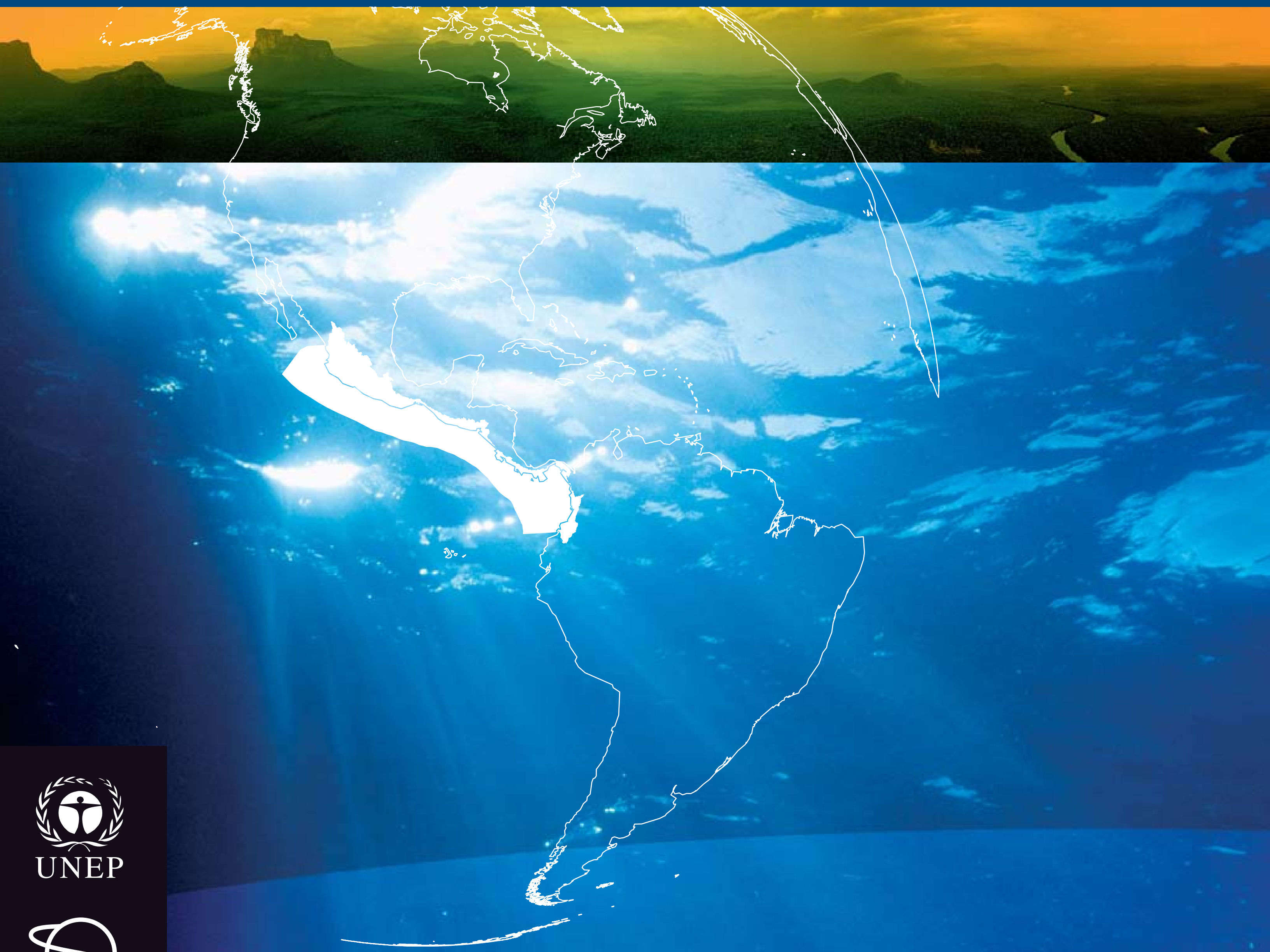
GIWA

Global International Waters Assessment



Eastern Equatorial Pacific

GIWA Regional assessment 65

Permanent Commission for the South Pacific (CPPS)

UNEP

GEF

Högskolan Kalmar University

Global International Waters Assessment

Regional assessments

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Regional assessment 65
Eastern Equatorial Pacific

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Executive summary

Regional Definition

The GIWA Eastern Equatorial Pacific region extends along the west coast of Central America from the Colombian-Ecuador border in the south to northern Central Mexico. It includes El Salvador and the Pacific coastal areas of seven other countries – Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama and Colombia. The region was divided into three sub-systems – Southwest Mexico, Central Equatorial Pacific and Pacific Colombian. The GIWA assessment focuses predominantly on the Central Equatorial Pacific sub-system as it includes most of the significant and reported transboundary issues.

The Southwest Mexico sub-system extends along 1 800 km of Mexico's Pacific coast from the border between the states of Nayarit and Sinaloa in the north to the border with Guatemala in the south. The Central Equatorial Pacific sub-system includes the western part of the Central American isthmus and extends along 3 870 km of Pacific coast from the Guatemala-Mexico border in the north to the Panama-Colombia border in the south. The Pacific Colombian sub-system's coast extends for 1 300 km from Colombia's border with Panama in the north to its border with Ecuador.

The climate of the Southwest Mexico sub-system ranges from tropical (in the lower-lying coastal areas) to warm temperate. The climate of the Central Equatorial Pacific sub-system is tropical to temperate with a winter dry period, when drought conditions occur in a corridor extending from Guatemala to the northern part of Costa Rica; also affecting parts of Panama. Drought conditions are intensified during El Niño events. The Pacific Colombian sub-system is wet tropical, influenced by the Intertropical Convergence Zone, its proximity to the ocean, and the El Niño climatic events.

The region's marine area is influenced by three major current systems – the California Current from the north, the Humboldt Current from the south and the Equatorial Counter-current from the west. The interactions of these currents result in zones of upwelling with productive fisheries. There are extensive lakes in the region, notably in Nicaragua. Two Guatemalean rivers discharge through neighbouring countries – the Suchiate in Mexico and the Paz in El Salvador. In El Salvador, transboundary rivers include the Paz, shared with Guatemala, and the Gosgocaran, shared with Honduras. Honduras also shares Nicaragua's Negro River.

Agriculture is the main economic activity in the region, providing employment for around half of the economically active population. Coastal and artisanal fisheries have a high socio-economic significance, employing around 500 000 fishermen and processing plant operators. Aquaculture, particularly of shrimps, is growing in the region, with 70% of Central America's total production coming from Honduras and Panama. Tourism is also growing, accounting for some 30% of GDP, making it the region's second most important economic activity. Except in Colombia and Mexico, industry is underdeveloped, contributing only 15% to the regional GDP. There is intensive shipping throughout the region including an intercontinental maritime route and, notably, the Panama Canal. Mining of the region's rich mineral resources produces significant proportions of the world's totals, especially silver, lead and zinc.

Assessment of the Southwest Mexico sub-system

Pollution was considered to be the priority concern of this sub-system. The enormous amount of untreated wastewater entering the aquatic environment is deteriorating the environmental quality of the sub-system's water bodies. In Mexico, two thirds of wastewater is discharged into the Pacific Ocean. Microbiological pollution on Mexican beaches has been identified as a priority by Mexican authorities due to the potential effects on human health and tourism. Fertiliser use in Mexico has increased considerably, causing eutrophication in many water bodies, notably Lake Chapala where there is a proliferation of algae and invasive aquatic weeds. Closed seasons during HAB events have resulted in economic losses of 200 million USD to the fisheries industry. Mexico uses more pesticides than any other country in the GIWA Eastern Equatorial Pacific region. However, DDT application has decreased considerably since the 1960s. Heavy metal contamination is particularly high in the Lerma River basin and Lake Chapala, causing toxicological induced mutations in some fish species. The water bodies of the sub-system carry large amounts of suspended solids which are causing severe sedimentation in lakes and coastal wetlands.

Freshwater shortage was considered to be the second priority concern of the Southwest Mexico sub-system. Although the rivers are highly dynamic and characterised by significant inter-annual fluctuations, discharges have shown a decreasing trend over the past 40 years, largely due to increased abstraction. The availability of water suitable for human consumption has declined due to contamination by the discharge of untreated wastewater. The aquifers in the Lerma-Santiago-Pacifico basin have been overabstracted mainly to supply water for agriculture. The depletion of groundwater supplies is concerning given that 70% of the basin's population obtain their water supply from aquifers.

Assessment of the Central Equatorial Pacific sub-system

Freshwater shortage was considered to be the priority aquatic concern. Although water resources are abundant they are unevenly distributed, some areas suffering shortages during the dry season. Pollution, deforestation and inappropriate soil management are adversely affecting downstream transboundary aquatic ecosystems by changing the dynamics of accretion and erosion, the supply of nutrients and the patterns of flooding, as well as by reducing the availability and quality of water resources. Areas deficient in water are generally the more densely populated with the greatest concentration of economic activity. Continuing population growth and economic development will increase the demand for water, increasing the extent and severity of water shortages. Excessive groundwater abstraction is threatening aquifers and resulting in acute water shortages for populations dependent on groundwater. Global climate change will affect the future availability of freshwater in the sub-system. Rainfall is expected to become more intense during the rainy season and droughts more severe during the dry season

Pollution was identified as the second priority concern. In 2000, approximately 22% of the population had no access to safe freshwater; in rural areas half the population obtained water from polluted natural water bodies. Wastewater discharged without treatment is the most widespread pollution issue. Excepting Costa Rica, there is a low level of sanitation coverage. In general, coverage of sanitation and drinking water services has not matched population growth and urban development. As a consequence, water-related diseases are increasingly prevalent. Acute diarrheic disease is the main cause of morbidity and infant mortality. Pesticides and fertilisers are used intensively in agriculture. They are responsible, together with domestic wastewater, for causing eutrophication in coastal areas, which is impacting the food security of the coastal population. Pollution of groundwater, a major source of water for coastal communities, is increasing; higher demand has led to increased abstraction, leading to saline intrusion. Groundwater is also being polluted by urban and agricultural run-off.

Assessment of the Pacific Colombian sub-system

The unsustainable exploitation of fish and other living resources was the principal concern of the sub-system. Despite most of the fisheries in Colombia being small scale and/or subsistence, the current level of exploitation is unsustainable; catches of some traditionally targeted species such as mackerel and sharks have declined. Similarly, stocks of freshwater commercial species are significantly depleted. Although there have been no studies of the level of by-catch in the Pacific Colombian, based on studies in territories within close proximity of the sub-system, it is believed that large quantities of fish are caught as by-catch in the shrimp trawling industry and the majority are discarded.

Pollution was considered by the regional team to be the second priority concern. The Pacific Colombian sub-system has the highest rate of fertiliser consumption on the Pacific coast of South America resulting in some areas, such as Tumaco and Buenaventura, having eutrophic conditions. Variable concentrations of pesticides have been found in water, sediment and organisms at different sites in Colombia. Concentrations of DDTs in surface sediments exceed international and national standards. Extensive deforestation has exacerbated erosion, increasing the amount of sediments entering the rivers. Unplanned urban development has resulted in wastes being disposed of inappropriately. Localised oil spills from exploitation, refining and transport activities have been reported.

Causal chain analysis

In the Southwest Mexico sub-system, only a quarter of the population is connected to wastewater treatment facilities. The sewage infrastructure that does exist is commonly non-operational, with most wastewater discharged directly into the ocean or inland waterways without treatment. Coastal tourism development is increasing further the pressure on sewer infrastructure. Regulatory agencies have achieved increasing success in controlling large-volume industrial polluters whose wastes flow into federal waterways. Pollution levels are still high, however, due to a lack of direct control over municipal pollution sources and weak enforcement power to collect fines from municipalities who exceed federal pollution limits. Local municipal governments lack technical expertise and financial capacity to create and maintain wastewater treatment networks.

In the Central Equatorial Pacific sub-system, freshwater shortage is being caused by the modification of stream flow, pollution and excessive abstraction of groundwater from aquifers. The demographic trends of the last four decades have led to increasing demand for freshwater resources for drinking water, agricultural production and industrial processes. Urbanisation has intensified and concentrated demand in areas that have limited freshwater availability. The current water distribution systems are obsolete and highly inefficient, but countries lack the economic resources needed to adopt water-efficient technologies. The development of freshwater supply and sanitation coverage is not keeping pace with population growth, posing a growing risk for human health. Low tariff rates for water and underinvestment in sanitation infrastructure are the principal causes of the lack of basic sanitation services. Most countries have weak legal and institutional frameworks for water management and there is a lack of a transboundary approach to shared basins. Other shortcomings are a lack of a multidisciplinary approach resulting in inter-institutional conflicts and a lack of monitoring, control and surveillance for the implementation of existing regulations. There is a dearth of knowledge regarding water quality and the effects of pollutants on ecosystems and their biota. There is also a lack of public awareness of water issues and there is no culture of water conservation. Other than the consumptive benefits of water, there is little recognition or valuation of the indirect benefits that water provides through ecosystem goods and services.

On the Pacific Colombian coast, non-selective and destructive fishing gear is used to increase short-term profits at the detriment of fish stocks and marine ecosystems. As the distribution of fish species has changed and stocks of traditionally exploited species have declined, the fishing industry has began to exploit stocks which are further offshore using new technologies. The fisheries sector concentrates on certain valuable species to supply the export, rather than domestic, fish market. Existing laws related to the fisheries are weakly enforced allowing domestic and foreign fishing fleets to avoid legislation. There is lack of institutional cooperation, fisheries statistics and stakeholder participation to aid and improve the effectiveness of decision making processes.

Policy options

Recommendations made by the GIWA regional experts of the Eastern Equatorial Pacific region coincide with those of international fora on water management and the Environmental Plan of Central America (PARCA). The policy options discussed address a range of root causes identified during the Causal chain analysis:

Policy options for addressing microbiological pollution in the Southwest Mexico sub-system:

- Rehabilitate existing, and construct new, wastewater treatment facilities;
- Introduce a fee-and-rebate system for municipal wastewater;
- Reduce excess water use;
- Formulate and implement education and information strategies;
- Publicly rate municipalities for their level of compliance with wastewater treatment standards;
- Create autonomous water districts; and
- Reform the pollution-related legal framework.

Policy options for addressing freshwater shortage in the Central Equatorial Pacific sub-system

- Integrate territorial planning with water management;
- Promote new development centres in rural areas;
- Strengthen and establish further monitoring programmes;
- Develop and implement environmental awareness programmes;
- Reorganise the water sector; and
- Finance the maintenance and expansion of water services by introducing water rates.

Policy options for addressing microbiological pollution in the Central Equatorial Pacific sub-system:

- Invest in treatment infrastructure;
- Adopt the polluter pays-principle;
- Review and reform regional and national legal frameworks;
- Strengthen the capacity of the agencies responsible for water management;
- Develop and implement environmental awareness programmes; and
- Strengthen information management.

Policy options for addressing overexploitation of the fisheries in the Pacific Colombian sub-system:

- Transfer of sustainable technologies;
- Enhance information management and education programmes;
- Further implement integrated coastal zone management (ICZM); and
- Strengthen the self-regulation of coastal communities.

The countries of the Eastern Equatorial Pacific region are inextricably linked by hydrological processes. Water is a vector transporting not only a wide variety of valuable resources but also problems from one country to another. In the Southwest Mexico sub-system, increased understanding of pollution issues, the establishment of communication networks between the stakeholders of a river basin, the creation of incentives as well as penalties for polluters, and greater civil legal powers will shift the political situation in favour of environmental protection. In order to address transboundary pollution and freshwater scarcity in the Central Equatorial Pacific sub-system, a first step would be the implementation of regional instruments of cooperation such as the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the North East Pacific. The regional experts recognise that the institutional inadequacies of water management need to be addressed, and recommended the development of environmental awareness programmes and the reorganisation of the water sector. To address the overexploitation of the fisheries in the Pacific Colombian sub-system, the regional experts recommended that the most feasible option would be to enhance information management and education programmes and to strengthen the self-regulations of local communities.

