water resources, integrated basin management rather than a local or national approach must be adopted.

Unsustainable exploitation of fish

The management of fisheries must be addressed with a regional approach, applying modern management criteria to promote their sustainability. As with pollution, the root causes of the overexploitation of fishing resources are the same in the three countries: over-development of fishing effort, weak mechanisms of control, and a lack of knowledge of the exploited species. Although significant achievements regarding regional cooperation have been realised, no regional management mechanisms, such as fishing quotas, mesh size or closed seasons, have been implemented. Each country is managing fisheries according to their own criteria based on national research, knowledge and capabilities. It is widely agreed that, at least in the case of the small schooling fish, which form the basis of the industrial fishery in the region, the three countries are exploiting the same populations.

It has been suggested that there should be a rationalisation of fishing production. The introduction of ecosystem and regional management approaches would not only allow the continuation of current industrial fisheries, but it would also promote the search for alternatives to diversify fishing products. This could involve the incorporation of added value to industrialised products and extensions to the market. The development of fishing indicators and the exchange of information between the countries of the region may initiate a regional management approach to fisheries in order to preserve the viability of the exploited stocks and satisfy the socio-economic necessities of the region.

The results of this assessment of the priority environmental concerns have highlighted the necessity to increase the level of cooperation though the strengthening of existing regional mechanisms to address the environmental problems of the region. The most viable mechanism is the Permanent Commission for the South Pacific (CPPS), which has been coordinating activities with the participation of institutions and groups of specialists from each country on a number of topics including fisheries, pollution, and integrated management of coastal resources, over the last 50 years. Governments of the region confirmed their will to continue this successful collaboration during the commemoration of the 50th Anniversary of the Santiago Declaration, which established the CPPS, in August 2002 in Santiago, Chile. The text of this declaration is included in Annex III.

Addressing these and other environmental problems affecting the South East Pacific Ocean is a major challenge for CPPS and the Humboldt Current region. Only through the responsible management of environmental problems currently affecting the area will a future healthy and productive environment be achieved.

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Annexes

Annex I
List of contributing authors and organisations

Name	Institution	Country	Field of work
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Mario Hurtado	Hurtado and Asociates	Ecuador	Environmental Consultant
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Rosa Aguilera Vidal	University of Conception	Chile	Economy
Carla Falcón Simonelli	DIRINMAR	Chile	Fisheries
Susana Arciniegas	Military Geographic Institute	Ecuador	Geographic information system
Hernán Moreano Andrade	PMRC	Ecuador	Integrated coastal zone management
Fernando Coello Navarro	Undersecretary of Fishing Resources	Ecuador	Fisheries
Miguel Fierro Samaniego	ESPOL	Ecuador	Socio-economic aspects of coastal management
Elizabeth Flores Abad	University of Guayaquil	Ecuador	Socio-economic aspects of coastal management
Manuel Valencia Touris	INOCAR	Ecuador	Industrial wastewater
Luis Arriaga Mosquera	National Institute of Fisheries	Ecuador	Fisheries, environmental politics
Héctor Ayón	ESPOL	Ecuador	Environment and natural resources, pollution
Hernán Moreano	DIGEIM (adviser)	Ecuador	Environmental politics
Godofredo Cañote	IMARPE	Peru	Environmental politics, fisheries
Sulma Carrasco	IMARPE	Peru	Pollution
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Elsa Galarza Contreras	IMARPE	Peru	Environment economy
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Fernando Félix	Plan of Action-CPPS	Ecuador	Editor

Annex II
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	1	15	Freshwater shortage	1.9
2. Pollution of existing supplies	2	60		
3. Changes in the water table	2	25		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	30
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	3	60
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	10
Weight average score for Economic impacts		**2.5**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	2	40
Degree of severity	Minimum 0 1 2 3 Severe	2	60
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	10
Weight average score for Health impacts		**1.9**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	2	60
Degree of severity	Minimum 0 1 2 3 Severe	2	20
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	20
Weight average score for Other social and community impacts		**2.0**	

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	2	35	Pollution	1.9
5. Eutrophication	1	5		
6. Chemical	2	30		
7. Suspended solids	2	10		
8. Solid wastes	2	5		
9. Thermal	1	3		
10. Radionuclides	1	2		
11. Spills	2	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	30
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	2	60
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	10
Weight average score for Economic impacts		**2.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	2	40
Degree of severity	Minimum 0 1 2 3 Severe	2	50
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	10
Weight average score for Health impacts		**1.9**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	2	50
Degree of severity	Minimum 0 1 2 3 Severe	2	30
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	20
Weight average score for Other social and community impacts		**2.0**	

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	2	55	Habitat and community modification	2.0
13. Modification of ecosystems or ecotones, including community structure and/or species composition	2	45		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	20
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	20
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	60
Weight average score for Economic impacts		**1.6**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	-
Degree of severity	Minimum – Severe 0 1 2 3	0	-
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	-
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	50
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Other social and community impacts		**2.0**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	60	Unsustainable exploitation of fish	2.1
15. Excessive by-catch and discards	0	5		
16. Destructive fishing practices	1	20		
17. Decreased viability of stock through pollution and disease	0	5		
18. Impact on biological and genetic diversity	1	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	3	25
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	50
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	25
Weight average score for Economic impacts		**2.8**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	-
Degree of severity	Minimum – Severe 0 1 2 3	0	-
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	-
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	50
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Other social and community impacts		**2.0**	

V: Global change

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	60	Global change	1.6
20. Sea level change	1	15		
21. Increased UV-B radiation as a result of ozone depletion	1	20		
22. Changes in ocean CO_2 source/sink function	0	5		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	30
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	2	50
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	20
Weight average score for Economic impacts		**2.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	2	40
Degree of severity	Minimum – Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	20
Weight average score for Health impacts		**1.8**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	3	40
Degree of severity	Minimum – Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	20
Weight average score for Other social and community impacts		**2.4**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score	Rank
	Environmental score		Economic score		Human health score		Social and community score			
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Freshwater shortage	1.9	2.1	2.5	2.7	1.9	2.1	2.0	2.2	**2.2**	**1**
Pollution	1.9	2.2	2.0	2.3	1.9	2.0	2.0	2.1	**2.1**	**2**
Habitat and community modification	2.0	2.2	1.6	1.6	0	0	2.0	2.1	**1.4**	**5**
Unsustainable exploitation of fish and other living resources	2.1	2.2	2.8	2.8	0	0	2.0	2.8	**1.8**	**4**
Global change	1.6	1.8	2.0	2.2	2.0	1.8	2.4	2.6	**2.1**	**3**

Annex III
List of conventions and specific laws that affect water use in the region

1. Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South Pacific (1981)

This Plan, as adopted, has the same characteristics as other Regional Seas programmes promoted by UNEP. The main objective of this regional cooperation mechanism is to protect the marine environment and coastal areas to safeguard the heath and well-being of current and future generations.

The general legal framework of the Plan of Action of the South East Pacific is the Convention for the Protection of the Marine Environment and Coastal Areas of the South East Pacific, also known as the "Lima Convention" of 1981, which binds the High Contracting Parties to make an effort, whether individually or through bilateral or multilateral cooperation, to adopt the appropriate measures to prevent, reduce and control the pollution of the marine environment and coastal areas in the South East Pacific and secure and adequate management of the natural resources.

The Plan of Action for the South East Pacific has the following components:

- Environmental assessment: This is the main component, which provides the scientific basis to implement the other components, and comprises an assessment of the pollution caused by oil spills; determination of the degree of pollution caused by industrial, mining and agricultural wastes and their effect; pollution caused by domestic wastes, radioactive pollution, pollution of the marine environment through the atmosphere, among others.
- Environmental management: Formulation and application of programmes to prevent, monitoring, reduce and eliminate pollution.
- Legal component: Development of regional instruments, which will be describes below, constitute a major achievement of the Plan of Action.
- Institutional and financial mechanisms: According to this component, the General Authority of the Plan of Action remains with the regular meeting of Government representatives (Intergovernmental Meetings). They are mandated to assess the implementation progress of the Plan of Action and approve the projects and activities.