Abbreviations and acronyms

ADD	Acute Diarrheic Disease
ANAM	Autoridad Nacional del Ambiente de Panamá
BDO	Biological Degradable Organic
BOD	Biological Oxygen Demand
CAC	California Current
CCA	Causal Chain Analysis
CCO	Comisión Colombiana del Océano
CNA	Comision Nacional del Agua
COCATRAM	Central American Commission for Maritime Transportation
COD	Chemical Oxygen Demand
CONADES	National Council for Sustainable Development
CONAZA	Comisión Nacional de zonas Áridas
CPPS	Comision Permanente del Pacifico Sur
DANE	Departamento Administrativo Nacional de Estadística
DDT	dichlorodiphenyltrichloroethane
EEZ	Exclusive Economic Zone
EPA	United States Environmental Protection Agency
EU	European Union
EUC	Equatorial Under-current
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
GDP	Gross Domestic Product
GIWA	Global International Waters Assessment
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
HABs	Harmful Algal Blooms
HC	Humboldt Current
ICA	Index of Water Quality
ICZM	integrated coastal zone management
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia
IGAC	Instituto Geográfico Agustin Codazzi
IHP	International Hydrological Programme
IIAP	Instituto de Investigaciones Ambientales del Pacífico
INDERENA	Instituto de desarollo de los recursos naturales renovables
INEGI	Instituto Nacional de Estadística, Geografía e Informática
INPA	Instituto Nacional de Pesca y Acuicultura
INVEMAR	Instituto de Investigaciones Marinas y Costeras
IPCC	Intergovernmental Panel on Climate Change
ISAT	Instituto de Salud, Ambiente y Trabajo
ITCZ	Intertropical Convergence Zone
IUCN	The World Conservation Union
LAC	Latin America and the Caribbean
LME	Large Marine Ecosystem
MARENA	Ministerio del Ambiente y los Recursos Naturales de Nicaragua
MARN	Ministerio de Medio Ambiente y Recursos Naturales
MINAE	Ministerio del Ambiente y Energía de Costa Rica
MMA	Ministerio del Medio Ambiente
MPN	Most Probable Number
MSY	Maximum Sustainable Yield
NEC	North Equatorial Current
NECC	North Equatorial Counter-current
NEP	The Northeast Pacific Regional Seas programme
NGOs	Non-Governmental Organisations
ODECA	Central American States Organization
OECD	Organisation for Economic Cooperation and Development
OMS	Organización Mundial de la Salud
OPS	Organización Panamericana de la Salud
PAHO	Pan American Health Organization
PARCA	Environmental Plan of Central America
PC	Peruvian Current
PCBs	Polychlorinated biphenyls

PNUD	Programa de las Naciones Unidas para el Desarrollo
PNUMA	Programa de Naciones Unidas para el Medio Ambiente
PSP	Paralytic Shellfish Poisoning
SEC	South Equatorial Current
SEMAR	Ministry of the Navy
SEMARNAT	Ministry of Environment and Natural Resources
SERNA	Secretary of Natural Resources and Environment
SNET	Servicio Nacional de Estudios Territoriales
TDSs	Total Dissolved Solids
TEDs	Turtle Exclusion Devices
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
WCMC	World Conservation Monitoring Centre
WFP	World Food Programme

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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 Eastern Equatorial Pacific region

The GIWA Eastern Equatorial Pacific region comprises the marine area and the basins of rivers draining into the Pacific Ocean along the west coast of Central America, from Central Mexico in the north to the Colombia-Ecuador border in the south (Figure 1). It includes parts of Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama and

Figure 1 The boundaries of the GIWA Eastern Equatorial Pacific region and its sub-systems.

Colombia, and all of El Salvador. The marine area includes the Tres Marías Islands at its northern limit. The marine boundary of the region is based on the criteria used to define the Large Marine Ecosystems (LME) of the Equatorial Pacific – the Humboldt Current and California Current (Sea Around Us Project 2002). The land boundary is mostly an arbitrary line based on differing historical and economic development, and population occupancy between the Caribbean and the Pacific zones of the Central American countries (PNUD/EU 1998); in the southern part of Colombia, it is taken as the west Andean mountain branch, which physically divides that country. The Gulf of Fonseca is an important transboundary feature of the region shared by three countries, El Salvador, Honduras and Nicaragua. There are minor transboundary rivers along the borders of several countries, as well as important national rivers that have transboundary impacts in the coastal zone.

The environmental characteristics of the Central American countries (Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama) are similar, and show distinct differences to Mexico and Colombia. For example, Colombia is among the six countries that possess over half of the global surface water resources (Tierramerica 2004), whereas water is scarce in most Central American countries. The environmental problems of Mexico and Colombia are also different because of their higher levels of industrialisation and urbanisation. Taking these differences into account, the regional experts considered it appropriate to divide the region into three sub-systems – the Mexican Southwest Pacific, Central Equatorial Pacific, and Pacific Colombian sub-systems (Figure 1). Because of the lack of significant transboundary issues in the Southwest Mexico and Pacific Colombian sub-systems, detailed Assessment and Causal chain analysis have been focused more on the Central Equatorial Pacific sub-system.

Physical characteristics

The countries of the Eastern Equatorial Pacific region have several environmental features in common. These include extensive coastal areas in the Pacific basin, unevenly distributed water resources and vulnerability to recurrent and extreme natural events, such as hurricanes and the El Niño phenomenon.

The Southwest Mexico sub-system includes seven coastal states (Nayarit, Jalisco, Colima, Michoacan, Guerrero, Oaxaca and Chiapas) along 1 800 km of the Pacific coast of Mexico. The sub-system stretches from the border between the states of Nayarit and Sinaloa in the north to the border with Guatemala in the south. It covers about 500 000 km^2, some 25% of Mexico's total area. The marine area is influenced by the cold California Current from the north and a branch of the warm Equatorial Current from the south. The interaction of these currents produces an active marine area. Major geographic features include the Gulf and Ithmus of Tehuantepec in the south of the sub-system and the Revillagigedo archipelago in the northwest.

The Central Equatorial sub-system includes the western part of the Central American isthmus, which is flanked to the east by the Caribbean Sea and to the west by the Pacific Ocean. It includes the coastal and marine areas of six countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama) with 3 870 km of coastline. It extends from the Guatemala-Mexico border in the north to the Panama-Colombia border in the south (Figure 1). The total coastal area influenced by the Pacific Ocean is estimated to be 150 300 km^2 (PNUMA 2001). The sub-system's continental area is characterised by a mountain range with two orographic systems – an older range in Guatemala, Honduras and Nicaragua and a younger one in Panama and Costa Rica, extending through the southeastern part of Nicaragua.

The Pacific Colombian coast is flanked by the Panama Bight in the Eastern Tropical region of the Pacific Ocean (Steer et al. 1997). It extends for 1 300 km from Colombia's border with Panama at Jurado in the north to its border with Equador near the outlet of the Mira River at Cape Manglares in the south (Figure 1) (Prahl et al. 1990, Restrepo & Kjerve 2000). It includes the islands of Gorgona, Gorgonilla and Malpelo (Steer et al. 1997). Its land area is 23 500 km^2 – around 2% of Colombian territory. Its oceanic area is 339 500 km^2.

Climate

The climate of the Southwest Mexico sub-system is strongly influenced by tropical anti-cyclones of the northern hemisphere. The area is sub-humid to temperate sub-humid with temperatures higher than 26°C along most of the coastal zone, dropping to between 18 and 21°C during the coldest months (Amendola et al. 2005). The sub-system receives over 800 mm of rainfall and even more in the southernmost part in Chiapas, although it decreases steadily towards the highlands. The rainy season is monsoonal in summer with convective rain.

The climate of the Central Equatorial Pacific sub-system is tropical to temperate with a variable dry period during the winter (Oficina de Coordinación Plan Puebla-Panama 2001). Conditions vary latitudinally. There is a dry zone, named by the FAO as the drought corridor, extending from Guatemala to the northern part of Costa Rica that experiences drought for at least five months of the year. There are also dry areas in Panama – the dry arc of Azuero. There is a high humidity transition zone in Guatemala and a rainy zone in the south of Costa Rica and Panama with dry periods of two months (Windevoxhel et al. 2000, WFP/FAO 2002). Other vulnerable zones include the dry arc of the Gulf of Fonseca on the Nicaraguan coast and some dry areas in the Paz River basin of El Salvador. The region is vulnerable to El Niño events, when the Pacific side of Central America receives abnormally little rainfall causing intense drought conditions, whereas the Caribbean side experiences a stronger rainy season (PNUD/EU 1998).

The Columbian Pacific sub-system is wet tropical and influenced by the Intertropical Convergence Zone (ITCZ), its proximity to the ocean and by climatic events such as the El Niño. The ITCZ is a zone of low atmospheric pressure, where northeast and southeast trade winds converge to create thermodynamic conditions that favour the development of clouds and rain; southeast trade winds deflect along the coast and become western equatorial or westerly winds (INVEMAR 2003a). Heavy rainfall occurs throughout the year (INVEMAR 2003a). Rainfall peaks twice – in April-June and September-November and is lowest in January-March (INVEMAR 2003a).

The marine area

The marine area of the Eastern Equatorial Pacific region is influenced by three major current systems – the California Current from the north, the Humboldt Current from the south and the Equatorial Counter-current from the west. The California Current covers the northern coastal region as far as the northwestern tip of El Salvador, distributing cold-temperate waters (Croom et al. 1995, PNUMA 2001). The North Equatorial Counter-current transports warm water into the region, branching north and south off Costa Rica, forming northward anti-cyclonic and southward cyclonic gyres (Figure 2). The southern part of the region is influenced by waters from diverse origins – the Southern Equatorial Current; the Equatorial under-current; the Peruvian Current, the coastal branch of which flows northward along the Pacific Colombian coast; and the northern extension of the Humboldt Current (PNUMA 2001).

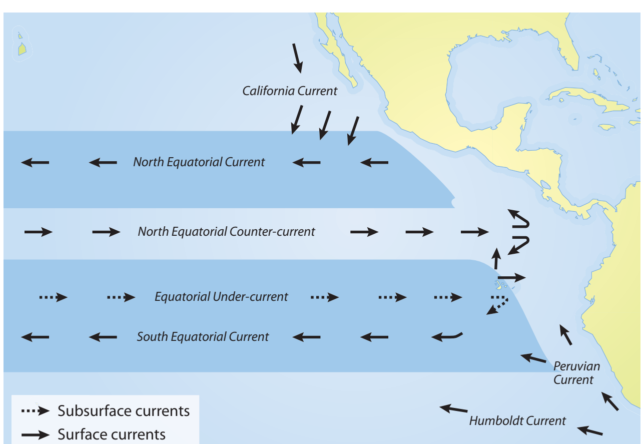

Figure 2 The ocean circulation in the Eastern Equatorial Pacific region. Surface currents (continuous arrows), subsurface currents (discontinuous arrows).

The interaction of these currents, their different types of water and their related gyres, results in a very active marine area. There are upwelling zones along the coasts of Panama, and smaller ones along the coast of Central America and offshore on the Costa Rica Dome. Upwelling in the northern coastal areas is particularly intense. These characteristics strongly influence the abundance and distribution of fishing resources and other coastal marine biota. The Costa Rica Dome, located between 8° and 11° N and 85° to 94° W, is a major ocean feature. It influences an area some 400 km in diameter especially between January and March. In this zone, the wind drives water to a depth of 1 250 m where it moves towards the western tropical circulation, producing a nutrient-rich upward flow (PNUMA 2001). The upwelling combined with coastal run-off stimulates moderately high productivity (150-300 g C/m^2/year) (FAO 1997). The upwellings are also influenced by winds blowing from the Caribbean Sea, the areas of upwelling coinciding with the three major mountain ranges of the region (Sea Around Us Project 2002).

The coastal area

The coastal belt of the Southwest Mexico sub-system ranges from mountainous with rocky shores to coastal plains with some extensive lagoons and barrier beaches. There are 13 lagoon systems with abundant forests including mangroves. In the marine area of the sub-system there are several coral reefs of biological importance. The Revillagigedo archipelago is located 700 km offshore and constitutes the westernmost feature of the region.

The coast of the Central Equatorial Pacific sub-system is characterised by peninsulas, gulfs and bays. There are extensive intertidal areas, barriers and coastal lagoons. Short rivers discharge significant volumes of freshwater and suspended solids into the Fonseca Gulf during the rainy season between May and September (Croom et al. 1995, Windevoxhel et al. 2000). Mangrove forests occupy the alluvial plains of the Chanturo-Teculapa-Panzacola river systems along most of 300 km of coastline extending southeastwards from near the border with Mexico (Florez-Verdugo et al. in Croom et al. 1995). Most of the Gulf of Panama coast is flat with small rivers and estuaries, swamps and mangroves; there are extensive salt marshes to the west of the Panama Canal.

The northern coast of the Pacific Colombian sub-system is mountainous with ravines and cliffs, whereas the southern coast is flat with sandy beaches, mangrove areas and extensive estuaries formed by numerous rivers such as San Juan and Patia. Rocky coasts and cliffs form 287 km of the northern coast at the foothills of the Baudo mountain range (Martínez in INVEMAR 2003a). South of Cape Corrientes, cliffs are discontinuous along the outlet of the San Juan River, Malaga Bay, Buenaventura Bay and the Gulf of Tortugas (INVEMAR 2003a). There are several sandy beaches on the northern coast, such as Solano Bay, Humboldt, Aguacate, Coredo, Ardita, Nabuga and Guaca. On the southern coast, beaches comprise sandy-muddy sediments originating from river discharges, as at Baudo, San Juan, Dagua, Anchicayá, Naya, Patía and Mira (Cantera & Arnaud 1995, Martínez in INVEMAR 2003a). At the mouths of the major estuaries there are important low-lying sandy islands (Martínez in INVEMAR 2003a). The main coastal lagoons and estuaries are those formed by deltas of rivers, such as Jurado and Partado, Catipre, Baudó, San Juan, San Juan de Micay, Guapí, Patía, and bays, such as Tumaco, Málaga and Buenaventura.

Biodiversity

Coastal upwelling inhibits the development of coral reefs (PNUMA/IUCN 1988). The reefs that do occur are small and discontinuous, and less abundant than those of the Caribbean coasts of Central America (Glynn & Wellington 1983). Fifteen species of coral have been reported as the most common in 42 important sites (PNUMA 2001), the greatest diversity occurring in Mexico, Costa Rica and Colombia. On the Colombian coast, small coral reefs include the corals *Pocillopora* sp., *Pavona*, *Porites*, *Psammocora* and *Gardineroseris planulata*. On some isolated rocky shores (Capes Corrientes and Marzo) coral colonies develop together with other sessile invertebrates, such as barnacles, octocorals and sponges, although they do not form true coral reefs. The presence of true coral reefs is directly determined by the availability of hard substrates and clear waters, away from river discharges and estuarine ecosystems with mangroves. According to their geographic distribution in relation to the continent, these communities are classified in three groups – the barrier reefs of the continental coast of North Choco (Utría Cove and Cupica Bay), the barrier reefs of the continental Gorgona island, and the barrier reefs of the oceanic Malpelo island (INVEMAR 2003a). The Central Equatorial Pacific sub-system's coastal waters and continental shelf include habitats for several species of economically important crustaceans. Some of these species inhabit muddy and sandy bottoms between 0 and 40 m depth, including crabs (*Callinectes arcuatus*) and some species of shallow water shrimp (Pineda-Polo 1992, Pineda et al. in INVEMAR 2003a).

Table 1 Extent and distribution of the mangrove forests in the Pacific coast of Colombia.

Region	Department	Area (ha)	%
Pacific	Cauca	36 276.8	9.57
	Choco	64 750.5	17.08
	Nariño	149 735.8	39.50
	Valle del Cauca	41 961.4	11.07
Subtotal		**292 724.5**	**100.00**

(Source: Zambrano and Rubiano, 1996; 1997, in: INVEMAR, 2003a)

There are 12 species of mangrove in the region. Mangroves are abundant in protected areas, particularly in Mexico, Panama, Colombia and the Gulf of Fonseca in Costa Rica (PNUMA 2001). Three countries, Colombia, Panama and Mexico, account for about 80% of the total coverage. Using radar images and air photos, Zambrano & Rubiano (1996) estimated the area of mangrove cover on Colombia's Pacific coast to be 2 930 ha (Table 1) (Informe de República de Colombia et al. 2002).

There are 15 wetlands of international importance in the region, together covering an area of 640 857 ha. Eleven of these are coastal (PNUMA 2001). Costa Rica has seven Ramsar sites in its Pacific coastal area (218 087 ha); Nicaragua, three (98 530 ha); Panama, two (94 570 ha); and the remaining countries, one each – Mexico (144 866 ha), Guatemala (13 500 ha), Honduras (13 850 ha) and El Salvador (1 517 ha). There are numerous highly productive and biologically diverse estuaries and lagoons in the region. El Salvador has more than 30 lagoons; Honduras is characterised by lagoons no more than 5 m deep; and lagoons occur also in Nicaragua and Costa Rica and in the south of Colombia (PNUMA 2001). There are few large islands in the region but over 180 small islands (e.g. Coiba, Otoque and Perlas). Beaches, dunes and cliffs are common; several beaches are important turtle nesting sites (Escobar 2005). In the Pacific Colombian sub-system, there are three protected areas – the National Parks of Sanquianga (80 000 ha); Gorgona (61 687 ha), which includes the islands Gorgona and Gorgonilla and their surrounding marine area; and Utria (54 300 ha), which includes a marine area of 12 000 ha (INVEMAR 2003a).

In the Pacific Colombian sub-system, there are several types of forest community including Tropical Wet Forest, Tropical Highly Wet Forest, Tropical Pluvial Forest, Pre-mountain Pluvial Forest, Low Mountain Pluvial Forest and Low Mountain Highly Wet Forest (INVEMAR 2003a).

Hydrology

The hydrology of the region has been described by UNEP (2001). In the Southwest Mexico sub-system, the major river basins include the Lerma-Santiago, Ameca and Balsas. Another basin, River Suchiate, is shared with Guatemala. Rainfall between 1941 and 2000 showed important seasonal variations among the different administrative districts on the southern Pacific slope (CNA 2002). In general, more than three-quarters of the rainfall occurs over the five months June to October, with a noticeable dry period between February and April. The South Border district has the highest rainfall, whereas Lerma-Santiago and Balsas districts have the lowest. The average annual rainfall in South Border is 2 260 mm; South Pacific, 1 130 mm; Balsas, 800 mm and Lerma-Santiago, 670 mm. On the Southwest Mexico slope the average annual surface run-off is 260 km^3. The South Border district accounts for 140 km^3 (54%) of the total; Balsas, 24 km^3; Lerma-Santiago, 32 km^3; and South Pacific, 32 km^3 (Figure 3). The annual groundwater recharge on the Pacific slope is 36 km^3. The largest proportion of this recharge occurs in South Border (17 km^3), with smaller volumes in Lerma-Santiago, 7.1 km^3; Balsas, 4.9 km^3; and South Pacific, 1.7 km^3.

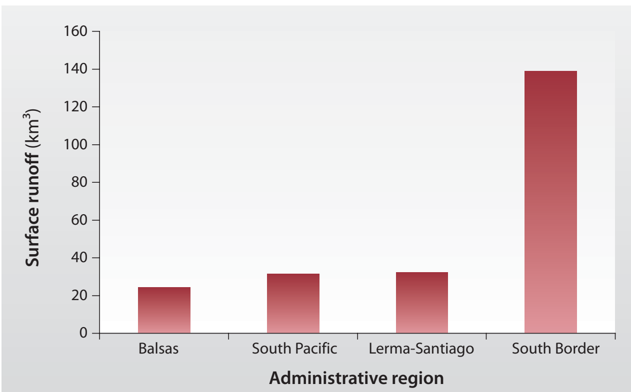

Figure 3 Surface run-off in the administrative districts of the Mexican Pacific sub-system.
(Source: CAN 2002)

In the Central Equatorial Pacific sub-system, although water resources are generally abundant due to the proximity of the sub-system to the ITCZ, they are unevenly distributed. According to FAO (2004a), Panama receives the highest average annual rainfall at 3 100 mm (in the range 1 100-5 500 mm). Costa Rica's annual average in the region is 1 400-2 500 mm; Nicaragua's, 500-2 000 mm; El Salvador's, 1 400-2 400 mm; and Guatemala's, 5 000 mm in the northwest but only 700 mm in the dry western area (near El Salvador and Honduras). Rivers discharging to the Pacific are generally dynamic, short with steeply sloping profiles (Figure 4); they transport high sediment loads, especially during the rainy season (May-November). Several rivers discharge through estuaries forming coastal wetlands (PNUMA 2001). The sub-system contains extensive lakes with surface areas totalling 17 700 km^2. Nicaragua has the greatest lake cover (59%) with the two major lakes of Central America, Xolotlán (1 053 km^2) and the Nicaragua or Cocibolca Lake (8 144 km^2). In Guatemala there are 23 lakes and 119 lagoons covering 950 km^2, while Honduras includes El Yojoa Lake (90 km^2).

Guatemala's surface water run-off to the Pacific amounts to 26 km^3/year. Two Guatemalean rivers discharge through neighbouring countries – the Suchiate in Mexico and the Paz in El Salvador. El Salvador has 180 rivers; the Lempa River forms the major hydrological system, covering some

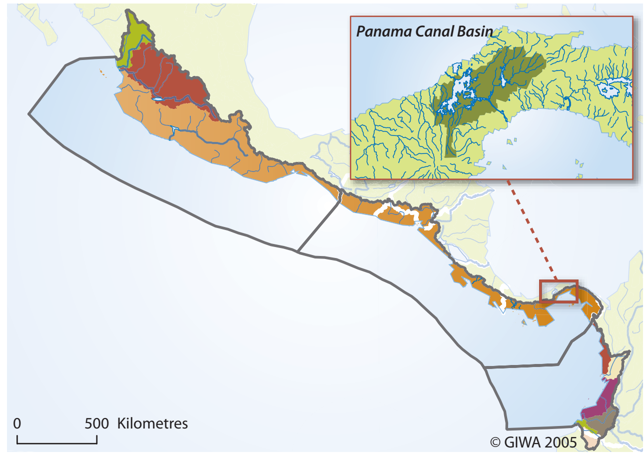

Figure 4 Drainage basins of the Eastern Equatorial Pacific.

50% of the country. Transboundary rivers include the Paz, shared with Guatemala, and the Gosgocaran, shared with Honduras. Honduras has a total surface run-off of 87 km^3/year, 13% of which discharges into the Pacific via the Gulf of Fonseca. Its transboundary rivers include the Gosgocaran, and the Negro, shared with Honduras. Nicaragua has eight river basins with short rivers (<20 km) on the Pacific slope; the Negro River being shared with Honduras; there are no transboundary rivers on its border with Costa Rica within the region. In Costa Rica, there are no transboundary rivers inside the boundaries of the region. Similarly in Panama, there are no transboundary rivers within the region; the Panama Canal basin contains the most important aquifers.

In the Pacific Colombian sub-system, there are vast surface water resources in five hydrologic regions. In 1979, average rainfall was around 3 000 mm, twice the average of the rest of South America and three times the world average (UNESCO in Marín 1992). The major surface water resources on the Pacific slope are the rivers Patía, San Juan, Mira, Micay, Dagua, Anchicaya and Guapi (Tables 2 and 3). The Mira River

Table 2 Monthly average discharges in rivers of the Colombian Pacific Basin.

River	Station	**Minimum** (m^3/s)	**Maximum** (m^3/s)	**Annual average** (m^3/s)
San Juan	San Juan	March: 1 570	November: 2 740	2 060
Micay	Angostura	July: 125	October: 472	132
Patia	Pusmeo	September: 170	December: 488	-

(Source: INVEMAR 2003)

Table 3 Discharges and draining areas of major rivers on the Pacific slope.

River	Station	**Area** (km^2)	**Discharges** (m^3/s)
San Juan	Malaguita	15 180	2 600
Patia	Pusmeo	14 162	346
Micay	Angostura	2 511	280

(Source: PMNR/MMA/IGAC 1999. Ecologic Zoning of the Colombian Pacific Region Project.)

basin is shared with Ecuador. The sub-system contains the rivers with the highest flows in Colombia, the average surface run-off on the Pacific slope being 6 900 m^3/s. There are no lakes along the Pacific Colombian coast except the Trueno Lagoon at Payan, Nariño. There are swamps in the Choco and Cauca departments but little information about them is available (INVEMAR 2003a).

Socio-economic characteristics

The countries of the Eastern Equatorial Pacific region share critical environmental problems related to development. These include poor levels of wastewater treatment and sanitation coverage, low levels of drinking water service, overpopulation, the overexploitation and depletion of natural resources as well as habitat destruction. Although countries in the region have different degrees of development, all of them face problems related to poverty. Countries have a high rate of population growth and are experiencing urbanisation.

The region is rich in natural resources on which its economy is highly dependant, either directly for exploitation, as in the cases of fishing, forestry and mining, or indirectly, e.g. for ecotourism. Mexico and Colombia have a higher level of industrialisation, however, in most of the countries agriculture plays an important social and economic role.

The region's population increased between 1975 and 2002 from 80.8 million to 180.3 million people (111.6%) (Figure 5). During the same period, the population density increased from 51 to 102 people/km² (100%). About 80% of the population live in Colombia and Mexico (Figure 5). In 2002 the proportion living in urban areas was 57% (WRI 2004). The population of the region increased at an annual rate of 2.2% during the period 1995-2000. It is expected that the rate will decrease to 2% during the period 2000-2005.

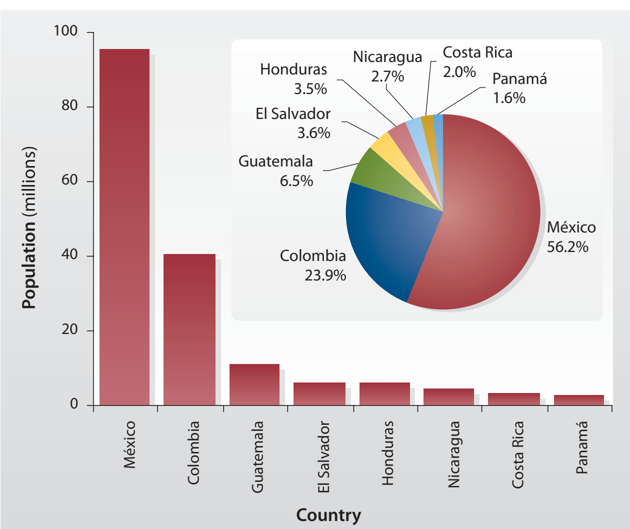

Figure 5 Population of the countries in the GIWA Eastern Equatorial Pacific region.
(Source: GIWA Task team)

There are four administrative districts – Balsas, South Pacific, Lerma-Santiago-Pacific and South Border.

In the Central Equatorial Pacific sub-system, the population has increased by 98% from 19.3 million to 37.7 million between 1975 and 2002. Over the same period the population density increased from 39 inhabitants/km² to 66 inhabitants/km². The population occupies only a quarter of the sub-system's territory with 70% inhabiting the Pacific slope. The urban area is 596 km², which is 0.09% of the sub-system's total. If current urbanisation trends continue, the urban area is expected to cover 913 km² by 2030. Urban populations increased by 29% over the period of 1975-2000, from 35.3% in 1975 to 56% in 2000. About 75% of the population will live in urban areas by 2030 as a consequence of natural population growth, longer life expectancy and migration from rural areas.

The total population of the Pacific Colombian sub-system was 7.8 million people in 2003; approximately 18% of the national population (estimates based on data from DANE 2001). Its growth rate is slightly lower than the national average (Figure 6). Its proportion of the national population will reduce from 18% to 17% between 1995 and 2020 and its population growth rate will reduce from 2% to 1% over the same period. It is estimated that by 2020 the coastal population will reach 9.9 million people (DANE 2001). According to the national census, except for the inhabitants of the Valle del Cauca department, the population of the sub-system is predominantly rural. It is employed mostly in agriculture

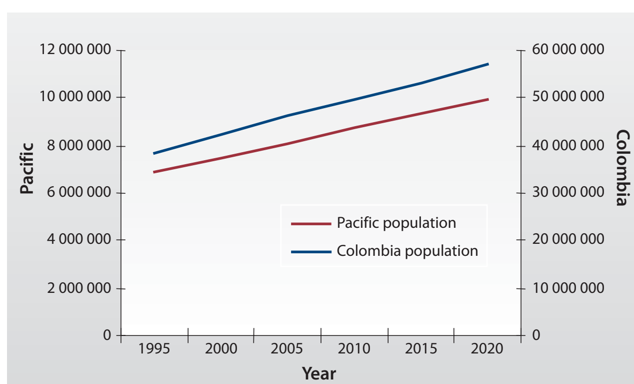

Figure 6 Development of the population of the Colombia Pacific sub-system between 1995 and 2000, with a projection to 2020.
(Source: DANE 2002, GIWA Task team)

(22%), trading (15%) and manufacturing industries (10%). In the Choco department, mining provides 23% of the employment, manufacturing in the Valle del Cauca, 12%, and fishing in the Nariño department, 2%.

Water supply and sanitation

The provision of water services surpasses the average population coverage of the Americas (82.9%) in only two countries in the region – Costa Rica (89%) and Mexico (85%). Three countries are below the average population coverage for Latin America and the Caribbean (LAC) – Guatemala (62%), Nicaragua (54%), and El Salvador (52%). Countries with the lowest access to drinking water provide alternative supply services called 'easy access' (access to a public source of water other than the pipeline connection). Countries with the largest proportion of their population relying on easy access drinking water are Guatemala (19%), Colombia (15%), and Nicaragua (12%). Figure 7 and 8 show the level of drinking water and sanitation coverage in the countries of the region.

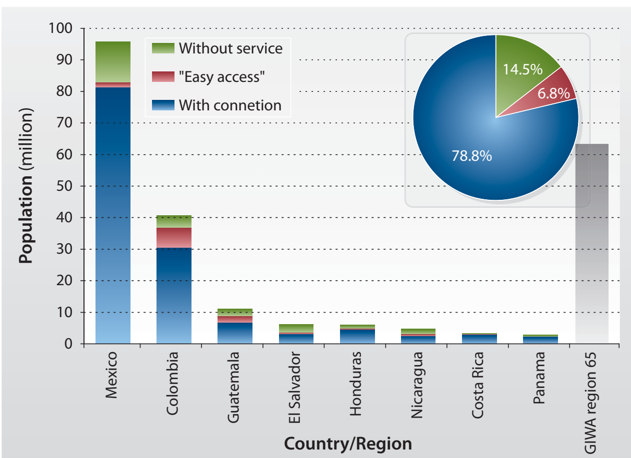

Figure 7 Drinking water coverage in the countries of the GIWA Eastern Equatorial Pacific region.
(Source: GIWA Task team)

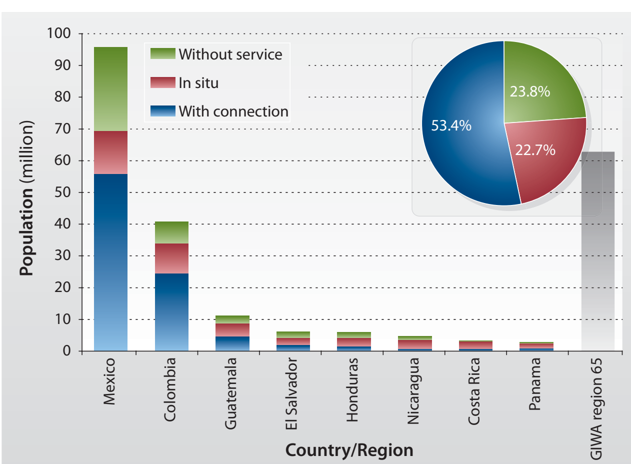

Figure 8 Sanitation coverage in countries of the GIWA Eastern Equatorial Pacific region.
(Source: PAHO 2001)

In the Southwest Mexico sub-system in 2001, the natural availability of water on the Pacific slope was about 294 km^3, 62% of the total reported for Mexico as a whole (472 km^3). The South Border administrative district accounts for one-third of the total available water of the country (156 km^3) or 53.1% of the Pacific slope. Other districts within the sub-system include Lerma-Santiago, 39.5 km^3 (13%), South Pacific, 33.1 km^3 (11%), and Balsas, 28.2 km^3 (10%) (Figure 9). South Pacific and South Border districts had water availability values of 8 344 and 26 791 m^3/inhabitant/year respectively, representing an abundance of water, while the more populated districts such as Balsas and Lerma-Santiago had values of 2 844 and 2 084 m^3/inhabitant/year, respectively, representing freshwater shortages (Figure 10).

In the Southwest Mexico sub-system, gross water extraction from the Pacific slope in 2000 was 44.7 km^3, notably in the Lerma-Santiago district (15 km^3). Extractions in the other districts were – Balsas, 7.7 km^3, South Pacific, 1.6 km^3 and South Border, 1.8 km^3. While South Border district had the highest available water resources on the Pacific slope, extraction there was the lowest. According to CNA (2002), 83.4% of

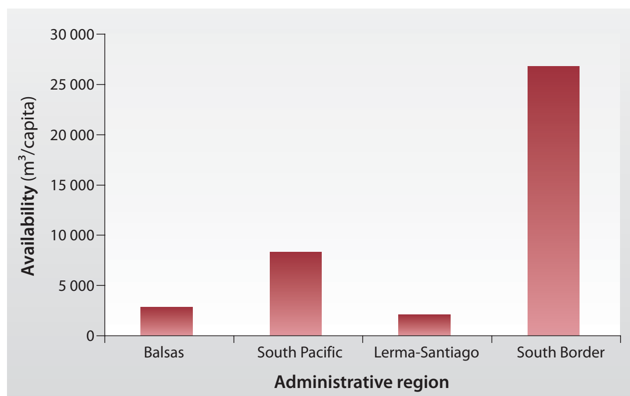

Figure 9 Water availability per capita in the administrative districts of the Southwest Mexico sub-system.
(Source: CNA 2002)

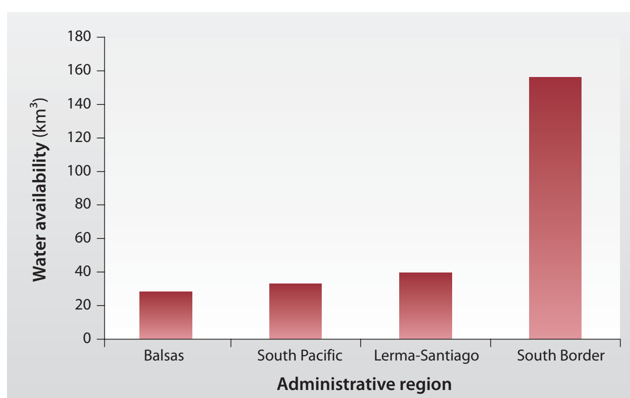

Figure 10 Water availability in the administrative districts of the Southwest Mexico sub-system.
(Source: CNA 2002)

water use on the Pacific slope in 2000 was for agriculture. Most of the demand for water for agricultural use comes from the Lerma-Santiago district (11.5 km^3), of which 56% is from surface water and 44% groundwater. In the south of the sub-system, volumes of water used for agriculture are lower; 1.1 km^3 in South Pacific and 1.0 km^3 in South Border. Urban water consumption is highest in the Lerma-Santiago district at 1 606 km^3, of which 1 207 km^3 is from groundwater and 399 km^3 from surface sources (CNA 2002). The demand in Balsas district is 800 km^3 (68% from groundwater); in South Border, 485 km^3 (181 km^3 groundwater); and in South Pacific, 323 km^3 (160 km^3 groundwater). Industrial use is greatest in Lerma-Santiago at 1 233 km^3 (around 66% groundwater); the demand in Balsas is 480 km^3 (around 66% groundwater); South Border, 286 km^3 (57% groundwater); and South Pacific, 114 km^3 (89.6% groundwater).