2. Convention for the Protection of the Marine Environment and the Coastal Zone of the South East Pacific (1981)

The Plenipotentiaries of Colombia, Chile, Ecuador, Panama and Peru signed the Convention for the Protection of the Marine Environment and Coastal Areas in the South East Pacific in Lima, Peru on November 12, 1981. The respective signatory Governments handed the ratification documents. The High Contracting Parties to this Convention manifested, in the recitals and preamble thereof, the need to protect and preserve the marine environment and coastal areas of the South East Pacific from all types of pollution and pollution sources; and emphasize the economic, social and cultural significance of the South East Pacific as a means of interlinking the countries within the region.

3. Agreement for the Regional Cooperation Against the Pollution of the South East Pacific by Hydrocarbons and other Harmful Substances in Cases of Emergency (1981)

This Agreement complements or is related to the previous Convention and specifically refers to the pollution caused by hydrocarbon and other harmful substances and to the need for regional cooperation in cases of emergency. This Agreement was signed on November 12, 1981 by the five member countries, which lodged their relevant ratification instruments with the General Secretariat of the CPPS.

4. Complementary Protocol to the Agreement for the Regional Cooperation Against the Pollution of the South East Pacific by Hydrocarbons and other Harmful Substances (1983)

The complementary Protocol of the Agreement on Regional Cooperation in Combating Pollution of the South East Pacific by Hydrocarbons and other Harmful Substances was signed on July 22, 1983. This regional document elaborates on the regional principles on regional cooperation against pollution caused by hydrocarbons and harmful substances in cases of emergency contained in the aforementioned Agreement of 1981.

5. Protocol for the Protection of the South East Pacific Against the Pollution from Land-based Sources (1983)

This Protocol provides for the general obligations, practices and procedures; cooperation and consultation guidelines and procedures between the Parties; surveillance programmes, exchange of information, scientific and technical cooperation; and penalty measures, among others.

6. Protocol for the Conservation and Management of Marine and Coastal protected Areas of the South East Pacific (1989).

The Governments acknowledge, through this Convention, the need to adopt appropriate measures to protect and preserve ecosystems that are fragile, vulnerable or which have a unique natural value, as well as the fauna and flora on the verge of depletion or extinction. It also establishes a principle of common interest to pursue the management of coastal areas attaching a rational value to the equilibrium that should exist between conservation and development.

This Convention also contains regulations regarding protected areas, common criteria to establish such areas, for regulation activities through and integrated environmental management mechanism within the guidelines contained in Article 5, buffer areas, measures to prevent, reduce and control pollution in protected areas, environmental impact assessment, establishing an integrated analysis procedure, scientific and technical cooperation; promotion of community involvement and environmental education, among others.

7. Protocol for the Protection of the South East Pacific Against Radioactive Pollution

This Protocol was signed in Paipa, Colombia, on September 21, 1989 and entered into force in 1994 after submission of the ratification instruments. It provides for regulations, principles, criteria and general obligations prohibiting the dumping of radioactive waste and other radioactive substances into the sea and/or seabed included within the scope of application of the Convention; i.e., the maritime area of the South East Pacific under the sovereignty and jurisdiction of Governments up to 200 nautical miles. This Protocol is also applicable to the Continental Shelf when extended by the High Contracting Parties beyond their 200 nautical mile zones.

8. Protocol on the Program for the Regional Study of the "El Niño" Phenomenon in the South East Pacific (ERFEN)

The States Members of the Permanent Commission for the South Pacific –CPPS signed this protocol on 6th November 1992 in Callao, Peru. The aim of ERFEN is forecast the ocean-atmospheric changes with enough anticipation to allow the issue of policies and emergency measures facing the yield variations in productive activities such as fishing, agriculture, industry and hydro-biological resource management, among others.

9. Project: Integrated Management of the Large Marine Ecosystem of the Humboldt Current (GEF/ONUDI-IMARPE/PERU-IFOP/CHILE)

The large marine ecosystem of the Humboldt Current is one of the most productive systems of the world. It depends of upwelling that provides a continuous supply of nutrients to surface waters where large populations of planktonic organisms grow. These populations are the basis of an ecosystem that influences the whole marine life along thousand kilometres of the west South American coasts. The project has to address four main problems:

- The unsustainable exploitation of the fishing resources.
- The insufficient knowledge of the variability of the system.
- Threats to the ecosystem biodiversity and relevant to the fishing production.
- Features related to the coastal habitat.

The project was designed to contribute with solutions for the above identified transboundary issues and pretend to increase the national capabilities including an integrated ecosystem approach.

10. Framework Agreement for the Conservation of Living Resources on the High Seas of the South East Pacific (Galápagos Agreement) (2000)

The countries of the South East Pacific belonging to the Permanent Commission for the South Pacific (Chile, Colombia, Ecuador and Peru) signed this agreement in 2000. The main objective of this Agreement is to define the legal framework for the conservation and management of living marine resources in the high seas zones of the South East Pacific, with special reference to straddling and highly migratory fish populations. The Agreement is applicable to the high seas beyond the external limits of the EEZ of the countries to the 120°W meridian between 5°N and 60°S.

11. Declaration of Ministers of Foreign Affairs on occasion of the 50th anniversary of the "Santiago Declaration" and the establishment of the Permanent Commission for the South Pacific CPPS (Santiago, Chile, 14 August, 2002 Santiago Declaration 2002)

The Ministry of Foreign Affairs of the Republic of Peru and Chile, the Vice-minister of Foreign Affairs of Ecuador, and the Vice-minister of Foreign Affairs for Multilateral Issues of Colombia convened at Santiago, Chile, within the framework of the celebration of the fiftieth anniversary of the "Santiago Declaration" of 1952, concerning the maritime zone and the establishment of the CPPS, deliver the following Declaration:

1. Express their satisfaction and pride upon celebrating the fiftieth anniversary of the Santiago Declaration which stipulated the principle of the two hundred nautical miles, practiced worldwide by states, as an essential part of the law of the sea.
2. Render tribute to the developers of the principles contained in the "Santiago Declaration" of 1952, who first declared the existence of a two hundred-mile jurisdictional maritime zone, on the basis of economic and conservation grounds, and who were tasked with defending the recognition of such zone in various international forums until set forth in the new law of the sea.

3. Renew the effectiveness and projection of the principles and purposes contained in the above mentioned declaration, as well as the international instruments approved for their future development.
4. Firmly support the successful task of the Permanent Commission for the South Pacific, which has coordinated the maritime policies of Chile, Colombia, Ecuador and Peru, and whose presence in important international forums has produced a significant impact upon the evolution of the law of the sea, widely contributing to the establishment of a global oceanic policy.
5. Within this context, the states reaffirm their authority in the 200 mile jurisdictional zone, the exercise of their sovereign rights therein, and their right to issue those measures required for the exploration, exploitation, conservation and administration of the resources existing therein, in accordance to globally accepted instruments and practices, with special reference to the United Nations Convention on the Law of the Sea. Likewise, the states reiterate their sovereign rights over their ports and their corresponding preferential rights, where appropriate, in the high seas.
6. Decide that the presence of the CPPS must extend its influence in the Pacific Ocean, given the organization's capacity as regional maritime agreement and strategic, political and operational strategy in the South East Pacific.
7. Congratulate one another for the recent inauguration of the permanent seat of the CPPS in the city of Guayaquil, Ecuador, as well as for the completion of the organization's re-structuring and modernization process.
8. Reiterate the convenience of continuing joint actions in competent international forums, with the aim of strengthening and consolidating the organization's principles and objectives, established as a regional maritime system.
9. Highlight that the fifty years during which the coastal states of the South East Pacific have administered the two hundred-mile maritime zone, have allowed this area to become one of the less contaminated areas of the world, where marine resources are exploited in a sustainable manner.
10. Celebrate the subscription, in August, 2000, of the "Framework Agreement for the Conservation of Living Marine Resources in the High Seas of the South East Pacific" or "Galapagos Agreement", which, once standing, shall be open to the accession of third states having an established interest in the area of application of the agreement.
11. Express that such agreement is a principle part of the regional maritime system of the South East Pacific, directed toward the establishment of a harmonic regime of conservation and protection of living marine resources, in the benefit of their coastal populations.
12. Agree that the organisation must mainly focus its activities toward the regional political coordination of ocean related subject matters, the implementation and development of the "Galapagos Agreement", scientific research related to oceanic-atmospheric alterations, especially the "El Niño" phenomenon; arrangement and conservation actions, the regional protection of the marine environment, overall management of coastal-marine zones, as well as cooperating and promoting the efficiency of artisanal and industrial fishing operations.
13. Express their concern over the increase of illicit activities in the South East Pacific and decide to instruct their minstries of foreign affairs and the general secretariat, to promote increased regional coordination and cooperation, at every level, with the support of the pertinent international organizations, in order to eradicate such operations.
14. Agree to promote and further the development of the regional fisheries industry under sustainable criteria, transfer of technology, the promotion of investments and the conduction of negotiation rounds.
15. Declare their firm disagreement with the application of unilateral and unjustified restrictions affecting trade of fisheries products and toward granting of subsidies which encourage non-sustainable fishing operations. in order to face such challenges, the states instruct their ministries of foreign affairs, with the support of the general secretary, to strengthen the negotiation capacities and ensure the design of a regional strategy.
16. Reiterate their full political support toward the Action Plan of the South East Pacific and their commitment to strengthen this regional cooperation mechanism in its institutional, legal and financial aspects, in order to ensure the effective compliance of the plan's objectives.
17. Express that the successful cooperation maintained during these fifty years, has allowed for a close relationship and understanding between the states parties, which commits them to keep working jointly on the basis of the common destiny of their nations, the protection of their resources, and maritime development.