Table 4 Renewable hydric resources in the sub-system by country. Percent indicates the proportion respect to the entire sub-system.

Country	Average rainfall 1961-1999 (mm/year)	Surface water produced		Recharge underground water		Total water resources		Total water resources 1997-2000		Volume per capita 2002 (m^3)
		km^3	%	km^3	%	km^3	%	km^3	%	
Costa Rica	2 926	75	12.2	37	26	112	16.6	112	16.2	26 764
El Salvador	1 724	18	2.9	6	4.2	18	2.67	25	3.6	3 872
Guatemala	2 712	101	16.5	34	24	109	16.2	111	16.1	9 277
Honduras	1 976	87	14.2	39	27.5	96	14.2	96	13.9	14 250
Nicaragua	2 391	186	30.4	59	41.5	190	28.2	197	28.5	36 784
Panama	2 692	144	23.5	21	14.7	147	21.8	148	21.4	50 299
Sub-system	2 403	611	100	142	100	672	100	689	100	23 541

Source: FAO (2002 a , and 2004a) and WRI (2004).

In the Central Equatorial Pacific sub-system, there are more than 81 basins draining to the Pacific, discharging a total volume of 672 km^3 annually (FAO 2004a). Panama and Nicaragua produce half of the surface water in the sub-system and Panama has the highest water availability – 50 300 m^3/inhabitant/year. Groundwater constitutes a major resource for agriculture, industry and domestic consumption (Table 4). Three of the most important basins are described below.

The Lempa River basin covers 18 311 km^2, shared by El Salvador (56%), Guatemala (14%) and Honduras (30%) (CCAD 2002). It is transboundary in nature, and embraces 45 municipalities with a total population in 2001 of 4.7 million people. This is around 13% of the sub-system's total population. The Lempa River is 335 km long and is the main source of freshwater for El Salvador (72% of that country's total surface water). The River also generates 65% of the country's electricity through three hydroelectric plants. Although the mid- and lower parts of the basin are in El Salvador, upstream activities have important implications for the whole basin (Artiga 2002).

The Grande de Tarcoles River basin in Costa Rica covers 2 156 km^2, around 4% of the country. Although only 88 km long and 36 km wide, it contains 53% of the Costa Rican population as well as the capital, San José. The basin is the location of 85% of the country's industry, trading and services. Its main aquifers, Barva and Colima, supply freshwater to 66% of the urban population (the cities of San José, Heredia, Alajuela). Its catchment includes pastureland (29%) and woodland (18%) (Ballesteros 2003). Although the basin lies entirely within Costa Rica, its drainage has transboundary impacts on the coastal waters of the Pacific Ocean.

The Panama Canal basin covers 5 527 km^2 – 6.5% of Panama's total area (Figure 4). According to Castro (2003), the basin includes two major components – the traditional basin and the western basin. The former covers 3 397 km^2 and includes the river basins of the Chagres (northbound flow to the Caribbean) and Grande (southbound flow to the Pacific), forming a unique navigation system through the Galliard Cut, excavated between 1904 and 1914. This system includes the Gatún Lake and the Alajuela Lake, built as an additional water reserve in the upper basin of the Chagres River after the construction of the Madden dam. The western basin covers 2 131 km^2 and includes the river basins of the Coclé del Norte, Indio and Caño Sucio, all of which discharge into the Caribbean Sea. The Panama Canal, about 80 km long, crosses the basin. Each vessel traversing the Canal uses 197 million litres of freshwater, which flows through floodgates to the ocean (Vargas 1998).

Economic activity

According to UNEP (2001), during the period 1994-1998 agriculture was the main economic activity in the region accounting for 20% of Gross Domestic Product (GDP). Countries with higher rates include Nicaragua (34%), Guatemala (23%) and Honduras (22%). Agriculture provides employment for around half of the economically active population. The major export products include coffee, bananas and sugar.

Historic and current fish production is mainly based on pelagic fisheries and, to a lesser extent, squid, shrimp and coastal demersal species (FAO 1997). Of the total catches in the region in 1997, Mexico accounted for 77%, with Panama and Colombia, 11% and 9% respectively (Figure 11). Coastal and artisanal fisheries have a high socio-economic significance; around half a million fishermen and processing plant operators are employed in the industry and in some communities the fisheries are the only source of employment. Aquaculture is a growing industry in the region, particularly shrimps (*Lithopenaeus* spp.) and, on a small

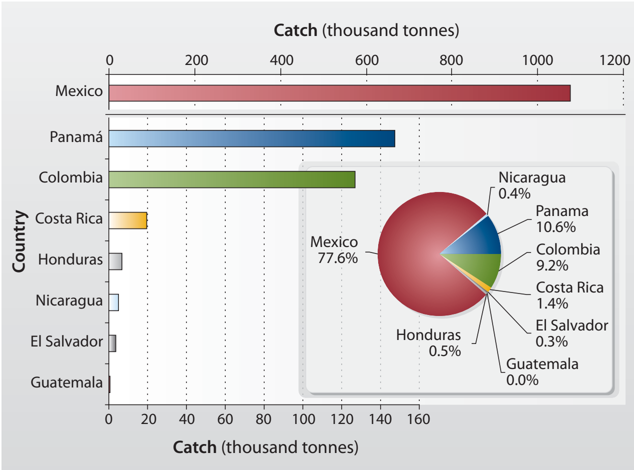

Figure 11 Fishing catches in the countries of the GIWA Eastern Equatorial Pacific region.
(Source: Sea Around Us Project 2002)

scale, molluscs and fish. In Central America, 70% of the total aquaculture production comes from Honduras and Panama. The United States imports about 95% of the cultured shrimp exports. In the Central Equatorial Pacific sub-system, fisheries production is dependent on the upwelling of nutrient-rich ocean waters, as at Papagayo (Costa Rica), and, to a lesser extent, the fishing grounds supported by nutrient run-off (PNUMA 2001).

Tourism has a growing economic importance in the region, which has many attractions including traditional modalities (sun and beaches) and emerging opportunities (ecotourism and agrotourism). Tourism accounts for around 30% of GDP, making it the region's second most important economic activity. According to the Central American Institute of Tourism, the numbers of tourists in most countries in 2000 exceeded 500 000. Costa Rica received 26% of the total number of visitors to Central America.

Except in Colombia and Mexico, industry is underdeveloped, contributing only 15% to the regional GDP. There is intensive commercial and tourist shipping throughout the region including an intercontinental maritime route. The most significant location for maritime traffic is the Panama Canal, where during 1990-1998 an average of 14 300 ships passed every year, generating an income of 420.3 million USD (PNUMA 2001). Mining of the region's rich mineral resources produces significant proportions of the world's totals – silver (18%), lead (6%), copper (3%), zinc (5%), gold (2%), nickel (3%) and tin (1%) (PNUMA 2001). Activities relating to oil include transportation, storing and refining. There are no offshore platforms in the region.

Regional cooperation

The countries in the region have adopted several legal mechanisms that aim to strengthen regional cooperation regarding the management of water. However, not every country in the region is party to the same conventions and agreements. The cooperation mechanisms listed below mainly involve the countries of the Central Equatorial Pacific sub-system. Mexico has stronger ties with the North American countries and has maintained bilateral agreements on water with the United States since the beginning of the 20th century. Panama and Colombia have also ratified the Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific (Lima Convention), adopted 1981, and the complementary protocols (see Annex III). In addition to those given below, other important initiatives concerning water issues in the Central Equatorial Pacific sub-system include the Dialogue on Water, Food and Environmental Sustainability, San Jose, Costa Rica (2001), and the Central American Summit on Sustainable Development, Nicaragua (1994) (Annex III).

The Northeast Pacific (NEP) Regional Seas programme

In response to the Central American Governments' call for more collaborative environmental mechanisms at a Meeting of Experts in 1996, the decision was taken in 1997 to incorporate the countries of the Northeast Pacific into its Regional Seas Programme. On 18th February 2002, the Convention for the Protection and Sustainable Development of the Marine and Coastal Environment for the Northeast Pacific (Antigua Convention) was signed by six of the member countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama), with Colombia and Mexico expressing an interest to sign. The Plan of Action of the Convention (Action Plan) was also adopted by the six member countries as well as Colombia and Mexico on 18th February 2002 in La Antigua, Guatemala.

The main objective of the Plan of Action is to provide a regional cooperative framework for promoting and facilitating the sustainable management of the marine and coastal resources of the countries of the northeast Pacific for the well-being of the present generation and future generations in the region. The Action Plan spans the area between the extreme south of the Pacific seaboard of Colombia, where it borders Ecuador, to the extreme north of Mexico on the Pacific, at its border with the United States. The region comprises what is known as the Great Marine Ecosystem of the California Current.

COCATRAM

The Executive secretariat for NEP is hosted by the Central American Commission for Maritime Transport (COCATRAM) in Guatemala.

COCATRAM is part of the Central America Integration System (SICA in Spanish). The objective of COCATRAM is to look at issues relating to the promotion of the development of the maritime and ports sub-sectors in Central America in order to strengthen, facilitate and foster internal and external foreign commerce in the region. The member countries to the Commission are: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. Colombia and Mexico are not part of COCATRAM.

Current activities undertaken by NEP:

- A regional diagnostic study on land-based sources of pollution in the Northeast Pacific;
- A regional profile on oil marine pollution and the capacity of the Northeast Pacific countries against oil pollution;
- A regional coastal and marine environmental institution directory; and
- Several proposed technical and economic projects on specific priority topics selected by the governments.

Central American Integration System (SICA, Sistema de Integración Centroamericana)

SICA was established by Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama through the adoption of the Protocol Letter of the Central American States Organization (ODECA), also known as the Tegucigalpa Protocol. This mechanism aims to initiate regional integration in order to promote peace, liberty, democracy and development, based on respect, mutual support and promotion of human rights. The General Secretariat rotates every six months among member states and supports regional integration initiatives.

Central American Commission on Environment and Development (CCAD, Comisión Centroamericana de Ambiente y Desarrollo)

This agreement was signed in Costa Rica in December 1989 by the Presidents of Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua. The objective of this agreement was to establish a regional regime of cooperation in order to achieve the optimal use of natural resources, the control of pollution and restoration of an ecological equilibrium which guarantees a better quality of life for the population of the Central American Isthmus. The Commission was mandated to:

- Valuate and protect the natural heredity of the region, characterised by its high biodiversity;
- Improve collaboration among member countries in order to promote sustainable development;
- Promote the coordination of governmental, non-governmental and international institutions in order to optimally use local resources, control pollution and restore an ecological equilibrium;
- Manage financial resources;
- Strengthen national capacities related to natural resources and environmental management;
- Harmonise political and legislative guidelines with strategies for achieving sustainable development in the region; and
- Determine priority areas of action including, among others, education and environmental training, the protection of river basins and shared ecosystems, the management of tropical forest, pollution control, the importing and handling of harmful substances, and other aspects with potential risks for human health.

Assessment

Table 5 Scoring table for the Central Equatorial Pacific sub-system.

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

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

Because of the lack of significant transboundary issues in the Southwest Mexico and Pacific Colombian sub-systems, detailed Assessment and Causal chain analysis focuses mainly on the Central Equatorial Pacific sub-system. In the Southwest Mexico sub-system there was a lack of information on the only transboundary river, the Suchiate, and in the Pacific Colombian sub-system there are no transboundary rivers. The regional experts therefore included analysis of national aquatic concerns which are believed to be affecting the pacific coastal zone of Mexico and Colombia and their neighbouring countries. Only freshwater shortage and pollution were assessed for the Southwest Mexico sub-system.

During the assessment process it was evident that several environmental issues do not have quantitative indicators to allow them to be objectively evaluated. They are therefore assessed using qualitative information and may include a degree of subjectivity. The GIWA scoring table (Table 5) shows the results for the Central Equatorial Pacific sub-system.

Freshwater shortage

The assessment of freshwater shortage evaluates the environmental and socio-economic impacts of three transboundary issues: modification of stream flow, pollution of existing supplies, and changes in the water table. Freshwater shortage is more severe in the Southwest Mexico and Central Equatorial Pacific sub-systems than in the Pacific Colombian sub-system.

Modification of stream flow

Southwest Mexico

Although the sub-system's rivers are highly dynamic and characterised by significant inter-annual fluctuations, discharges have shown a decreasing trend over the past 40 years, largely due to increasing abstraction for human uses. The mean annual discharge declined from 323 m^3/s to 278 m^3/s between the periods 1965-1969 and 1975-1979, and in the period 1979-1980 the mean discharge was only 177 m^3/s, the lowest on record. The mean discharge had reduced by up to 45% by the early 1980s. Figure 12 shows the discharges of the five rivers with the largest data series: Lerma-Santiago, Armería, Coahhuayana, Papagayo and Verde. These are not transboundary rivers but the changes in discharges may have important implications for adjoining river basins and coastal areas.

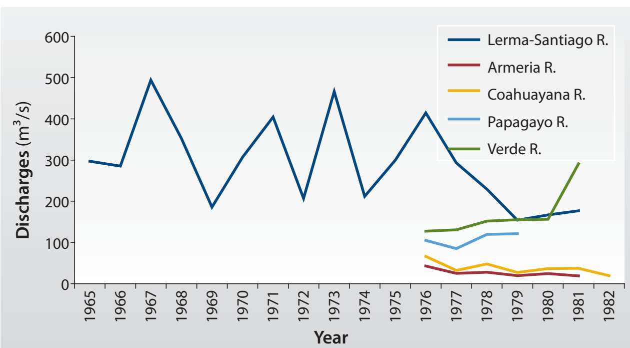

Figure 12 Annual discharges of five Mexican rivers.
(Source: Vörösmarty et al. 1998)

Lake Chapala, the largest freshwater reservoir in Mexico, supplies water to the city of Guadalajara. According to SEMARNAT (2004), five years after the Lake reached its maximum level in 1993, its water volume had decreased by 3 404 million m^3, representing only 61% of its storage capacity. This was attributed to increased consumption and higher evaporation rates.

Central Equatorial Pacific

Despite all countries of the Central Equatorial Pacific sub-system having abundant water resources and extracting relatively limited quantities (2.4% of the total availability, estimated at 690 km^3), some areas experience water scarcity during the dry season when river flows are considerably reduced. This situation is exacerbated during warm El Niño events. Lower flows and reduced water availability and quality have been caused by a progressive deterioration in the environmental quality of the river basins due primarily to deforestation, increased water extraction and pollution. River discharges are also affected by dams, which interrupt the natural flow of nutrients to coastal waters, as reported for the Bayano River in Panama by Franco (2001).

Discharges of the transboundary Lempa River measured at San Marcos in El Salvador show considerable inter-annual fluctuations, although only a short time series of data is available (Figure 13). According to SNET (2002), the discharges of the Lempa River in 2002 were 42% below the historic average. The reduction in water availability has also been attributed to the loss of fog forests in the upper sections of the basins, such as the Lempa (Llort & Montufart 2002).

Deforestation and inappropriate agricultural practices in the catchments has affected run-off patterns and the flow rates of rivers such as the Choluteca, Lempa and Motagua. These human activities have increased erosion and consequently the amount of suspended

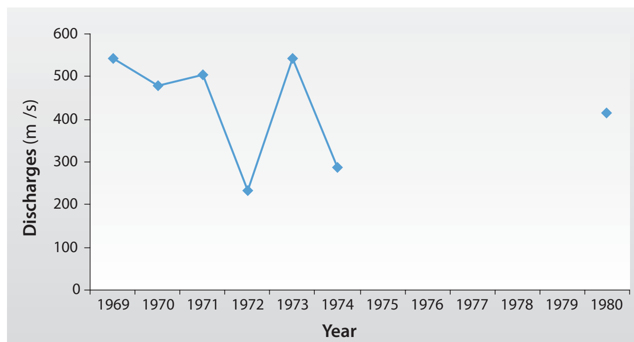

Figure 13 Annual discharges of Lempa River 1969-1974 and 1980.
(Source: Vörösmarty et al. 1998)

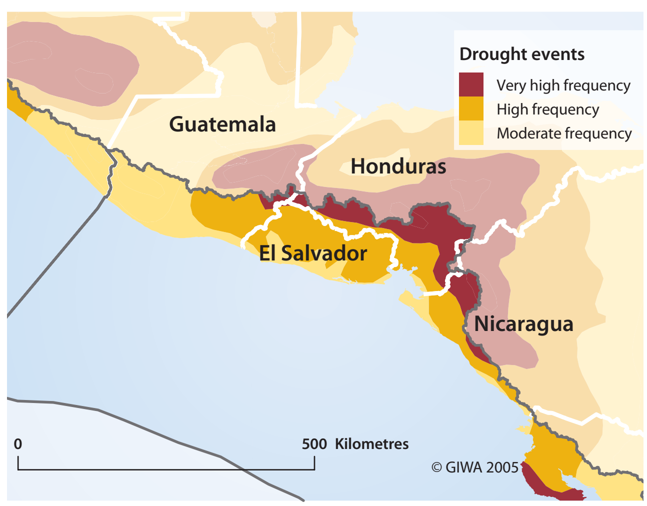

Figure 14 The Central American drought corridor. Colours show the frequency of dry periods.
(Sources: WFP/FAO 2002)

solids in the river waters. The capacities of freshwater bodies, including reservoirs, in the lower sections of the river basins have been reduced due to sediment trapping. This is increasing the extents and frequencies of floods. In Honduras, Costa Rica and Panama floods are now the most frequent natural disaster.

El Niño events affect water availability in the sub-system by increasing the lengths of dry periods. Rainfall can be reduced by 30-60% in the most affected areas (WFP/FAO 2002). During an El Niño, river flows are reduced significantly, exacerbating the effects of a normal dry season (WFP/FAO 2002) (Figure 14).

Pacific Colombian

Although there are no transboundary rivers in the Pacific Colombian sub-system, the main rivers discharge considerable quantities of water into coastal areas with potential transboundary implications for neighbouring countries.

The assessment of stream flow modification was based on available information on the discharges of three major rivers, the San Juan, Patía and Mira, and several minor rivers, as well as the average number of rainy days on the Pacific slope (CCO 2002). There is no evidence of significant changes to the discharges of these rivers or the number of rainy days (Figures 15 and 16) (IDEAM 2001).

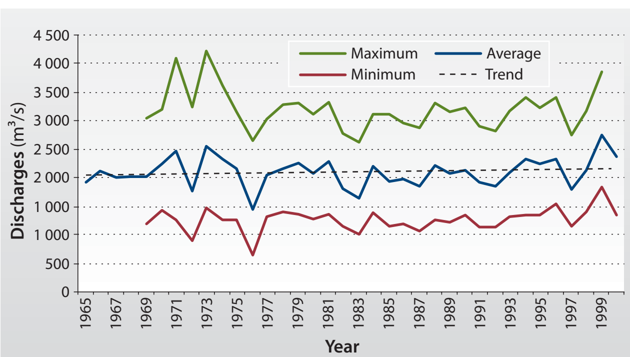

Figure 15 Annual discharges of the San Juan River. *(Source: IDEAM 2001)*

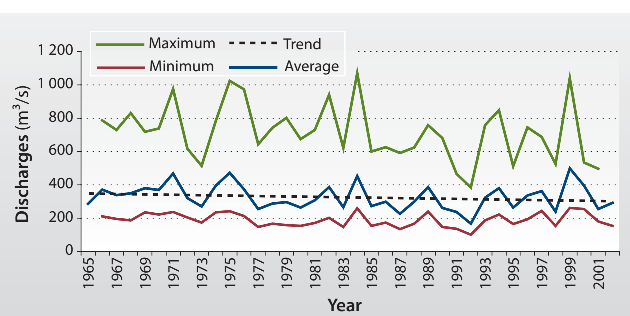

Figure 16 Annual discharges of the Patia River. *(Source: IDEAM 2001)*

Pollution of existing supplies

Southwest Mexico

Only 23% of municipal wastewater (46 m^3/s) receives treatment in the 1 018 treatment plants in Mexico (CAN 2002). Most wastewater is therefore discharged into rivers, lakes and other water bodies without treatment, thus reducing the availability of water suitable for human consumption.

Mexican authorities use an Index of Water Quality (ICA) to assess water bodies. According to this index, the country's water bodies are classified as follows: 5% are excellent, 22% acceptable, 49% slightly polluted, 15% polluted, 7% highly polluted and 2% contain toxic substances (CAN, 2002). Two of the four basins with the highest pollution levels, Lerma (including Lake Chapala) and Balsas, are in the Southwest Mexico sub-system. Tables 6, 7 and 8 show various indicators of the quality of the Lerma and Balsas rivers and Lake Chapala between 1990 and 2001. There appears to be no improvement in the general condition of these water bodies. High concentrations of the measured parameters, such as biological oxygen demand (BOD) and chemical oxygen demand (COD), are maintained throughout the decade.

Central Equatorial Pacific

Pollution is evident in several major basins of Central America, including the Lempa River, shared by El Salvador, Guatemala and Honduras, and the Grande de Tárcoles River basin in Costa Rica. El Salvador is particularly affected as its main sources of freshwater, the Lempa River and Ilopango and Coatepeque lakes, are highly polluted by wastewater discharges. A two-year study in the Lempa River showed that 95% of samples contained *E. coli* (Levin 2002). In 2001, a study undertaken in the rural areas of El Salvador found that 43% of the samples taken from water supplied through pipes and 85% of the samples from wells were polluted by faecal coliforms (OPS/OMS 2003). In 2000, approximately 22% of the sub-system's population had no access to safe freshwater. The level of coverage for rural populations is less; around 50% are without access to safe drinking water due to pollution and the lack of treatment facilities (OPS/OMS 2001a).

According to PNUMA (2001), 95% of the municipal wastewater generated in the sub-system enters natural water bodies without receiving appropriate treatment. In four of the six countries of the sub-system, only 1-4% of the wastewater disposed of through sewerage systems receives treatment, and in Nicaragua and Panama, 34% and 18% respectively (OPS/OMS 2001a). In Costa Rica, all wastewater transported through the sewerage system is discharged without treatment (Ballesteros 2003). Similarly in Honduras, wastewater generated at Tegucigalpa, including that of industrial origin, is

Table 6 Quality of the Lerma River according to physical, chemical and biological parameters 1990-2001.

Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ammonium(NH_4)	Mg/L		0.39	0.59	1.3	3.34			1.35	18.45	0.75		
BOD (20°C, 5d)	MPN/100mL	13.5	2.9	15.3	16.1	9.58		17	12	92.33	11	30	7.31
COD ($K_2Cr_2O_7$)	mgO_2/L		35	63.3	63.3	39				134	58	63.5	44.4
Nitrates (NO_3)	mgO_2/L	0.44	0.55	1.17	1.7	0.49		0.78	0.3	0.82	0.26	0.55	1.27
Ortophosphates	mg/L		0.39		0.55	1.65			2.6	5.63	2.83	2.83	1.01
Dissolved Oxygen	mgO_2/L	2.4	4.35	3.17	3.97	5.7		5.76	3.52	0.7	6.6	2.21	6.04
Dissolved solids	mg/L					223		487	782	634	7	500	418
Suspended solids	mg/L				304	380		40.3	189	253	8.22	40	63.6
pH	pH units	7.8	8	8	7.2	7.4	7.7	7.6	8	8.1	8.2	7.5	7.7

(Source: CAN 2002)

Table 7 Quality of the Balsas River according to physical, chemical and biological parameters 1990-2001.

Parameter	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Ammonium(NH_4)	Mg/L				0.2								
BOD (20°C, 5d)	MPN/100mL	1.74	1.	3.4		1.46	1.47	2.34	2.43	1.7	3.68	2.29	
COD ($K_2Cr_2O_7$)	mgO_2/L	10.4	5.1	25.8		10.4	43.5				16		
Nitrates (NO_3)	mgO_2/L					0.11							
Ortophosphates	mg/L	0.064	0.067	0.06	0.065	0.11							
Dissolved Oxygen	mgO_2/L	6.38	6.26	7	5.97	3.7	5.2	3.26	6.43	6.69	6.66	2.9	6.06
Dissolved solids	mg/L		128	74	174	233	170	182	177	235	40.8	2.76	148
Suspended solids	mg/L				48	7.8	37.3	19	21		77.5	59	22.5
pH	pH units						8.4	7.7	7.9	8	7.5	7.4	7.3

(Source: CAN 2002)

Table 8 Quality of the Chapala Lake according to physical, chemical and biological parameters 1990-2001.

Parameter	Unit	1990	1991	1992	1994	1996	1997	1998	1999	2000	2001
Ammonium(NH_4)	Mg/L	0.41	0.32	0.33	1.79	0.13	0.22	0.15	0.238		1.26
BOD (20°C, 5d)	MPN/100mL	1.71	1.23	1.22	1.17	2.34	2.85	2.46	3.86	2	3.59
COD ($K_2Cr_2O_7$)	mgO_2/L	30	31.61	41.29	31.1			39.6	42.4	47	58.43
Nitrates (NO_3)	mgO_2/L	0.15	0.36	0.18	0.23	0.17	0.12	0.12	0.082	0.195	
Ortophosphates	mg/L	0.24	0.28	0.27	0.32	0.43	0.38	0.38	0.382	0.46	0.751
Dissolved Oxygen	mgO_2/L	7.6	7.18	7.45	6.8	6.7	7.3	7.55	7.34	8.6	8.1
Dissolved solids	mg/L	662	850	613	481.7	613.5	643.5	730.8	790	802	943
Suspended solids	mg/L	52	40	37	35.7	25	44	61.6	66	66	89
pH	pH units	8.92	8.59	7.59	8.55	8.80	9	9.2			8.75

(Source: CAN 2002)

discharged into Choluteca River without treatment. In Guatemala, only 15 out of 344 municipalities apply any treatment to their wastewaters from urban areas. Thus, most of the pollution in the surface waters of the sub-system originates in the lack of appropriate treatment.

Some coastal industries use large amounts of water which is later discharged into the surrounding water bodies without treatment. In Costa Rica, the coffee industry is still a major source of pollution, despite a programme to reduce pollutant discharges being established in 1989. Today, approximately 45% of the pollution charge and BOD reaching the Tárcoles River originates from the coffee industry. Some studies have shown that this industry may be responsible for up to 77% of the pollutant load (Ballesteros 2003).

Higher water demand, driven largely by the expansion of the tourism industry, has led to increased abstraction from aquifers, which are a major source of water for coastal communities. This has led to saline intrusion in aquifers used by 31% of five communities monitored, some of whom were forced to abandon their source (Gamez 2002). Aquifers in the metropolitan area of Alajuela, Cartago and Guanacaste have increasing concentrations of nitrates originating from fertilisers and septic tanks (Reynolds & Fraile 2002). Urban and agricultural run-off are responsible for polluting the Managua aquifer that provides freshwater to 1.2 million people. Around 20% of the freshwater used by the population in the capitals of San José, San Salvador, Managua and Tegucigalpa comes from underground sources, which are being affected by pollution.

The sub-system has one of the largest rates of pesticide consumption in Latin America (2 kg/person), attributed to the intensification of farming to suply the export market. There is also evidence that agricultural by-products make a significant contribution to the deterioration of surface water quality. According to Ballesteros (2003), in Costa Rica around 50% of all agricultural wastes enter water bodies.

Pacific Colombian

Most available information regarding the pollution of freshwater supplies is on urban centres (Calero et al. 1996). In Tumaco and Buenaventura there is a risk of contamination due to the large volumes of hydrocarbons transported in the area. In the rest of the Colombian Pacific basin, hydrocarbon activities are less significant and there is greater water exchange (Castro et al. 2003). Freshwater supplies can also be contaminated with persistent organic pollutants (POPs), particularly DDT, and by a variety of other agrochemicals used in illegal drug cultivation (IDEAM 2002).

Changes in the water table

Southwest Mexico

In 2000, 96 of Mexico's 653 aquifers were considered overexploited (SEMARNAT 2002). In recent years, the volume of water extracted has remained constant at about 29 km^3/year. The aquifers in the Lerma-Santiago-Pacifico basin have been overabstracted mainly to supply water for agriculture. In the state of Nayarit, saline intrusion in the aquifers has been reported (SEMARNAT 2002). Groundwater is used less, without any apparent problems, in the remaining basins of the sub-system.

Central Equatorial Pacific

Groundwater is the main source of freshwater in this sub-system. In El Salvador, around 60% of the freshwater is sourced from the aquifers of the metropolitan area of San Salvador, which are currently overabstracted. Groundwater abstraction in Nicaragua exceeds the recharge rate of aquifers. In 1995, the potential abstraction rate was estimated at 535 300 m^3/day for the Managua aquifer. The demand for that year was 424 000 m^3/day but it reached 553 000 m^3/day by 2000 (MARENA 2003). In the dry arc of Azuero (Panama), aquifers are pumped to their limits during drought periods. In Honduras, the renewable volume of groundwater in the Pacific slope was estimated to be 1.1 km^3/year. A reduction in this volume has been reported in the valleys of Choluteca, Tegucigalpa and Comayagua due to extensive abstraction for irrigation (PNUMA 2001). In Costa Rica, the aquifer that supplies the city of San Jose is depleted (Lezama-López 2003). Irrigated agriculture withdraws enormous quantities of water in Costa Rica (Ballesteros 2003). The Grande de Tarcoles River basin's natural forest cover has reduced from 66 096 ha in 1992 to 38 384 ha in 2000; this may affect both the recharge rate and the water quality of the aquifers (Ballesteros 2003).

According to the UNESCO International Hydrological Programme (IHP), the total water abstracted in the sub-system increased by 2.1 km^3 between 1950 and 2000 and will increase to 2.9 km^3 in 2010. Water abstraction in 2010 will be nine times the rate of 1950, and rates are expected to increase by a further 21% by 2025. Illegal connections consume around 40% of the water available in the sub-system.

Pacific Colombian

No quantitative information was available concerning this issue but water is known to be highly abundant in Colombia with high aquifer recharge rates. Changes in the water table were therefore not considered to have any adverse environmental impacts. Although there is an inventory of the aquifers exploited in other parts of Colombia, it does not include the Pacific slope (IDEAM 2001).

Socio-economic impacts

Southwest Mexico

Water availability in Mexico has decreased from 31 000 m^3/person/year in 1910 to 10 000 m^3/person/year in 1970, and only 5 000 m^3/person/year in 2001. There is expected to be only 3 750 m^3/person/year by 2020 (SEMARNAT 2002). Mexico consumes more than 15% of its water resources annually, which is classified as moderate pressure (PNUMA 2000). Water demand has increased in parallel with population growth and economic development.

In 2000, Mexico had moderate sanitation coverage and freshwater supply (76% and 88% respectively) (SEMARNAT 2002). Between 1990 and 2000, progress in improving the coverage of basic services was variable amongst the states located in the Southwest Mexico sub-system. On average, only 68 l/person/day of the water supply is disinfected in Mexico which is posing health risks for a large proportion of the population, particularly in the southernmost states of the sub-system which contain mainly rural populations.

The overexploitation of aquifers is also of concern given that 70% of the freshwater supply is groundwater; 75 million people (55 million in cities and 20 million in rural communities) obtain their water supply from aquifers (SEMARNAT 2002). In future, it will be difficult to substantially increase water supply coverage as there is already enormous pressure on water resources in the Southwest Mexico sub-system.

Water conflicts have arisen in the past decade in Mexico. Sainz & Becera (2005) reviewed 3 800 cases of conflict related to water between 1990 and 2002. Most of these conflicts were concerning availability, tariff increases, infrastructure improvements or aquifer related issues. About 60% of these cases occurred in locations where aquifers are overabstracted.

Central Equatorial Pacific

Although the availability of water per person is adequate, only 78% of the population had access to drinking water services in 2000. The Pan-American Health Organization classifies the sub-system as level V – low-coverage level (OPS/OMS 2001a). The level of coverage has not increased at the same rate as population growth. In fact, the proportion of the population without adequate sanitation and freshwater services increases year by year. Poor water quality is posing health risks for the population. In some rural areas where freshwater services are often interrupted by technical failures there is higher prevalence of water-related diseases, especially diarrhoea.

The contamination of several freshwater sources in the Central Equatorial sub-system has increased the cost of treatment for drinking water. Pollutant concentrations in water bodies increase when river flows decrease during dry periods, increasing the risk of pathogenic diseases and the rates of morbidity and mortality. Acute diarrhoea is the main cause of infant mortality (children under five years old). In El Salvador, 12 000 children die annually due to water-borne diseases and annual cases of diarrhoea and parasitism increased from 150 000 to 220 000 over a 10-year period (Levin 2002).

The Pan-American Health Organization has demonstrated that access to water is directly related to poverty (OPS/OMS 2001b, 2001c), which is more severe in rural areas. The Indian population, artisanal fishermen and small farmers have particularly limited access to safe water and are vulnerable to water-borne diseases. In rural areas in El Salvador, 40% of the population (around 200 000 people in 1999) use water from natural sources. Poverty has increased as a result of water shortages, combined with unemployment and reductions in food availability. The resultant social insecurity has prompted migration from rural areas to cities.

The depletion and contamination of groundwater resources may impede economic development in the sub-system. If this trend continues, it is expected that by 2025 the sub-system will be developing under conditions of increasing water shortage.