The Ministry of Foreign Affairs of the Republic of Peru, the Vice-minister of Foreign Affairs of Ecuador, and the Vice-minister of Foreign Affairs for Multilateral Issues of Colombia, express their gratitude toward the people and the Government of Chile, for their warm hospitality and friendship, which renew the fraternal relationship and cooperation links of the member states of the CPPS.

Annex IV
Data on pollution

Table 1 Total and faecal coliforms in water, Ecuador 1987-2002.

Site	Year	Total coliforms (NMP/100 ml)		Faecal coliforms (NMP/100 ml)		Source
		Min	Max	Min	Max	
Gulf of Guayaquil	1987	17	1 100	580	10 000	CPPS 2000a
	1989	4	2 400	300	5 000	CPPS 2000a
	1994	8	1 600	320	9 060	CPPS 2000a
	1994-1996	ND	ND	ND	1 000 000	Pin et al. 1998
Estero Salado	1986	43	2 000 billion	4	1 100 billion	CPPS 2000a
	1988	90 000	93 billion	ND	ND	CPPS 2000a
	1988	447	123 million	430	16 million	CPPS 2000a
	1988	5	21 billion	4	1.1 billion	CPPS 2000a
	1989	ND	ND	350	6 400	CPPS 2000a
	1989	ND	ND	78	147 000	CPPS 2000a
	1990	ND	ND	93	160 000	CPPS 2000a
	1994	ND	ND	1 020	35 000	CPPS 2000a
	1996	11	220	11	75	Valencia et al. 2000
	1998	2	240	2	2	Valencia et al. 2000
	2001	<70	240	ND	ND	INOCAR 2001a
Guayas River	1988	20	1 800	2 300	4 300	CPPS 2000a
	1988	93	1 025	550	5 600	CPPS 2000a
	1989	ND	ND	9 000	90 000	CPPS 2000a
	1990	ND	ND	530	13 600	CPPS 2000a
	1991	30	1 790	100	9 300	CPPS 2000a
	1996	240	93 000	ND	ND	Valencia et al. 2000
	1997	2 400	1 1 00	ND	ND	Valencia et al. 2000
	2000	4 600	11 000	2 400	11 000	INOCAR 2000
Guayas-Daule	1984	88	11 000	900	46 000	CPPS 2000a
	1985	1 500	24 000	3 900	24 000	CPPS 2000a
	1986	900	46 000	ND	ND	CPPS 2000a
Babahoyo-Guayas	1984	2 300	11 000	400	110 000	CPPS 2000a
	1986	2 300	11 000	400	124 000	CPPS 2000a
Manta	1985	4	2 400	90	2 400	CPPS 2000a
Santa Elena	1985	43	2 400	43	2 300	CPPS 2000a
Puerto Bolívar	1985	23	93	9	43	CPPS 2000a
	2002	ND	ND	ND	200	INOCAR 2002b
Daule River	1986	ND	8 757	ND	4 193	CPPS 2000a
	1986	ND	62 536	ND	25 946	CPPS 2000a
	1986	ND	7 242	ND	3 68	CPPS 2000a
San Lorenzo	2001	ND	<70	ND	ND	INOCAR 2001b
Atacames	2002	8 400	8 900	5 100	5 600	INOCAR 2002a
Santa Cruz Island (Galapagos Islands)	1999	ND	240	ND	15	Morán & Valencia 2000
San Cristobal Island (Galapagos Islands)	1999	ND	16	ND	8.8	Morán & Valencia 2000
Santa María, Isabela, Darwin Islands (Galapagos Islands)	1999	ND	5	ND	2	Morán & Valencia 2000

Note:: ND = No Data

Table 2 Total and faecal coliforms in water, Peru 1987-2002.

Site	Year	Total coliforms (NMP/100 ml)		Faecal coliforms (NMP/100 ml)		Source
		Min	Max	Min	Max	
Huarmey	2000	ND	ND	30	15 billion	Tam et al. 2000
Rimac- Callao	1989	460 000	46 billion	ND	ND	CPPS 2000a
	1995	ND	930 million	ND	ND	Sánchez et al. 1996
	2000	ND	ND	30	2 300	Guzman et al. 2000
Tumbes	2000	ND	ND	30	43	Castillo et al. 2000
Lima-Metropolitan	2001	ND	ND	30	93	Orozco 2002
Paita	2001	ND	ND	30	23	Sánchez et al. 2002
Supe Paramonga	2001	ND	ND	30	23	Orozco 2002
Huacho -Carquin	1995	430	93 000	<3	93 000	Sánchez et al. 1996
	2001	ND	ND	30	93 000 23 000	Orozco 2002
Callao	2001	ND	ND	30	230 000	Jacinto et al. 2001
Cañete	2001	ND	ND	30	430	Orozco 2002
Callao	2002	ND	ND	70 billion	2.3 million	Sánchez et al. 2002
Huarmey	2002	ND	ND	30	430	Cabello et al. 2002
Paita	1995	<3	43 000	ND	ND	Sánchez et al. 1996
	2002	ND	ND	90 billion	930	Jacinto et al. 2001
Ferrol-Chimbote	1989	23	16 000	12	16 000	CPPS 2000a
		ND	4.3 billion	ND	ND	CPPS 2000a
	2002	ND	ND	30	930 23 000	Sánchez et al. 2002
Cañete	2002	ND	ND	30	930	Sanchez et al. 2002
Bahía Ancón	1988	43	2 400	4	2 400	CPPS 2000a
	1989	17	1 100	9	1 000	CPPS 2000a
Pisco-Paracas	1988	23	2 400	4	2 400	CPPS 2000a
	1989	8	1 600	3	1 600	CPPS 2000a
	1995	ND	9 300	ND	9 300	Sánchez et al. 1996
	2002	ND	ND	30	90 billion	Jacinto et al. 2001
Ilo-Ite	2002	ND	ND	30	230	Jacinto et al. 2001
Agua Dulce	1987	43	110 000	11	4 600	CPPS 2000a
La Pampilla	1987	39	110 000	9	110 000	CPPS 2000a
La Chira	1987	640	46 000	460	16 000	CPPS 2000a
La Herradura	1987	9	46 000	9	9 000	CPPS 2000a
Marbella	1987	240	24 000	9	11 000	CPPS 2000[a]
Talara	1995	ND	ND	<3	9 300	Sánchez et al. 1996
Huacho-Carquin	2002	ND	ND	30	230 000	Orozco 2002
Supe-Paramonga	2002	ND	ND	30	2 300	Sánchez et al. 2002

Note:: ND = No Data

Table 3 Average values of total and faecal coliforms in coastal surface waters in Chile during 1994 (Zúñiga and Burgos, 1996).