Water availability *per capita* declined by 62% between the 1950s and the 1990s. Between 1995 and 2025, water availability is expected to decrease from 8 580 m^3/person to 1 780 m^3/person in El Salvador and from 33 810 m^3/person to 4 830 m^3/person in Guatemala (PNUD 2003). Agriculture will be one of the sectors most affected by water shortages because of the large amounts of water needed for export products. Extension of agricultural areas will further reduce water availability, particularly in El Salvador and Costa Rica (Pratt & Girot 1999). A large proportion of the workforce is employed in the agricultural sector, thus a decline in agricultural production due to decreased water availability will increase unemployment. In drought prone areas, poverty will increase resulting in social instability. Tourism, another large consumer of water, would also suffer as a result of water shortages. Tourism accounts for around 13% of the sub-system's gross product and the sector is expected to grow in the future (PNUMA 2001).

In the drought corridor, limited water availability and food insecurity have forced people to gather food from the forest. Over 20% obtain water from public or private wells. Small farmers do not own the land and pay for its use with part of their harvest, but during dry years, when harvests are reduced or lost, they struggle to pay the land owners. In the drought corridor the effects of reduced rainfall during the El Niño become most evident during the sowing and harvest seasons (May-August and September-November), affecting around 8.6 million people (WFP/FAO 2002).

Pacific Colombian

The most affected economic sectors include agriculture, industry and public services (energy and water supply). The sectors demanding the highest volumes of water are agriculture (48%), domestic use (36%) and industry (7%) (MMA 2002c). The economic implications of water shortages include (i) increased costs of extraction and (ii) increased costs of water treatment and pollution control. In the Valle del Cauca Department, for example, significant investment has been required to supply water to the agricultural sector. Water charges and retributive rates have been introduced in many areas to control water pollution (MMA 2002d).

According to DANE (2001), despite abundant water supplies on the coast of Colombia, technical and financial constraints as well as poor management are responsible for the low level of freshwater supply coverage, which has negatively impacted human health and the population's quality of life. The low level of coverage in rural areas is resulting in high rates of infant mortality and morbidity, the prevalence of gastroenteric diseases and the steady increase in cases of cholera (INDERENA 1992). The infant mortality rate is three times higher than the national average (IIAP 2001a). In 1997, the survey Life Quality by the National Department of Statistics (DANE) indicated that water coverage was less than 70% in the Pacific region, with 17% of the population supplied by communal aqueducts, 4% wells, 1% rainwater, 7% rivers and 1% by other sources.

The sanitation situation in the coastal municipalities is precarious in both coverage and quality. Freshwater supply and sanitation coverage in the largest villages is, at most, 48% and 10%, respectively. In Buenaventura and Tumaco, the major coastal cities in the sub-system, freshwater coverage is 35% and sanitation 7%, whereas in the highland cities (outside of the sub-system) of Bogota, Medellin and Cali, freshwater coverage is 85%, 91% and 94%, respectively. Freshwater coverage in rural areas is only 4% and sanitation is less than 1% (IIAP 2001a).

Conclusions and future outlook

Water resources are abundant but unevenly distributed in the region. There are areas with abundant water resources and others that suffer from shortages during the dry season. Areas deficient of water are generally the more densely populated and have the greatest concentration of economic activities. Aquifers are particularly overexploited. During extreme seasons, some areas of the region can experience catastrophic droughts, or floods associated with hurricanes that track across the Caribbean. The situation is exacerbated by inappropriate natural resource management practices, especially deforestation that affects erosion and run-off patterns in most river basins.

Population growth and economic development, such as agriculture, industry and tourism, will increase the future demand for water, thus increasing the extent and severity of water shortages. Groundwater abstraction is threatening aquifers and resulting in acute water shortages in several areas whose populations are dependent on groundwater. The use of groundwater will increase as the quality of surface water deteriorates due to population growth, deforestation, increasing food agriculture and longer drought periods. Freshwater supply coverage is particularly low in rural and minor urban settlements. The lack of wastewater treatment and the associated contamination of freshwater systems are reducing the availability of water for direct consumption, thus increasing water treatment costs. Human health impacts such as increased infant mortality and morbidity have been associated with the lack and poor quality of freshwater supplies. Rural populations are particularly affected as there are limited water and sanitation services and most water is obtained directly from natural sources.

IMPACT Pollution

Pollution may become critical if mitigation measures are not implemented in the short-term. Human activities are resulting in pollution entering the aquatic environment, particularly municipal wastewater, hydrocarbon spills and agricultural run-off. Although tides, currents and water exchange can disperse the organic matter contained in coastal water bodies, population growth and economic development is leading to increasing pollution loads which are resulting in adverse impacts on the marine environment. No sources of thermal pollution were reported in the region and is therefore not further discussed.

Microbiological

Southwest Mexico

Mexico is the major polluter in the GIWA Eastern Equatorial Pacific region, responsible for two-thirds of the region's total wastewater discharged into the Pacific Ocean (1.17 billion m^3/year) (PNUMA 2001). In 1999, the total volume of wastewater discharged by Mexico was 780 150 m^3, with a BOD load of 226 660 tonnes and COD load of 508 180 tonnes. Further, the projected population by 2020 will generate a volume of wastewater twice that of 1990.

The enormous amount of untreated wastewater entering the aquatic environment is deteriorating the environmental quality of the water bodies in the sub-system. According to PNUMA (2001), domestic wastewater is the primary land-based source of pollution in the coastal marine environment. Table 9 shows values of faecal coliforms reported in several major water bodies in the sub-system. Faecal coliforms in the Lerma and Balsas rivers have values that continue to exceed the levels permissible in Mexico (<10 000 MPN/l for water supply sources). In contrast, conditions in Lake Chapala improved considerably during the second half of the 1990s.

Table 9 Total coliform (MPN/100mL) in major water bodies of the sub-system during the period 1991-2001.

Water body	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Lerma River	2,000	4,700	2,800	4.3E4		1.3E4	6.8E4	1.4E6	1,000	4,017	4,076
Balsas River				1.8E4	1.5E4	9.8E4	1.2E6	5,008	500	3.6E4	6,133
Lake Chapala	4.4E5	5.3E7		18.5		48	24	26	46.8	5	4,625

(Source: CNA 2002)

Microbiological pollution on Mexican beaches has been identified as a priority issue by Mexican authorities due to the potential effects on human health and tourism. In 2002, the Ministries of Environment and Natural Resources (SEMARNAT), Health (SS) and the Navy (SEMAR) began conducting microbiological monitoring on beaches. This study showed that the most important tourist beaches located in the Southwest Mexico sub-system, such as Zihuatanejo, Acapulco, Bahía de Banderas, Puerto Angel and Puerto Escondido, were among the most polluted beaches in Mexico (SEMAR 2004).

A study carried out in Acapulco Bay over the period 1998-2000 shows that water quality decreases seasonally at the beginning of the rainy period in July due to increased run-off and tourism wastewater; maximum values of between 100 000 and 10 million MPN/l are recorded in July (Leal et al. 2000). During this study *Vibrio cholerae* and *Shigella* sp. were detected in several locations.

Central Equatorial Pacific

The main source of microbiological pollution is the discharge of untreated wastewater into the sewerage system or natural water bodies. The failure to appropriately dispose of excrement and the use of latrines and septic wells in porous soils is contributing significant loads of microbiological pollution. The total volume of wastewater discharged into the sub-system was 367 billion m^3 in 1999, with a BOD load of 104 630 tonnes and a COD load of 234 350 tonnes (Table 10). These total loads may be considered as minimum values and are likely to represent only around 20-22% of the total wastes discharged in the sub-system. The low levels of wastewater treatment in the sub-system (10.3% on average) results in around 95% of wastewater reaching the Pacific Ocean with a high load of organic matter, nutrients and microbial pollutants (PNUMA 2001). Table 11 shows the main coastal areas affected by pollution.

Table 10 Wastewater, solids and nutrient discharges in the Central Equatorial Pacific sub-system by country.

Country	Wastewater ($10^3 m^3$/year)	BOD (tonnes/ year)	COD (tonnes/ year)	Suspended solids (tonnes/year)	TDS (tonnes/ year)	N (tonnes/ year)	P (tonnes/ year)
Panama	166 010.8	45 898.1	102 644.7	48 600.4	82 192.5	7 431.1	900.7
Costa Rica	30 366.1	8 257.9	18 451.6	8 499.0	15 136.2	1 368.50	165.9
Nicaragua	45 501.0	14 275.7	32 123.3	18 136.0	21 272.3	1 923.20	233.1
El Salvador	49 589.8	14 353.8	32 175.3	16 344.6	24 075.8	2 176.70	263.8
Honduras	59 888.1	17 030.3	38 141.1	18 874.7	29 300.9	2 649.10	321.1
Guatemala	15 964.0	4 814.2	10 812.9	5 810.9	7 607.3	687.8	83.4
Total	**367 198.8**	**104 630.0**	**234 348.9**	**116 265.6**	**179 585**	**16 236.4**	**1968**

(Source: PNUMA 2001)

Significant discharges are introduced through the basins of the rivers Tárcoles, Tempisque and Barranca into the Gulf of Nicoya, Costa Rica (León in Ramírez & Espejel 2001). If the current population growth continues and the volumes of untreated discharges per head of population are maintained, the total volume of discharges will double in the next two decades. These discharges are directly responsible for the presence of pathogenic microorganisms, such as coliforms, on the beaches and in the coastal waters of Costa Rica, El Salvador, Nicaragua and Panama. No information was available about the contribution of livestock to the microbiological pollution of surface waters in the sub-system. However, its impact may be significant considering the importance of livestock production to the regional economy.

High concentrations of pathogenic micro-organisms associated with water pollution have been recorded in water bodies and on beaches of the sub-system, posing health risks for the population and affecting some economic activities. Concentrations of total coliforms between 80 and 16 000 MPN/ml and faecal coliforms between 0 and 160 MPN/l were recorded in Panama Bay between 1985 and 1987 (CPPS 2000). The highest values coincided with wastewater outfalls. In Puntarenas, Panama, concentrations of total coliforms between 160 and 200 million MPN/l and faecal coliforms between 20 and 92 million MPN/l were recently reported (Acuña et al. in Wo-Ching & Cordero 2001). All these concentrations exceed national and international standards (EPA 1983).

Several rivers including Torres, Maria Aguilar, Tiribi, Virilla, Segundo and tributaries of Grande de Tárcoles River have concentrations of total coliforms above 100 million MPN/l and the surface aquifers of Barva are unsafe due to high concentrations of coliforms (Ballesteros 2003). In El Salvador, several beaches and coastal areas, such as Jiquilisco, El Zapote and Don Diego, have concentrations of coliforms above national and international standards. In the El Zapote estuary (Barra de Santiago), Raquena & Miton (in Rubio 1994) found concentrations of faecal coliforms between 600 and 5 000 MPN/l and, in Zanjones, La Danta and Aguachapio, concentrations of between 3 000 and 240 000 MPN/l, and total coliforms of around 240 000 MPN/l.

During the 1990s around 60% of the sub-system's urban population was connected to the sewerage network and 51% used some type of *in situ* service. In contrast, the rural population was not served by a sewerage network and all sanitation solutions were *in situ*. By the end of the 1990s the sanitation coverage improved considerably, especially in Nicaragua and Guatemala, where it had increased up to 80% by 2000. During the same period, El Salvador and Honduras increased their level of coverage by only 8% (OPS/OMS 2001a), and Panama from

Table 11 Coastal areas affected by pollution in the Central Equatorial Pacific sub-system.

Country	Severe	Severe/Moderate	Moderate	Slight
Costa Rica	▪ *Grande de Tarcoles Barranca Basin* ▪ *Gulf of Nicoya* Wastewater, Solid wastes, Sedimentation, Agrochemical	▪ *Puntarenas Estuary* Wastewater, Solid wastes, Sedimentation, Habitat modification	▪ *Moín* ▪ *Limón* ▪ *Puerto Caldera* Wastewater, Agrochemicals, Oil	▪ *Golfito* ▪ *Agua Dulce*
El Salvador	▪ *Estero Jaltepeque* ▪ *Lempa River basin, Sampuyo, Jalponga etc.* Wastewater, Solid wastes, Sedimentation, Agrochemical, Heavy metals	▪ *Bahía Jiquilisco* ▪ *Bahía La Unión* ▪ *Acajutla* Agrochemical, Heavy metals Wastewater, Oil		
Guatemala			▪ *Puerto Quetzal* ▪ *Champerico* Wastewater Oils, Solid wastes	
Honduras	▪ *Gulf of Fonseca* Agrochemicals, Nutrients, Aquaculture wastes		▪ *Amapala* ▪ *Cedeño* ▪ *San Lorenzo* Wastewater, Solid wastes, Oil	
Nicaragua	▪ *Real Estuary* ▪ *Volcano-Pacific basin* ▪ *Negro River* Wastewater, Solid wastes, Pesticides, Sedimentation, Deforestation	▪ *Corinto* ▪ *Atoya-Sucio River (El Viejo-Chinandega- North Pacific)* ▪ *Chiquito River (Leon-South Pacific)* ▪ *Jesús Quisala River (San Rafael, Managua-South Pacific)* ▪ *Grande Carazo River (Jinotepe, Carazo-South Pacific)* Wastewater, Solid wastes, Pesticides, Sedimentation, Nutrients	▪ *Central zone, rivers* ▪ *Jesús-Quizada* Wastewater, Nutrients, Solid wastes	
Panama	▪ *Panama Bay (inner area)* Wastewater, Solid wastes, Pesticides, Eutrophication, Oil, Heavy metals	▪ *Vacamonte* Solid wastes, Oil	▪ *Gulf of Chiriqui* ▪ *Charco Azul* Sedimentation, Pesticides, Oil	▪ *Agua Dulce* Nutrients, Oil

(Source: PNUMA 2001)

84% to 93%. The situation of Costa Rica was different; during the early 1990s the coverage was 97% but a decade later it had decreased to 94%. Despite this, Costa Rica continues to have the highest level of sanitation coverage in the sub-system. According to OPS/OMS (2001a), the treatment of industrial effluents is very low, 1-4% for most countries though 34% in Nicaragua.

Pacific Colombian

A total of 87 200 m^3/day of untreated wastewater is discharged into the coastal waters of the Colombian Pacific, with a biological degradable organic (BDO) charge equivalent to 16.5 tonnes/day (Garay et al. 2002). Most of this load (91.5%) is produced in the Valle del Cauca and Nariño Departments, especially by the urban centres of Buenaventura and Tumaco. Microbiological pollution has continued to exceed permissible limits in the waters of both these cities. Table 12 shows the concentrations of coliforms in the cities in the late 1980s. In 2002, most of the monitored beaches located in the Nariño, Valle del Cauca and Choco Departments surpassed the Colombian Permissible Limit (2 000 MPN/l), especially during the rainy season (Vélez et al. 2003).

Table 12 Total and faecal coliforms at Tumaco and Buenaventura.

Year	Tumaco				Buenaventura			
	Total coliforms (MPN/100 mL)		Faecal coliforms (MPN/100 mL)		Total coliforms (MPN/100 mL)		Faecal coliforms (MPN/100 mL)	
	Min	Max	Min	Max	Min	Max	Min	Max
1986	91	11 000	36	11 000	40	11 000	200	4 600
1987	36	11 000	18	11 000	44	15 000	21	2 300
1988	17	43 000	20	3 300	210	110 000	93	46 000
1989	12	90 000	22	27 000	13	4 600	13	4 600
1990	33	66 000	19	22 000	80	9 200	79	5 400

(Source: CPPS 2000)

Eutrophication

Southwest Mexico

Wastewater discharges and agricultural run-off are the main sources of nutrient enrichment in the aquatic environment of the Southwest Mexico sub-system. Domestic discharges were estimated to introduce a total of 34 200 tonnes of nitrogen and 4 150 tonnes of phosphorus every year into the Pacific Ocean (PNUMA 2001). The major source of nutrient enrichment in the coastal environment, however, is from agricultural run-off. In Mexico, fertiliser application increased from 2.87 million tonnes in 1980 to 3.93 million tonnes in 2000 and use per hectare increased over the same period from 110 kg/ha to 160 kg/ha (Espinoza 2002). Contreras et al. (1995) analysed the water of 39 coastal lagoons in Mexico, 20 of which are located in the Southwest Mexico sub-system. They concluded that most of these water bodies are in a permanent state of eutrophication. Some lagoons contained high concentrations of nitrites and nitrates, whereas others in the states of Oaxaca and Chiapas showed high concentrations of phosphorus. In Lake Chapala, high levels of phosphorus (80 times higher than permitted by international standards) and the proliferation of algae and invasive aquatic weeds were clear indicators of eutrophication (Living Lakes 2005).

Central Equatorial Pacific

Nitrates and phosphates contained in municipal wastewater and agricultural run-off are responsible for eutrophication in the rivers and coastal areas of the sub-system. Farmers in the sub-system use large quantities of fertiliser, with consumption having increased from 76 kg/ha in 1990 to 131 kg/ha in 2000. Deforestation exacerbates the problem by causing soils enriched with nitrogen to be washed out.

Agriculture, livestock and wastewater run-off pollutes the Grande de Tarcoles River basin and severely affects the waters of the Gulf of Nicoya and the mid-Pacific coast. The basin contributes 61% of the nitrogen and 31% of the phosphorus that is discharged into the Gulf (Díaz & Fernández 1994). In total, the Gulf receives 300 tonnes/year of phosphorous and 2 000 tonnes/year of nitrogen from the Grande de Tárcoles and Barranca river basins (Table 13) (León in Ramírez & Espejel 2001). In Panama Bay, at the outlets of the rivers Curundú, Matías Hernández, Juan Díaz, Matasnillo, Abajo and Tapia, there are high values of nitrates, phosphates and chlorophyll-a. These rivers receive wastewater from Panama City (Álvarez et al. 1989). High nutrient concentrations have also been reported at Puerto Corinto, El Realejo, Estero Chocolate, La Esparta and El Real in Nicaragua (Sánchez 2001). The total charges of nitrogen and phosphorus from coastal settlements are around 16 270 tonnes/year and 1 970 tonnes/year, respectively.

Harmful Algal Blooms (HABs) produced by algae of the genus *Anabaena* and *Oscillatoria* have been associated with eutrophication processes in Jiquilisco Bay and at Puerto Triunfo in El Salvador (Rubio et al. 2001).

Table 13 Concentrations of nutrients in the Gulf of Nicoya.

Site	O_2mg/l	$Si(OH)_2$uM	PO_4uM	NO_2-NO_3uM	Secchi (m)
Gulf upper part Gulf lower part	5.3-8.6 7.5-8.7	5.7-14.3 1.7-35.9	0.15-2.64 0.04-0.81	0.2-25.7 0.0-12.6	0.2-1.6 1.9-17.6
Tarcoles River	5.8	17.3	3.20	16.80	-
Barranca River	6.7	128.0	0.71	12.0	-
Tempisque River	5.4	13.3	0.71	14.6	-

(Source: Wo-Ching and Cordero 2001)

Pacific Colombian

Besides the nutrients contained in wastewater, agricultural run-off is contributing to the nutrient enrichment of the coastal marine environment. Colombia has the highest rate of fertiliser consumption (81 kg/ha) on the Pacific coast of South America (CPPS 2000). The total consumption of fertilisers in Colombia reached 556 000 tonnes in 1997. Some areas, such as water bodies near Tumaco and Buenaventura, have eutrophic conditions (Escobar 2001).

Chemical

Southwest Mexico

Mexico uses more pesticides than any other country in the GIWA Eastern Equatorial Pacific region. Between 1974-1977 and 1982-1984, average annual pesticide use increased by 44%, from 19 148 tonnes to 27 630 tonnes per year. DDT has been regularly used in Mexico since the 1950s to combat malaria. Around 70 million tonnes of DDT has been used in the country but the number of doses applied per year has decreased considerably from 5.7 million in the period 1957-1960 to 829 000 in the 1980's (ISAT 2001). Residuals of DDT have been found in humans (maternal milk, fatty tissue and blood, 0.9-17 mg/kg), soil (50-83 mg/kg), sediments (1.8-27 µg/kg), food (milk 85-159 µg/kg and butter 49 µg/kg), cattle (0.21-1.9 mg/kg) and in aquatic species such as shrimp and oysters (0.056-9.2 ng/g) and fish (38 ng/g) (ISAT 2001).

Heavy metal contamination is particularly high in the Lerma River basin. It is estimated that petrochemical, metallurgic, textile and automotive industries located in the central states of Queretaro and Guanajuato discharge more than 12 400 g of chromium and more than 4 300 g of zinc daily into the waters of the basin (SEMARNAT 2004). The Chapala Lake is highly polluted with heavy metals (e.g. cyanide, chromium, leads and mercury), causing toxicological induced mutations in some fish species (Living Lakes 2005). Concentrations of heavy metals in most Mexican water bodies, sediments and organisms (molluscs, crustaceans, fish and mammals) are relatively low, although moderate concentrations have been found in parts of the northeast Pacific (Páez 1999).

Central Equatorial Pacific

Agricultural run-off is the main source of chemical pollution, caused by the widespread use of pesticides in agriculture, especially for export production. Pesticide application (2 kg/person) is one of the highest in Latin America (Tribunal Centroamericano del Agua 2004). Large amounts are used in the production of export crops such as rice, bananas and sugar cane. According to Álvarez & Manelia (1996), polychlorinated biphenyls (PCBs), mirex, lindano and heptacloro are discharged by the Bayano River into Panama Bay. In El Salvador, the Jaltepeque estuary and Jiquilisco Bay receive waters heavily contaminated with pesticides from the rivers Lempa, Grande de San Miguel, Sapuyo, Jalponga, Huiscoyolapa, Amayo, Requinte and El Molino (Rubio et al. 2001). In Costa Rica, rivers carrying pesticides to the Gulf of Nicoya include Tempisque, Grande de Tárcoles and Barranca (Wo-Ching & Cordero 2001, León in Ramírez & Espejel 2001). An estimated 250 000 m^3 of liquid residuals are deposited daily in the Virilla River (Grande de Tárcoles upper basin) which take only 24 hours to reach the Gulf of Nicoya (León in Ramírez & Espejel 2001).

High concentrations of pesticides have been found in coastal waters, sediments and biota, posing risks for humans and other living organisms. Cedeño (1995) reported DDT concentrations of 12 ng/g in surface sediments, 5 200 ng/g in the tissue of clams at Peñitas-El Toro (Nicaragua) and 450 ng/g in the tissue of black clams (*Anadara* spp.) in the El Realejo estuary. Pesticides in fish, crustacean and mollusc tissue were reported at Jiquilisco Bay, El Salvador (Rubio et al. 2001), and Panama Bay (Alvarez et al. 1989, Alvarez & Manelia 1996) (Tables 14 and 15). The concentrations of DDTs in black clams indicate high pollution levels and those in surface sediments exceed international standards (FDA 1993).

Heavy metals from mining washes and industries, which are introduced directly into natural water bodies of the sub-system, are also present at these sites. Mining activity is artisanal and carried out far away from coastal areas; run-off from these activities enters surface waters. Examples include discharges of cyanide and mercury from gold extraction (PNUMA 2001). Six mining accidents occurred in Panama between 1995 and 2000 causing cyanide spills. In Nicaragua, around 124 kg of mercury is released annually from artisanal mining with unknown effects on coastal waters.

Table 14 Concentrations of pesticides in the tissue of several species in Jiquilisco Bay, El Salvador.

Common/scientific name	DDT	Endrin	Dieldrin	Etil Parathion
Bass (*Cynoscion* sp)	2.33	0.16	0.04	0.00
Mullet (*Mugil* ssp)	1.86	0.27	0.05	0.00
Grunt (*Pomadasys* sp)	1.79	0.07	0.52	0.00
Shrimp (*Penaeus* sp)	0.65	0.00	0.00	0.00
Black clam (*Anadara* sp)	0.75	0.05	0.03	0.00
Mussela (*Mytella* sp)	0.62	0.03	0.02	0.01
Starfish (*Oreaste* sp)	0.35	0.06	0.02	0.00

(Source: Cedeño 1995)

Table 15 Concentrations of pesticides found in some marine species in Panama Bay.

Common/scientific name	Pesticide	Concentration (ppb)
Pompano (*Vomer declivifrons*)	PDC-1260	0.62
Red snapper (*Lutjanus guttatus*)	B-BHC p-pDDE Mirex	8.60 32.8 166.0
Silver drum (*Larimus argenteus*)	B-BHC Lindano Mirex	2.156.9 2.318.0 2.516.0
Green Jack (*Caranx caballus*)	Lindano PpDDE	16.0 28.0
Catfish (*Arius* ssp)	B-BHC p-pDDE	760.3 103.5
Lobster (*Panulirus gracilis*)	B-BHC	169.0
Scallop (*Arquipecten circularis*)	B-BHC	213.1

(Source: Álvarez et al. 1989, Álvarez & Manelia 1996)

Heavy metals such as lead, copper and chromium have been reported in sediments and surface waters in several countries in the sub-system, notably Panama, Nicaragua and Costa Rica (Table 16). Concentrations of <1.0 ppb of mercury and 4-38 mg/l of copper were found in Panama. These mercury concentrations are not significant (EPA 2005), but those of copper exceed national standards and pose a risk to aquatic organisms. High levels of cadmium and copper have been found in three areas of Nicaragua: El Sitio, Pasacaballos and Puerto Corinto (Cedeño 1995, Sánchez 2001). Totals of 400 tonnes of copper, 130 tonnes of nickel, 86 tonnes of lead, 600 tonnes of zinc and 75 tonnes of chromium are discharged annually into the Gulf of Nicoya, Costa Rica (León in Ramírez & Espejel 2001).

Table 16 Concentrations of heavy metals found in sediments in several areas of the Central Equatorial Pacific sub-system.

Country/site	Lead (ug/g)			Copper (ug/g)	Chromium (ug/g)	
	1981-1996	1985	1998	1986	1981-1996	1998
Panama						
Panama Bay		20-204		27-110 000		
Costa Rica						
Gulf of Nicoya	5.4-83.6			0.13	862.7	
Nicaragua						
El Sitio			13.87	2.42		10.96
Pasacaballo			13.96	2.73		12.52
Corinto			16.9	3.13		11.73

(Source: Alvarez et al. 1989, Sánchez 2001, Wo-Ching & Cordero 2001)

Industrial discharges of chemical substances are poorly documented in the region. Most available information is related to the presence of inorganic chemicals in organic matter. This was discussed in the section on microbiological pollution. Other chemicals are discharged in small proportions within wastewater.

Pacific Colombian

Around 33 000 tonnes/year of 600 different pesticides are used in Colombia, including organophosphate, organochloride, carbonates and piretrins (Garay et al. 2001). They are used mainly in rice and potato production, but also on banana and sugar cane plantations. On the Pacific coast, agriculture is mainly carried out in the Choco and Valle del Cauca Departments. Variable concentrations of pesticides have been found in water, sediment and organisms at different sites in Colombia. Concentrations of DDTs in surface sediments exceed international and national standards, ranging between 2.2 and 66.7 ng/g (average of 12.4 ng/g). The highest concentrations of pesticides, especially heptachlor and aldrin, were found at Tumaco and Pindo. Despite relatively limited agricultural development on the Pacific coast of Colombia, pesticides found in coastal areas may originate from their use in anti-malaria campaigns, the fumigation of illegal drug crops, and from substances used in wood treatment (Vélez et al. 2003). The impact of these pesticides on the local biota is unknown. The long-term effects on the sub-system's ecosystems from the increasing use of pesticides and gliphosphate to combat illegal drug cultures in Colombia are also unknown.

Heavy metals such as mercury, copper, lead, cadmium, chromium and zinc have also been found in water, sediments and marine biota in Colombia (CPPS 2001). Concentrations of cadmium of between 0.39 and 10.6 mg/kg were found in sediments at Buenaventura. These exceed international standards and Canadian guidelines for sediment quality and the protection of aquatic life. Other heavy metals found in high concentrations in sediments include lead and mercury (CPPS 2001).

Suspended solids

Southwest Mexico

In Mexico, 259 540 tonnes of suspended solids and 378 130 tonnes of total dissolved solids (TDSs) were discharged in wastewater in 2000 (PNUMA 2001). Most suspended solids found in aquatic systems originate from increased erosion caused by a range of anthropogenic activities, particularly deforestation. Approximately 60% of Mexico (about 120 million ha) is affected by either severe or extremely severe soil degradation. Water and aeolian erosion severely affects about 30% and 43% of the country, respectively (CONAZA 1994, INEGI 1998). As a consequence, the water bodies of the sub-system carry large amounts of suspended solids, leading to severe sedimentation in lakes and coastal wetlands. For example, Lake Chapala has received 78 million m^3 of sediment between 1930 and 1977 from the Lerma River, reducing its storage capacity by 2.5 million m^3/year (SEMARNAT 2004).

Central Equatorial Pacific

Municipal wastewater and run-off from catchment areas are the main sources of suspended solids in rivers and coastal waters. In 1999, coastal settlements produced 116 270 tonnes of suspended solids and 179 590 tonnes of TDS (PNUMA 2001). Erosion due to deforestation and poor agricultural practices is resulting in unknown quantities of sediment entering aquatic systems. The deforestation rate is almost 400 000 ha/year, making it one of the highest in the world (Tribunal Centroamericano del Agua 2004). Pratt & Girot (1999) noted that erosion affects the soils of over 25% of the sub-system's area. Consequently, most of the rivers transport large amounts of sediment to the lower reaches of the basin and the sea. In Panama, 25% of the eroded soil is estimated to settle in lakes Gatún and Alajuela (Franco 2001), which have, as a consequence, lost 8% and 6% respectively of their useful storage capacity. The flow rates and capacities of some of the rivers in the sub-system, such as Choluteca, Lempa and Motagua, have also been reduced. In Costa Rica and Nicaragua, the processing of coffee also contributes sediments to water bodies. Coastal industries discharge effluents containing high concentrations of BOD, suspended solids, oils and nutrients (PNUMA 2001).

Rivers discharging into the Gulf of Fonseca deposit 3 million m^3 of sediment every year, resulting in a loss of benthic communities (CCAD/IUCN 1999a). Sánchez (2001) and Rubio et al. (2001) reported high rates of sedimentation along the Pacific coast of Nicaragua and in some coastal areas of El Salvador where most of the 148 million tonnes of soil eroded from agricultural land in the 1990s entered the Gulf of Fonseca (Sánchez 2001). In El Salvador, the rivers Paz, Sansonate, Lempa and Grande de San Miguel carry large amounts of suspended solids (Rubio 1994, Rubio et al. 2001). In Panama between 1970 and 1987, soil erosion increased by 60%, severely affecting aquatic ecosystems. Between 1981 and 1994, the Panama Canal basin received large quantities of sediment from the rivers Boquerón (870 tonnes/km^2/year), Pequeni (664 tonnes/km^2/year) and Gatún (293 tonnes/km^2/year) (Heackadon et al. 1999).

The accumulation of sediments in the lower sections of the river basins is impacting communities and ecosystems. In the Gulf of Fonseca, aquatic ecosystems have been smothered by sediments resulting in a loss of biodiversity. Sedimentation has impeded access to some port facilities (CCAD/IUCN 1999a); and it is affecting 35% of the coastal and marine protected areas, with coastal wetlands being especially vulnerable (PNUMA 2001). Further, the growth of some coral reefs in Costa Rica is inhibited by sedimentation (PNUMA/IUCN 1998).

Pacific Colombian

Due to the short distance between the mountains and the sea in the Pacific Colombian sub-system, rivers contain a high load of sediments and other suspended materials. Extensive deforestation has exacerbated erosion, increasing further the sediments entering the rivers (Restrepo & Kjerve 2000, IDEAM 2002). The increased concentrations of sediments in river discharges are especially evident along the coast of the Valle del Cauca Department (INVEMAR 2003b). Further, coastal settlements discharge wastewater containing approximately 10.7 tonnes of suspended solids every day (Garay et al. 2001).

Solid wastes

Southwest Mexico

An estimated 15.3 million tonnes of solid waste is produced in the Southwest Mexico sub-system every year; 6.75 million tonnes/year of which originates from coastal settlements (PNUMA 2001). Mexico generates over half the solid wastes in the GIWA Eastern Equatorial Pacific region. In Mexico, the collection services cover 49% of cities with more than 100 000 inhabitants. Most solid wastes reaching the coasts of Mexico include organic matter of urban, agricultural and industrial origin, which after oxidative processes become inorganic stable compounds and can increase microbiological pollution (Páez 1999). In 2002, the Ministry of Navy (SEMAR) collected 58 000 tonnes of solid waste from Mexican beaches.

Central Equatorial Pacific

The sub-system generates around 32 300 tonnes/day of solid waste (Acurio et al. 1997). There is a lack of statistics on the coverage of collection services, except for in the urban areas of Costa Rica (66%), Honduras (20%) and Guatemala (47%) where the services are concentrated. Overall, the level of coverage is believed to be low. Most solid waste is disposed of inappropriately, some dumped directly into water bodies. Wastes are not separated except, in some countries, hospital wastes. Consequently, solid wastes accumulate in the outlets of rivers such as Volcano-Pacific in Nicaragua, Virilla-Grande de Tárcoles in Costa Rica (Wo-Ching & Cordero 2001), and the rivers discharging into Panama Bay. In El Salvador, wastes are disposed of in open areas without treatment, often obstructing port activities (Rubio et al. 2001).

There are several environmental impacts caused by solid wastes, including increased BOD loads resulting from contained organic matter. In sites receiving solid wastes, soils may become acidic and leachates can contaminate aquifers. Improperly disposed solid wastes also provide breeding environments for vermin, which may become disease vectors. Debris can also harm wildlife through ingestion or entanglement.