Site	Total coliforms (NMP/100 ml)	Faecal coliforms (NMP/100 ml)
Arica	7.8	2
Iquique	7.8	2
Tocopilla	ND	ND
Antofagasta	2 400	1 600
Chanaral	ND	ND
Coquimbo	ND	ND
Quintero	23	2
Concon	13	4.5
Valparaiso	130	33
Playa Ancha	ND	ND
San Antonio	1 600	33
Talcahuano	3.6	3.6
San Vicente	1 100	210
Valdivia	210	130
Puerto Montt	2	2
Castro	240	130
Punta Arenas	1 600	540

Note: ND = No Data.

(Source: Zúñiga & Burgos 1996)

Table 5 Concentrations of POPs in sediment and water, Peru 1994-1996.

Site	Pesticide						
	Lindane	DDT	DDE	DDD	Aldrin	Arochlor 1254	Arochlor 1260
Fertiza (ng/g)	ND	0.230-2.66	1.65	1.02	ND	ND	ND
Chillón River (ng/g)	ND	ND	16.89	ND	ND	12.09	9.94
Pisco (ng/g)	ND	ND	0.426	ND	ND	ND	ND
Ite (ng/g)	9.23	ND	ND	0.21	3	7	2.14
Huacho (ng/g)	ND	4.45	ND	ND	ND	8	ND
Cañete River (water) (ng/g)	ND	2.8	ND	ND	ND	21.02	ND
Cañete River (sediments) (ng/g)	ND	2.8	ND	ND	ND	ND	ND

Note: ND = No Data.

(Source:CPPS 2000a, Cabello & Sánchez 2003)

Table 6 Concentrations of POPs, Chile.

Site	Pesticide					
	Lindane	DDT	pp' DDE	pp'DDD	Aldrin	Arochlor 54
VIII Region (water) (ppb)	0.001-0.015	ND	ND	ND	0-0.013	ND
VIII Region (sediments) (ppb)	0.02-1.364	0.02-0.68	ND	ND	0.015-0.374	ND
Concepción Bay (ppb)	ND	0.45-0.68	ND	ND	ND	ND
Concón/Acocagua River (pg/g)	500	400-9 800	100-5 700	2 500-6 100	ND	1 200-45 100

Note: ND = No Data.

(Source: CPPS 2000a, based on Chuecas et al.1989 and SERPLAC 1980)

Table 4 Concentrations of POPs in water and sediments, Ecuador.

Site	Pesticide																						
	BCH	Alfa BCH	Delta BCH	Lindane	Heptachlor	DDT	4,4'DDT	4,4' DDE	4,4'DDD	Chlordane	Aldrin	Dieldrin	Endin	Malathion	Parathion	Tilt	Calixin	Toxapheno	Endosulfan	Metoxichlore	Imazalil	Chloratonil	Methyl Paration
Guayas River (ppb) [a]	0.028	ND	ND	0.039	0.007	0.02	ND	ND	ND	0.05-2.72	0.056	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Guayas River (mg/l) [b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	23	ND	ND	ND	ND	ND	ND	ND	ND
Shrimp ponds (µg/kg) [c]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.018	0.018	ND	ND	ND	ND	ND	ND
Daule River (ug/l) [d]	ND	ND	ND	ND	ND	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
Estero Salado (µg/kg) [e]	ND	ND	0.58-0.41	0.2-1.98	ND	ND	ND	0.065	ND	ND	0.07-1.62	ND	ND	ND	ND	ND	ND	ND	0.32-0.36	ND	ND	ND	ND
Guayaquil City (µg/kg) [f]	ND	ND	ND	0.059-0.12	ND	ND	ND	0.13-0.15	ND	ND	0.24-0.38	ND	0.41	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Atacames (µg/kg) [g]	ND	ND	1.48-1.61	0.29	0.24	ND	0.03	0.22-0.48	5.86	ND	0.36-0.66	0.27-0.94	ND	ND	ND	ND	ND	ND	0.56-1.24	ND	ND	ND	ND
Santa Rosa (µg/kg) [h]	ND	0.57-2.1	ND	ND	ND	ND	ND	ND	ND	ND	0.17-0.44	0.23	0.7	ND	ND	ND	ND	ND	ND	0.91	0.31	2.1	1.63-4.32

Note: ND = No Data.

(Source: [a] PMRC 1993, [b] Ormaza 1994, [c] Intriago et al. 1994, [d] CPPS 2000a, [e] INOCAR 2001a, [f] INOCAR 2001b, [g] INOCAR 2002a; [h] INOCAR 2002b)

Table 7 Concentations of copper in water, Ecuador.

Site	Copper in water (µg/l)					Source
	1985	1986	1987	1988	1989	
Esmeraldas	1.1-20					Arcos 1985
	0.6-1.7					
		1. 6				Arcos 1986
		1.1-20.6				Samaniego 1986
		0.615				
		0.1-7.2				
			3.2-8.2			CPPS 2000a
Manta		0.2-1.2				Arcos 1986
					3.2-6.8	Choez 1989
B. Caráquez					2-4	Choez 1989
					2.4	CPPS 2000a
Monteverde					4.2-5.2	Choez 1989
La Libertad					4.7-7.2	Choez 1989
Santa Elena			0.03-20			Choez 1989
					3.9-7.7	CPPS 2000a
Salinas		0.3-0.9				Arcos 1986
					7.28	Choez 1989
					8.22	CPPS 2000a
Anconcito					3.3-4.2	Choez 1989
Ancón					5.8-6.8	Choez1989
Chanduy				4.7-7.3		Arcos 1986
Playas	0.1-0.4					Arcos 1985
					5.2-6.1	Choez 1989
Daule River	42.3-81.8					Solórzano 1985
	42-104					INP 1986
		37-126				
		53.3-104.7				Pérez 1986
					1.3-6.6	Pérez 1989
Babahoyo River	51.8-94.5					Solórzano 1985
		5-37				INP 1986
		53.33-104.7				Pérez 1986
				24-36.2		ESPOL 1987
					4-11.3	Pérez 1989
Guayas River	39.8-66.7					Solórzano 1985
		15-95				INP 1986
		4.8				Samaniego 1986
				4.4-7.3		Choez 1989
Estero Salado	0-135					Pérez 1986
		0-30				INP 1986
		0-199				Pérez 1986
			2			Samaniego 1986
					1.33-4	Pérez 1989
El Oro		3.32-18.8				Samaniego 1986
		3.9-7.7				ESPOL 1987
Puerto Bolívar		0.2-0.9				Arcos 1986
					6.9	Chóez 1989
Jambelí					3.7-7.7	Chóez 1989

Note: ND = No Data.

Table 8 Concentration of copper in biota, Ecuador.

Site	Biota	Copper (µg/g)
Santa Elena	Molluscs	4.75-31.25
Santa Elena	Fish	2.75-37.5
Puerto Bolívar	Fish	7.5-20.0
Puerto Bolívar	Fish	10.0-11.3

(Source: CPPS 2000a)

Table 9 Concentration of lead in biota, Ecuador.

Site	Biota	Lead (µg/g)
Santa Elena	Molluscs	0.0-62.5
Santa Elena	Fishes	0.25-27.5
Puerto Bolívar	Fishes	0.0-12.5

(Source: DIGMER 1988)

Table 9 Concentration of lead in water, Ecuador.

Site	Lead in water (µg/l)				Source
	1984-1987	1984	1994	1996	
Santa Elena	0.0001-0.0004	ND	ND	ND	Samaniego 1986, Arcos 1985
Daule River	ND	10	ND	ND	Solórzano 1985
Babahoyo River	ND	10-52.8	ND	ND	Solórzano 1985
Guayas River	ND	10-74	ND	ND	Solórzano 1985
Guayas River Basin	ND	ND	ND	5-15	CEDEGE 1996 in Intriago 1998
Gulf of Guayaquil	ND	10-74	0.29	ND	Pérez 1986, CAMM 1996, Intriago 1998

Note: ND = No Data.

Table 10 Concentration of copper in water, Peru.

Site	Copper in water (µg/l)				Source
	1984-1987	1985	1999	2000	
Callao	71-196	71-196	ND	ND	Guillén & Aquino 1978, López 1982, Ministerio de Salud de Peru 1986, Valcarcel et al. 1975, Guillén et al. 1986, Castañeda 1980
Chimbote	45-76	ND	ND	ND	Ministerio de Salud de Peru 1986, Valcarcel et al. 1975, Guillén et al. 1986, Castañeda 1980
Laguna Verde	62-98	ND	ND	ND	Valcarcel et al. 1975
Ite	107-857 65-220	ND	ND	ND	Ministerio de Salud 1986, Valcarcel et al. 1975, López 1982
Paracas	71-89	ND	ND	ND	Valcarcel et al. 1975, López 1982
Rimac River	9-50	75-650 100-370 38-100	62-1,820	13.9-1.056	Ministerio de Salud de Peru 1986, Guillén 1981, Castañeda 1980, CPPS 2000a

Note: ND = No Data.

Table 11 Concentration of copper in sediments, Ecuador.

Site	Copper in sediments (mg/kg)									Source
	1985	1986	1987	1988	1989	1994	1998-1999	2001	2002	
Esmeraldas	ND	ND	10-35	22.0-45.5 6.0-10.7 17.0-50.5	22.0-7	ND	ND	ND	ND	DIGMER 1988, Choez 1989
Manta	16.5-72.2	ND	ND	7.5-53.7	ND	ND	ND	ND	ND	DIGMER 1988
Guayas	ND	ND	ND		ND	40-113.0	ND	ND	ND	DIGMER 1988
La Libertad	ND	4.0-16.0	ND	9.5-15.5	ND	ND	ND	ND	ND	Choez 1989
Santa Elena	2.5-30	3.2-14.5	ND		ND	ND	ND	ND	ND	DIGMER 1988
Salinas	ND	ND	ND	9.0-10.0	ND	ND	ND	ND	ND	DIGMER 1988
Anconcito	ND	ND	ND	6.0-16.0	ND	ND	ND	ND	ND	Choez 1989
Chanduy	ND	ND	ND	7.2-10.5	ND	ND	ND	ND	ND	DIGMER 1988
Playas	ND	ND	6.0-19.2	5.5-14.0	ND	ND	ND	ND	ND	Choez 1989
Posorja	ND	ND	ND	8.7-31.5	ND	ND	ND	ND	ND	Choez 1989
Estero Salado	ND	ND	ND	ND	ND	ND	35-45.5	1-47.7	ND	Choez 1989, INOCAR 2001a
El Oro	ND	ND	ND	6.0-27.0	ND	ND	ND	ND	ND	Choez 1989
Puerto Bolívar	2.5-45.7	6.0-27.0	4.8-18	7.7-32.0 13.7-27.5	ND	ND	ND	ND	ND	DIGMER 1988, Choez 1989:
Jubones River	ND	ND	ND	ND	ND	ND	ND	ND	28.66	INOCAR 2002b
Santa Rosa Estuary	ND	ND	ND	ND	ND	ND	ND	ND	6.0-27.5	INOCAR 2002b

Note: ND = No Data.

Table 12 Concentations of cadmium in water and sediments, Ecuador.

Site	Cadmium in water (µg/l)					Cadmium in sediments (µg/l)		Source
	1984	1985	1986	1987	1989	1999	2001	
Esmeraldas	ND	ND	ND	ND	0.5-0.7	ND	ND	Chóez 1989
Manta	ND	ND	ND	ND	0.2-0.7	ND	ND	Chóez 1989
B. Caráquez	ND	ND	ND	ND	0.2	ND	ND	Chóez 1989
La Libertad	ND	ND	ND	ND	0.73-0.87	ND	ND	Chóez 1989
Salinas	ND	ND	ND	ND	0.2-3.59	ND	ND	Chóez 1989
Anconcito	ND	ND	ND	ND	0.85-1.21	ND	ND	Chóez 1989
Ancón	ND	ND	ND	ND	0.4	ND	ND	Chóez 1989
Posorja	ND	ND	ND	ND	0.73-0.85	ND	ND	Chóez 1989
Daule River	ND	14.48-<50	ND	ND	ND	ND	ND	Solórzano 1985
Babahoyo River	ND	7.47-<50	0.1-3.45	ND	ND	ND	ND	Solórzano 1985 CPPS 2000a
Guayas River	10.5-50	ND	ND	ND	ND	ND	ND	Solórzano 1985
Estero Salado	ND	ND	ND	ND	ND	0.97-1.94	0-3	INOCAR 2001a
Gulf of Guayaquil	ND	ND	7.5-10	ND	ND	ND	ND	INP 1986
El Oro	ND	ND	ND	0.73-3.45	ND	ND	ND	CPPS 2000a
Jubobes River	ND	ND	0.1	ND	ND	ND	ND	Chóez 1986
Jambelí	ND	ND	0-0.85	ND	ND	ND	ND	Chóez 1986

Note: ND = No Data.

Table 13 Concentration of lead in sediments, Ecuador.

Site	Lead in sediments (mg/kg)								Source
	1984	1986	1987	1988	1994	1998-1999	2001	2002	
Esmeraldas	ND	ND	12.5-42.5	3.7-10	ND	ND	ND	ND	DIGMER 1988, Choez 1989
Manabí	ND	ND	ND	5-15	ND	ND	ND	ND	Choez 1989
Manta	ND	ND	4.5-9	5-12	ND	ND	ND	ND	DIGMER 1988
Santa Elena	ND	ND	2.5-11	17.5-157.5	ND	ND	ND	ND	DIGMER 1988
La Libertad	ND	ND	ND	4.6-14.1	ND	ND	ND	ND	Choez 1989
Santa Rosa	ND	ND	ND	11.2	ND	ND	ND	ND	Choez 1989
Salinas	ND	ND	ND	10-16.2 14-51.2 13.7-17.5	ND	ND	ND	ND	Choez 1989, DIGMER 1994
Anconcito	6.8-13	ND	ND	5.7-8	ND	ND	ND	ND	Solórzano 1985, Choez 1989
Chanduy	ND	ND	ND	7.5-17.5	ND	ND	ND	ND	Choez 1989
Playas	ND	6.7-8	ND	ND	ND	ND	ND	ND	Choez 1989
Posorja	ND	ND	ND	15-16.2	ND	ND	ND	ND	Choez 1989
Guayas	ND	ND	ND	ND	125-218	ND	ND	ND	DIGMER 1994
Estero Salado	ND	ND	ND	ND	ND	3.2-9.76	0-34	ND	INOCAR 2001a
Puerto Bolívar	ND	ND	ND	4.8-21.2	ND	ND	ND	ND	DIGMER 1988;
Santa Rosa	ND	ND	ND	ND	ND	ND	ND	23.33	INOCAR 2002b
Jubones River	ND	ND	ND	ND	ND	ND	ND	21.34	INOCAR 2002b

Note: ND = No Data.

Table 14 Concentration of copper in sediments, Peru.

Site	Copper in sediments (mg/kg)							Source
	1984-1987	1985	1987	1989	1996	2000*	2002	
Chimbote	0.1-0.6	16.46-64.48	ND	ND	28.7-108	80-199	17.6-.23.4	Echegaray 1986, Jacinto et al. 1996, Guzmán 2003
Santa River	ND	ND	ND	ND	ND	ND	13.4-17.3	Sánchez et al. 2002
Paramonga	ND	ND	ND	ND	ND	164-267	ND	Instituto Cuanto 2001
Fortaleza River	ND	ND	ND	ND	ND	ND	69.7-74.7	Sánchez et al. 2002
Supe	ND	ND	ND	ND	ND	67-220	52.1-142.2	Instituto Cuanto 2001, Sánchez et al. 2002
Pativilca River	ND	ND	ND	ND	ND	ND	66.45	Sánchez et al. 2002
Rimac River	ND	109	ND	ND	ND	ND	ND	Echegaray 1986
Callao	ND	0-135.4	18-160	ND	ND	28-43.7	7.7-74.7	Echegaray 1986, Guzmán et al. 2000, Sánchez et al. 2002
Cañete	ND	ND	ND	ND	ND	ND	14.8-28.7	Sánchez et al. 2002
Cañete River	ND	ND	ND	ND	ND	ND	23.2-24.5	Sánchez et al. 2002
Pisco	ND	0-46.8	0.12-50	ND	50.5-91.7	ND	17.8-71.6	Echegaray 1986, Guzmán et al. 1997, Guzmán 2003
Paracas	ND	ND	ND	73.71	ND	ND	ND	Hinojosa & Ormeño 1989
Ite	ND	1 320	ND	65-220	31.2-826.3	ND	29.6-226.82	Echegaray 1986, Guzmán 2003
Tacna	ND	11.9-135.8	0.15-0.3	ND	ND	ND	ND	Echegaray 1986

*Note: ND = No Data. * Liofilised (freeze drying) sample*

Table 15 Concentration of copper in biota, Peru.

Site	Biota	Copper in biota (µg/g)									Source
		1972/1980	1981/1989	1986/1987	1989	1994	1995	1996	2001	2002	
Littoral	Molluscs	0.08-1.38	1.1-4.45	ND	ND	ND	ND	ND	ND	ND	Echegaray & Guerín 1989
	Fishes	0.03-0.43	ND	ND	ND	ND	ND	ND	ND	ND	
	Molluscs	ND	0.33-1.02	ND	ND	ND	ND	ND	ND	ND	
Chimbote	Molluscs	ND	ND	0.7-2.8	ND	0.48-18.5	0.38-1.21	0.42-22.5	ND	14.8-17.3	Echegaray et al. 1987, Jacinto et al. 1996, 1997, Guzmán et al. 1997, Guzmán 2003
	Crustaceans	ND	ND	ND	ND	8.1	ND	2.37-6.03	ND	12.9-14.2	
	Fishes	ND	ND	ND	ND	0.48-0.74	ND	ND	ND	1.21-3.73	
Huarmey	Molluscs	ND	ND	ND	ND	ND	ND	ND	2.9-27.9	ND	Jacinto et al. 2001
	Crustaceans	ND	ND	ND	ND	ND	ND	ND	19.54	ND	
	Fishes	ND	ND	ND	ND	ND	ND	ND	1.97	ND	
Callao	Molluscs	ND	ND	ND	ND	0.49-29.6	0,92-33.2	0.32-14.9	9.5-17.5	1.96-40.9	Guzmán 1996, Guzmán et al. 1997
	Crustaceans	ND	ND	ND	ND	8.16-10.8	4.23-21.7	7.4-15.7	ND	ND	
	Fishes	ND	ND	ND	ND	0.52-0.64	0.34-0.48	0.64	7.71	ND	
Cañete	Crustaceans	ND	ND	ND	ND	ND	ND	ND	0.2	12.4-43.7	Sánchez & Orozco 1997
	Molluscs	ND	ND	ND	ND	ND	ND	ND	1.27	ND	
	Fishes	ND	ND	ND	ND	ND	ND	ND	0.2	1.53-6.22	
Pisco	Molluscs	ND	ND	0.7-6.8	0.02-2.61	ND	1.42-1.97	9.38	ND	ND	Echegaray et al. 1987, Hinojosa & Hormeno 1989, Guzmán et al. 1997
	Crustaceans	ND	ND	ND	ND	ND	ND	4.08-7.58	ND	ND	
	Fishes	ND	ND	ND	ND	ND	0.44	ND	ND	ND	
Paracas	Molluscs	ND	ND	ND	0.11-0.28	ND	ND	ND	ND	ND	Hinojosa & Hormeno 1989
Ilo	Molluscs	ND	ND	ND	ND	ND	4.7-26.8	13.5-283	ND	ND	Jacinto & Carbrera 1998
	Crustaceans	ND	ND	ND	ND	ND	ND	16.4	ND	ND	
Ite	Molluscs	ND	ND	ND	ND	ND	ND	1.7-153.1	ND	ND	IMARPE database
	Crustaceans	ND	ND	ND	ND	ND	ND	13.5-21.1	ND	ND	

Note: ND = No Data.

Table 16 Concentration of copper in water, Chile.

Site	Copper in water							Source
	1981 (ug/l)	1982 (ug/l)	1983 (ug/l)	1984-1987 (ug/l)	1987 (mg/l)	1989 (mg/l)	1994 (mg/l)	
R I Arica	ND	ND	ND	ND	ND	ND	3.05	Zúñiga & Burgos 1996
R I Iquique	ND	ND	ND	ND	ND	ND	8.17	Zúñiga & Burgos 1996
R II Tacopilla	ND	ND	ND	ND	ND	ND	66.99	Zúñiga & Burgos 1996
R II Antofagasta	ND	ND	ND	ND	ND	ND	11.39	Zúñiga & Burgos 1996
R III Charañal	ND	ND	ND	ND	ND	ND	21.89	Zúñiga & Burgos 1996
R IV Coquimbo	ND	ND	ND	ND	ND	ND	2.85	Zúñiga & Burgos 1996
R V Quintero	ND	ND	ND	ND	ND	ND	5.66	Zúñiga & Burgos 1996
R V Aconcagua River outlet	4.18	2.2	8.7	ND	ND	ND	ND	Pinochet et al. 1989
R V Valparaíso	ND	ND	0.05-2.4	0.6-2.4	7.99-19.56	4.29-19.5	ND	De Gregory et al. 1983, Universdad de Valparaiso 1987, Chiang 1989
R V Concon	ND	ND	ND	ND	3.43-20.58	3.43-26.8	5.22	Universdad de Valparaiso 1987, Chiang 1989, Zúñiga & Burgos 1996
R V San Antonio	ND	ND	ND	ND	ND	ND	ND	Zúñiga & Burgos 1996
R VIII Talcahuano	ND	ND	ND	ND	ND	ND	2.4	Zúñiga & Burgos 1996
R VIII Concepción	ND	ND	ND	0.6-0.7	ND	ND	ND	Universdad de Concepción 1980, 1985, 1986
San Vicente	ND	ND	ND	0.56-0.58	ND	ND	4.54	Zúñiga & Burgos 1996
Arauco Gulf	ND	ND	ND	0.56- 0.65	ND	ND	ND	Universdad de Concepción 1980
Valdivia	ND	ND	ND	ND	ND	ND	3.07	Zúñiga & Burgos 1996
R X Puerto Montt	ND	ND	ND	ND	ND	ND	5.35	Zúñiga & Burgos 1996
R X Castro	ND	ND	ND	ND	ND	ND	2.59	Zúñiga & Burgos 1996
R XII Punta Arenas	ND	ND	ND	ND	ND	ND	2.12 ?	Zúñiga & Burgos 1996
Playa Ancha	ND	ND	ND	ND	ND	ND	6.07	Universdad de Concepción 1980, Zúñiga & Burgos 1996
Renanca	ND	ND	ND	ND	ND	ND	10.97	Pinochet et al. 1989, Zúñiga & Burgos 1996

Note: ND = No Data.

Table 17 Concentration of copper in sediments, Chile.

Site	Copper in sediments					Source
	1977- 1979 (ppb)	1984-1986 (ug/g)	1986 (mg/kg)	1988 (mg/kg)	1994 (mg/kg)	
North Zone	ND	ND	ND	39.6-121.6*	ND	Zúñiga & Burgos 1996
R I Arica	ND	ND	ND	ND	130.1	Zúñiga & Burgos 1996
R I Iquique	ND	ND	12.3-26.4	ND	153.6	Bore 1987, Zúñiga & Burgos 1996
R II Antofagasta	ND	ND	ND	ND	5 789	Zúñiga & Burgos 1996
R III Charañal	16,628	ND	ND	ND	1 721	Zúñiga & Burgos 1996, Castilla & Nealer 1978, Castilla 1983
R IV Coquimbo	7-1,120a	ND	11.4-21.9	ND	4 518	Bore 1987, Chuecas et al. 1989, Zúñiga & Burgos 1996
R V Quintero	ND	ND	ND	ND	80.4	Zúñiga & Burgos 1996
R V Valparaíso	ND	ND	35.1-125.9	ND	ND	Universdad de Valparaíso 1987
R V Concon*	ND	ND	ND	ND	31.9	Zúñiga & Burgos 1996
R V San Antonio	ND	ND	ND	ND	216.5	Zúñiga & Burgos 1996
R VIII Talcahuano	ND	ND	ND	ND	60.3	Zúñiga & Burgos 1996
R VIII Concepción	ND	40.8-40.	ND	ND	ND	Universdad de Concepción 1980
San Vicente	ND	27.3-27.7	ND	ND	95.9	Universdad de Concepción 1980, Zúñiga & Burgos 1996
Arauco Gulf	ND	23.61	ND	ND	ND	Zúñiga & Burgos 1996
Valdivia	ND	ND	ND	ND	24.6	Zúñiga & Burgos 1996
R X Puerto Montt	ND	ND	ND	ND	24.6	Zúñiga & Burgos 1996
R X Castro	ND	ND	ND	ND	16.2	Zúñiga & Burgos 1996
R XII Punta Arenas	ND	ND	ND	ND	18.4	Zúñiga & Burgos 1996
Playa Ancha **	ND	ND	ND	ND	126.2	Zúñiga & Burgos 1996

*Note: * Concentration in ppb.*

Table 18 Concentration of copper in biota, Chile.

Site	Biota	Copper in biota				Source
		1984/1987 (µg/g)	1987 (mg/kg)	1987/1988 (mg/kg)	1994 (mg/kg)	
R I Arica	Molluscs	ND	ND	ND	0.3-0.1 ?	Zúñiga & Burgos 1996
R I Iquique	Molluscs	ND	1.09-7.94	0.08-7.23	1.3	Bore 1987, Chuecas et al. 1989, Zúñiga & Burgos 1996
R II Antofagasta	Molluscs	ND	ND	ND	ND	Zúñiga & Burgos 1996
R III Caldera	Molluscs	ND	7.92-22.5	0.08-8.45	ND	Bore 1987, Chuecas et al. 1989
R III Charañal	Fishes	ND	0.47-0.51	0.08-8.45	ND	Bore 1987
R IV Coquimbo	Molluscs	ND	1.01-2.15	ND	ND	Bore 1987, Chuecas et al. 1989
	Fishes	ND	0.33-3.85	ND	ND	
R V Quintero	Molluscs	ND	ND	ND	80.9	Bore 1987, Zúñiga & Burgos 1996
R V Valparaíso	Molluscs	0.9-5.97	ND	ND	51.4	Universdad de Valparaíso 1987, Zúñiga & Burgos 1996, Chuecas et al. 1989, Chiang & Nuñez 1983
	Fishes	0.50-0.80	0.75-14.36	ND	ND	
R V Concon	Molluscs	ND	ND	ND	88.4	Zúñiga & Burgos 1996
R V San Antonio	Molluscs	ND	ND	ND	30.2	Zúñiga & Burgos 1996
Central Zone	Molluscs	ND	ND	0.759	1416	Chuecas et al. 1989
	Fishes	ND	ND	0.30-1343	ND	
Central-South	Molluscs	ND	ND	4.36-14.36	ND	Chuecas et al. 1989
R VIII Talcahuano	Molluscs	ND	ND	ND	25.8	Chuecas et al. 1989
R VIII Concepción	Molluscs	0.081-15	ND	ND	ND	Universdad de Concepción 1980, 1987, 1988, Castilla 1983
San Vicente	Molluscs	0-6.1	ND	ND	28.8	Chuecas et al. 1989
Arauco Gulf	Molluscs	0-8.1	ND	ND	ND	Chuecas et al. 1989
Valdivia	Molluscs	ND	ND	ND	13.6	Chuecas et al. 1989
R X Puerto Montt	Molluscs	ND	ND	ND	14.3	Chuecas et al. 1989
R X Castro	Molluscs	ND	ND	ND	10.8	Chuecas et al. 1989
R XII Punta Arenas	Molluscs	ND	ND	ND	15.7	Chuecas et al. 1989
Magallanes	Molluscs	ND	ND	0.94-3.18	ND	Lecaros & Astorga 1989

Note: ND = No Data.

Table 19 Concentration of hydrocarbon in water, Ecuador

Site	Hydrocarbon in water (µg/l)										Source
	1985	1986	1987	1988	1989	1990	1994	1998-2001	2001	2002	
Esmeraldas	ND	ND	0.08-1.7	0.1-2.1	0.1-0.4	ND	ND	ND	ND	ND	INOCAR 1988 Valencia 1991
San Lorenzo	ND	ND	ND	ND	ND	ND	ND	ND	0.2-1.9	ND	INOCAR 2001b
Atacames	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.7-2.5	INOCAR 2002a
Manta	ND	ND	0.9-2.8	1.3-2.3	0.2-0.5	ND	ND	ND	ND	ND	INOCAR 1988, Valencia 1991
Salinas	ND	0.6-1.4	0.06-1.06	0.08-0.31	0.1-0.3	ND	ND	ND	ND	ND	Valencia 1991
Guayaquil	0.09-5.15	ND	ND	0.24-1.1	0.06-1.12	0.03-1.08	ND	ND	5	ND	DIGMER 1987, CPPS 2000a, INOCAR 2001b
GuayasRiver	ND	ND	ND	ND	ND	ND	1.05-2.28	0.1-0.8	ND	ND	INOCAR 2001a, Valencia et al. 1996
Estero Salado	ND	ND	ND	ND	ND	ND	0.76-1.5	ND	ND	ND	Valencia 1991,
Puerto Bolívar	60	10-25	45-70	ND	0.1-0.3	ND	ND	ND	ND	ND	DIGMER 1987, Valencia 1991
Santa Rosa	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.15-0.35	INOCAR 2002b

Note: ND = No Data.

Table 20 Concentration of hydrocarbon in water, Peru.

Site	Hydrocarbon in water (µg/l)											Source
	1985	1986	1987	1988	1989	1995	1996	1999	2000	2001	2002	
Talara	ND	ND	0.2-9.83	1.42-26.5	ND	ND	0.13-19.63	ND	ND	ND	ND	Jacinto 1991, Jacinto & Cabello 1996
Ferrol of Chimbote	ND	ND	ND	ND	ND	ND	0.89-20.21	ND	0.88-1.8	ND	0.1-10.20	Jacinto & Cabello 1996, Cabello & Jacinto 2002
Paita	ND	ND	ND	ND	ND	ND	0.19-6.1	ND	<0.01-2.62	ND	0.1-1.63	Jacinto & Cabello 1996, Cabello & Jacinto 2002
Callao	0.2-5.77	0.2-1.71	0.06-8.54	ND	0-4.5	0.05-1.87	0.27-6.22	30.12-53.12	0.21-11.20	30.12-53.12	0.34-4.02	Jacinto 1991, Sánchez et al. 1996, Jacinto & Cabello 1996, Cabello & Jacinto 2002
La Pampilla	ND	ND	ND	ND	ND	0.62-1.46	ND	ND	ND	ND	ND	IMARPE 1996
Pisco Bay	ND	ND	ND	ND	ND	ND	0.1.-3.57	ND	ND	ND	0.33-19.6	Jacinto & Cabello 1996, Cabello & Jacinto 2002
Ilo-Ite	ND	ND	ND	1.58-5.7	ND	ND	ND	0.69-4	ND	ND	0.11-12.2	Jacinto & Cabello 1996, Cabello & Jacinto 2002

Note: ND = No Data.

Table 21 Concentration of hydrocarbon in sediments, Peru.

Site	Hydrcarbon in sediments (µg/l)								Source
	1987	1988	1992	1995	1996	1999	2000	2002	
Talara	2-4.2	6.3-25	ND	ND	0.13-19.63	ND	ND	ND	Jacinto 1991, Jacinto & Cabello 1996
Ferrol of Chimbote	ND	ND	ND	ND	0.89-20.21	ND	ND	0.1-10.2	Jacinto & Cabello 1996, Cabello & Jacinto 2002
Paita	ND	ND	ND	ND	0.19-6.1	ND	ND	0.1-1.63	Jacinto & Cabello 1996, Cabello & Jacinto 2002
Callao	6..9-16	2.9-10.5	1.1-8.8	2.2-2.3	0.33-33.38	30.12-53.12	0.21-11.2	0.34-4.02	Jacinto 1991, Jacinto & Cabello 1996, Cabello & Jacinto 2002
Pisco Bay	0.6-2.3	ND	ND	ND	ND	ND	ND	ND	Jacinto 1991
Ilo-Ite	ND	ND	ND	ND	ND	ND	ND	0.23-2.27	Cabello & Jacinto 2002

Note: ND = No Data.

Table 22 Concentration of hydrocarbon in water, Chile

Site	Hydrocarbon in water (µg/l)				Source
	1985	1986	1987	1988	
Quintero	ND	0.01-1.97	0.27-1.97	ND	Andrade & Alcázar 1989
Valparaíso	2-66	0.42-3.66	0.01-1.22	0.14-0.6	Alcázar et al. 1986, Dorion & Bonnet 1989
Concepción	ND	0.83-5	ND	44	Alcázar et al. 1986, Dorion & Bonnet 1989
Magallanes Strait	ND	ND	ND	2.08-8.92	Dorion & Bonnet 1989
Iquique/ Antofagasta	ND	ND	ND	2.5-5	Alcázar et al. 1989
Caldeera/ Coquimbo	ND	ND	ND	2.1-5	Alcázar et al. 1989

Note: ND = No Data.

Table 23 Concentrations of hydrocarbons in sediments, Chile.

Site	Hydrocarbon in sediments (µg/l)		Source
	1986	1988	
Valparaíso	ND	0.1-0.36	Alcázar et al. 1989
Concepción	2.52-5.06	ND	Alcázar et al. 1989
Magallanes Strait	ND	142-1860	Alcázar et al. 1989
Iquique/ Antofagasta	ND	0.77-7.95	Alcázar et al. 1989
Caldeera/ Coquimbo	ND	0.8-0.31	Alcázar et al. 1989

Note: ND = No Data.

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Humboldt Current region. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF"*.

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: *"GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference"*.

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

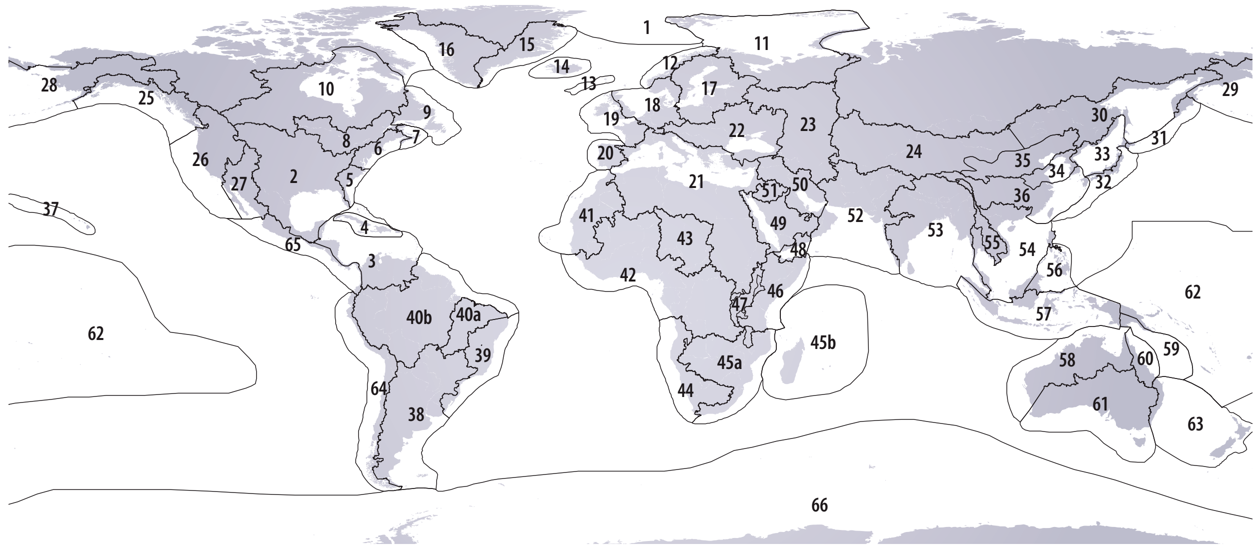
- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1 Arctic
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal (LME)
21 Mediterranean Sea (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 East Bering Sea (LME)
29 West Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan/East Sea (LME)
34 Yellow Sea (LME)
35 Bohai Sea
36 East-China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Brazilian Northeast (LME)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
48 Gulf of Aden
49 Red Sea (LME)
50 The Gulf
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal S.E.
54 South China Sea (LME)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Small Island States
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

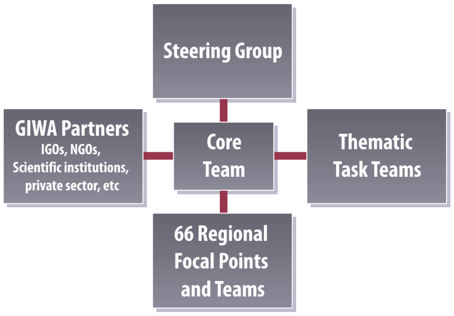


Figure 2 The organisation of the GIWA project.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO2 source/sink function	**V Global change**

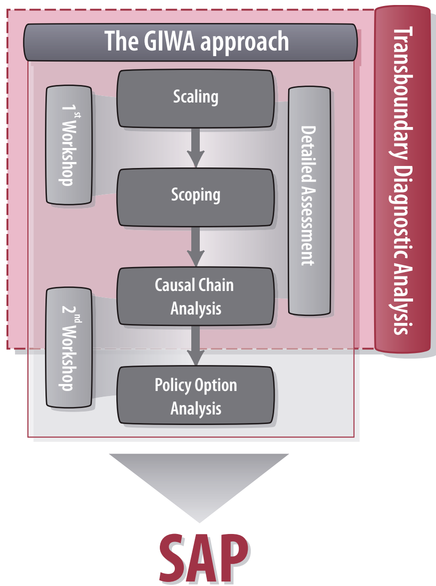

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.*" The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern. In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small – Very large (0 1 2 3)	2	50
Degree of severity	Minimum – Severe (0 1 2 3)	2	30
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

Global International Waters Assessment

Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km²); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km²; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km² .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km²;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/ suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

GIWA

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of the world's transboundary waters that recognises the inextricable links between the freshwater and the coastal marine environments and integrates environmental and socio-economic information to determine the impacts of a broad range of influences on the world's aquatic environment.

Broad Transboundary Approach

GIWA recognises that many water bodies and resources, and the human impacts on them, are not confined to a single country.

Regional Assessment – Global Perspective

GIWA provides a global perspective of the world's transboundary waters by assessing regions that encompass major drainage basins and adjacent Large Marine Ecosystems. The GIWA Assessment incorporates information and multidisciplinary expertise from all countries sharing the transboundary water resources of each region.

Global Comparability

In each region, the assessment focuses on five major concerns comprising 22 specific water-related issues.

Integration of Information and Ecosystems

GIWA recognises the inextricable links between the freshwater and the coastal marine environments and assesses them together as an integrated unit. GIWA recognises that the integration of socio-economic and environmental information and expertise is essential in order to obtain an holistic understanding of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

GIWA identifies the priority concerns of each region, determines their societal root causes and discusses options to mitigate the future impact of those concerns.

This Report

This report presents the GIWA assessment of the Humboldt Current region, located along western South America, stretching from the Ecuadorian-Colombian border to the south of Chile. The world's largest upwelling area, supporting highly productive fisheries, is located within the boundaries of the region. The economy of the region is primarily based on fisheries, agriculture, oil-related industry, mining and maritime transport. As a result of the activities of these sectors Pollution has come to constitute the major environmental and socio-economic concern in the region, followed by Unsustainable exploitation of fish and other living resources. In the report the past and present status as well as future prospects of these concerns are discussed and subsequently traced back to their root causes. Policy options to mitigate these problems are proposed and aim to provide solutions to these fundamental issues in order to enhance the management of the regions aquatic environment.

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