Pacific Colombian

The unplanned development of urban centres in the Pacific Colombian sub-system has resulted in wastes being inappropriately disposed. As a consequence, waste accumulates on beaches. In 1996, 320 tonnes/day of solid waste was produced by communities along the Pacific coast of Colombia (CPPS 2000). Buenaventura generated 250 tonnes/day (78% of the total), 180 tonnes of which were collected and 70 tonnes were disposed of in open dumps. In Tumaco, only 40% (70 tonnes/day) of its solid waste is collected. Another major source of solid waste is the timber industry which generates around 570 000 m^3/year (CPPS 2000).

Radionuclides

There are no reports of radionuclide pollution in the region. However, there is a potential risk of nuclear pollution from the transport of radioactive material through the Panama Canal (Gibbs in Escobar 2000). It is estimated that 10 vessels per month carry radioactive loads through the Canal, each holding 12-14 containers with 30-60 tonnes of nuclear material. Most radioactive materials include ^{132}I, ^{3}H, material for industrial purposes and non-destructive trials (^{192}Ir, ^{60}Co), as well as non-irradiated fuel (a mixture of plutonium oxide or enriched uranium). In general, loads passing through the Panama Canal are classified as 'type B' or as having a 'mid to high level of activity'. The material most frequently transported through the Canal is depleted uranium hexafluoride (UF_6), the transportation of which is strictly controlled.

Radionuclides of natural and anthropogenic origin (^{40}K and ^{137}C) were found in the Gulf of Nicoya, Costa Rica, with concentrations exceeding international averages in the case of ^{40}K (Loria et al. 2002). The source of this isotope could be agricultural activities along the Grande de Tárcoles River, whereas the presence of ^{137}C is associated with nuclear tests conducted elsewhere.

Spills

Southwest Mexico

The majority of oil spills are caused by operational failures in ports, during the shipment of oil and gasoline, and by pipeline damage. Minor contamination is caused by oils and other hydrocarbons entering the sewerage system and then being discharged in coastal areas. These residuals can originate from burned oil from cars, the maintenance of vessels in dry docks, and motors used by industry. Polycyclic aromatic hydrocarbons are found in the sediments and coastal areas surrounding the port of Salina Cruz (Oaxaca State in southern Mexico) where one of the most significant petrochemical industries is located (Botello et al. 1998).

Central Equatorial Pacific

Most oil spills in the sub-system occur in ports and at storage sites. The 1 900 vessels/year transiting the Panama Canal introduce approximately 200 tonnes of oil per year into the bay (Kiewcinsky 1986). Additionally, spills totalling 384 m^3 were reported in the ports Balboa, Cristóbal and Vacamonte in 1999. Most discharges were of diesel, bunker or cesspool residuals (PNUMA 2001). The trans-isthmus oil pipeline is another potential source of oil pollution (PNUMA 1999). In Charco Azul, Gulf of Chiriqui, spills of up to 800 m^3 were reported in 1978 (CPPS 2000). In other areas of the sub-system, oil spills total 600 m^3/year. Spills total 28 m^3/year in Guatemala and El Salvador, and 32 m^3/year in Honduras. Around 40-60% of the total spills are caused by the fishing fleet (Escobar 2003), whereas spills resulting from shipping accidents are uncommon and of low impact.

Pacific Colombian

Several minor spills that occurred in 1976 and 1998 in Ecuador affected the Colombian coasts of Nariño and Valle del Cauca, including Gorgona Island and Tumaco (MMA 2002b). Exploitation, refining and transport activities have resulted in chronic pollution, particularly around Tumaco

(Vélez 2003). In the late 1990s, the average hydrocarbon concentrations were recorded as 25 µg/l in coastal waters, 1.18 µg/g in sediments and 7.45 µg/g in mollusc bivalves (Garay et al. 2002). Between 1986 and 1999, there were 654 acts of sabotage to the Colombian oil pipeline, which caused the spillage of 336 420 m^3 of oil into the environment, resulting in remediation costs of 37.7 million USD (Vélez 2003).

Socio-economic impacts

Southwest Mexico

In Mexico, 74.5% of the population had access to sanitation services in the form of a sewerage system (58.4%) or *in situ* solutions (14.1%) in 2000 (OPS/OMS 2001a). This means that a total of 26.4 million inhabitants dispose their wastewater and excreta inappropriately. The proportion of the population with sanitation services or *in situ* solutions in Mexico is lower than the average for the LAC (79.2% and 30.6% respectively) (OPS/OMS 2001a).

The economic impact of water pollution in Mexico has not been fully examined. Qualitative evidence suggests that tourists are discouraged from visiting polluted areas and are selecting alternative tourism destinations (Muñoz-Pineda pers. comm.). Coastal water pollution negatively affects diving and other forms of tourism, as well as the commercial fisheries, as it is degrading aquatic ecosystems, particularly coral reefs and their associated living resources (Coral Reef Alliance 2003).

In Mexico, microbiological pollution in coastal waters poses health risks for bathers as exposure can result in disease, including gastroenteritis, acute febrile respiratory illness and hepatitis. Children, the elderly and individuals with weak immune systems are particularly vulnerable; even with treatment some of these diseases can be fatal (Hancock & Gilmore 2004).

Digestive tract diseases related to the consumption of contaminated water or shellfish include acute gastroenteritis, typhoid fever, hepatitis A and cholera. Nasal and pharyngeal diseases are also associated with poor water quality. Gastroenteritis is the most common disease affecting children, the poor and other vulnerable groups (CPPS 2001, UNEP 2000). In general, gastrointestinal disorders are the main cause of infant mortality.

Eutrophication may increase the frequency of HABs in Mexican Pacific waters. Toxic HABs were reported in Mazatlan in 1979 and Oaxaca-Chiapas in 1989 (Cortés et al. 1993). More than 300 cases of paralytic shellfish poisoning (PSP) have occurred in Mexico with 17 mortalities. Closed seasons during the HAB events have resulted in economic losses of 200 million USD to the fisheries industry (Schoijet 2002).

Central Equatorial Pacific

Untreated domestic and industrial wastewaters are major sources of pollution in the sub-system and a significant cause of enteric diseases. As many as 12 diseases produced by pathogenic micro-organisms are linked to polluted waters. They affect mainly the vulnerable groups of the population, especially children (PNUMA 2001). Acute diarrheic disease (ADD) is the main cause of infant mortality (children under five years old). In the past 30 years, 5 million children died from this disease, although the mortality rate has decreased significantly in recent years (Tribunal Centroamericano del Agua 2004). ADD and other water-related diseases are still the main cause of the high rates of morbidity and mortality in the sub-system. The current infant mortality rate is 36‰, decreasing to a quarter of the rate in 1970 when it was 135‰. In the case of Costa Rica, which has the highest living standards in the sub-system, it was 16‰ in 1998. In Nicaragua, which has the lowest per capita income, the rate decreased from 165‰ in 1970 to 48 ‰ in 1998. Despite this progress, infant mortality rates remain comparably high, even in Costa Rica (Ballesteros 2003).

Cholera is another disease affecting the population of the sub-system. During the 1990s, the Pan-American Health Organization recorded 254 077 cases of cholera. Countries with the most cases are Guatemala, 33.9%; Nicaragua, 12.8%; and El Salvador, 12%. A total of 27 412 cases of dengue fever were reported in 2001, of which 991 were hemorrhagic dengue fever which killed 28 people (OPS/OMS 2004). Because sanitation coverage is not increasing in line with population growth, the prevalence of diseases will increase.

The economic costs of environmental degradation caused by pollution in the sub-system have not been sufficiently researched. The total cost of pollution in the Gulf of Nicoya, Costa Rica, has been estimated at 203 million USD per year (Castro et al. 2000). These costs include the treatment of wastewater and solid wastes of domestic and industrial origin and the loss of revenues by productive activities such as tourism, fishing and farming. Every year between 1 000 and 2 000 persons in Central America are poisoned by pesticides; the associated medical costs are between 32 and 92 USD per person, depending on the type of toxin (García 1998). Litter accumulation has reduced the aesthetic value of coastal sites, thus affecting tourism and posing a permanent risk for fishing and maritime traffic.

Pacific Colombian

The impact of pollution on human health in the Pacific Colombian sub-system is considered as moderate to severe. Several private enterprises that provide freshwater and sanitation services in the Valle del Cauca Department have been charged retributive fees (pollution tax). Recently, the government institution Corporación Autónoma Regional del Valle del Cauca began legal proceedings against four of the five enterprises operating in this department because they have failed to pay the retributive fees since 1997. The fees are owed for the discharge of 68 700 kg/day of pollutants into water bodies in the Cauca River basin (El País 2004).

In terms of morbidity, the low sanitation coverage seriously affects the health of the population. Between 5 and 10% of deaths are related to the lack of sewerage services, the inappropriate disposal of wastes and poor freshwater quality. About 50 000 people die annually from water related disease in Colombia. The two major causes of infant mortality are gastroenteric diseases and malnutrition, which also increase the vulnerability of children to other infectious diseases (INDERENA 1992). The population in the Pacific region of Colombia has the highest risk of infant morbidity and mortality (Yepes 1990). The infant mortality in the Choco Department is 150‰, which is three times the national average, and the life expectancy is 12 years lower than in Cali City (INDERENA 1992).

Conclusions and future outlook

Wastewater discharged without treatment through the sewerage network or directly into water bodies is the most widespread pollution issue. There is a low level of sanitation coverage in most of the countries in the Eastern Equatorial Pacific region. In general, the coverage of sanitation and drinking water services has not grown in line with population growth and urban development. As a consequence, water-related diseases are increasingly prevalent with acute diarrheic disease the main cause of morbidity and infant mortality. Poorer communities, children and the elderly are the most vulnerable groups.

Pesticides and fertilisers are used intensively in agriculture. They are responsible, in combination with domestic wastewater, for causing eutrophication and toxic pollution in coastal areas which is impacting marine ecosystems and thus the food security of the coastal population. Although there is a dearth of information regarding the effects of pollutants in the coastal zone of the region, it is expected that pesticides, heavy metals and other pollutants are accumulating in coastal areas and are impacting marine biota. Pollution has a direct impact on human health as a result of deficiencies in freshwater supply, sanitation and wastes collection services. Pollution is threatening economic development, particularly tourism.

IMPACT Habitat and community modification

Habitat and community modification is being caused by a range of human activities including deforestation, fishing, tourism and aquaculture. Lakes, rivers, mangroves, benthic ecosystems and coral reefs have been degraded, but no quantitative data is available. Data related to the loss of native species or changes in community structure caused by alien species is similarly unavailable.

Habitat and community modification was assessed for the Central Equatorial Pacific and Pacific Colombian sub-systems.

Loss of ecosystems

Central Equatorial Pacific

Aquatic ecosystems and habitats are severely affected by sedimentation, particularly corals reefs at Punto Islotes and Agua Dulce in Costa Rica, as well as some shallow water coral reefs at Baru and Chiriqui in Panama. At Iguana Island (Panama) around 80% of the coral reef has been destroyed by oil spills, whereas the coral reefs at Coiba and in the Gulf of Chiriquí have been partly destroyed by trawlers (Escobar 1996). During the warm phase of the El Niño events in 1982-1983 and 1997-1998, widespread coral bleaching occurred in Panama (PNUMA 2001).

Wetlands and mangroves are impacted by solid wastes, such as in the Volcano-Pacific basin in Nicaragua, La Unión Bay in the Gulf of Fonseca and in the lower sections of the river basins of Matasnillo, Tapias, Juan Díaz, Río Abajo, Chilibre and Chilibrillo in the Gulf of Panama. An estimated 98% of estuaries in the sub-system are affected by sedimentation, wastewater and agro-chemicals (PNUMA 2001).

Mangrove forests have been used for several purposes, including aquaculture, agriculture, urbanisation, firewood, construction and to obtain salts and tannins. In the Gulf of Fonseca, mangrove forests have been cleared for shrimp ponds, and salt and tannin production. In 1993, 89 200 m^3 of firewood from mangrove forests was used for salt extraction (1 tonnes of salt requires 3.5 tonnes of wood). The extent of the mangrove area has been reduced from 104 911 ha in 1976 to 69 109 ha in 1997, while the shrimp farming area has increased from 8 000 ha in the 1980s to 29 370 ha in 1997 (CCAD/IUCN 1999a). By 1994, Honduras had lost around 12% of its mangrove forest due to aquaculture (Figure 17). Prior to the 1960s, there were 500 000 ha of mangrove in the central provinces of Herrera, Los Santos and part of Cocle (Panama), but by 1988 only 176 000 ha remained. In a 30-year period, 5 647 ha of mangrove forest were cleared for agricultural purposes in Soná, 1 345 ha in Veraguas province and 2 157 ha in Chiriqui (López et al. 1996). The consequences of mangrove destruction include increases in coastal erosion, higher penetration of the saline wedge in some estuaries, soil salinisation and, in particular, a decrease in biological productivity which directly impacts the artisanal fishery (PNUMA 2001).

Pacific Colombian

Mangrove and alluvial forests are the most affected ecosystems. Between 1980 and 1990, agriculture expanded by 108 623 ha at the expense of forests, while at the same time, the Andean forests were reduced by 23 302 ha. Mangrove forests are unsustainably exploited as they are valuable resources for humans (República de Colombia et al. 2002). Mangroves have been destroyed mainly to build aquaculture infrastructure (Conservación Internacional 2004), but also due to logging, in-filling, construction, the accumulation of wastes and wastewater contamination, among other threats (Table 17) (MMA 2002b).

Table 17 Main activities affecting mangrove forests in the Pacific Colombian sub-system.

Activities/causes	Choco	Valle	Cauca	Nariño
Sedimentation		✓	✓	✓
Roads, airports, maritime and port infrastructure	✓	✓	✓	
Expansion of the urban frontier		✓		✓
Expansion of agriculture and livestock frontier		✓	✓	✓
Eutrophication		✓		✓
Logging, filling and construction		✓		✓
Inappropriate forestry	✓	✓	✓	✓
Pollution by hydrocarbons		✓	✓	✓
Shrimp farms				✓
Natural disasters	✓		✓	✓

(Source: MMA 2002c)

Anthropogenic activities are also reducing biodiversity; for example, the richness and abundance of coprophages beetles has declined (Family Scarabaeidae, Subfamily Scarabaeinae) (República de Colombia et al. 2002).

The forests in the river basins of the sub-system have been extensively modified; 22.1% (2.23 million ha) of the total surface area of the sub-system has experienced moderate intervention and 12.3% (1.24 million ha) is degraded (República de Colombia et al. 2002). The deforestation rate in the region over the past 17 years has been around 110 000 ha/year, which has caused the loss of more than half of the sub-system's original forest (Conservation International 2004).

Modification of ecosystems

Central Equatorial Pacific

Several aquatic environments and communities are affected by environmental deterioration in the Central Equatorial Pacific sub-system. Mangroves are the most impacted coastal ecosystem, especially at Puntarenas, Costa Rica; in El Salvador between the outlets of the rivers Paz and Jiquilisco; in the estuaries of El Zapote, San Diego and Jaltepeque; and near Maculita Beach (Rubio et al. 2001). In Nicaragua, the most impacted areas are the estuaries of El Realejo, Jiquilillo and Chichigalpa (Sánchez 2001); mangrove forests in the lower basin of rivers draining into Panama Bay (Franco 2001); and mangroves in the Gulf of Fonseca (CCAD/IUCN 1999a). Among the measures adopted by the governments of the region to protect their biodiversity is the creation of protected areas. However, around 35% of the coastal and marine protected areas had deteriorated by 2001 due to a variety of causes, such as sedimentation, mangrove clearing, pollution and overfishing (PNUMA 2001). The status of mangrove forests on the Pacific coast is considered to be vulnerable, in the Gulf of Fonseca and northern dry coast as endangered, and in the southern part of the dry coast as critical. Only a small proportion of the Pacific mangrove forests are relatively stable. The modification of mangrove and estuarine ecosystems has affected important fish nursery and recruitment grounds. Further, trawling is altering benthic habitats in coastal waters.

Pacific Colombian

Habitat modification is evident in wetlands as well as natural forests (IDEAM 2002). These ecosystems are degraded more than on the plains as concessions have been granted to several enterprises to extract wood pulp from both wetlands and rainforests (Conservation International 2004). Coastal ecosystems, in particular mangroves, are considered fragile and vulnerable as a result of high rates of erosion and habitat fragmentation. These issues raise concern about the sustainability of the region and its resilience to the current rates of exploitation (Conservation International 2004).

Although several alien species are known to have been introduced into Colombian waters, there is limited information regarding their distribution and impact on aquatic ecosystems. However, introduced species of cichlids, gerrids and shrimps, among others, may be affecting the biodiversity of the sub-system. In some cases, these species are introduced by government institutions without consideration of the environmental consequences (Conservation International 2004). *Acrostichum aureum*, an alien fern species, has been detected in deforested mangrove zones (MMA 2002b).

Socio-economic impacts

The economic impact of the loss and modification of ecosystems is insufficiently documented. According to the regional team, habitat modification has reduced income and investment opportunities. The loss and degradation of mangrove forests has compromised their ability to provide valuable resources for local communities. Around 820 000 people depend directly on the Gulf of Fonseca's resources. Despite the importance of mangroves in the Gulf as nursery and recruitment areas for important commercial fisheries, large areas of forest have been destroyed by a variety of human activities (see Figure 17). A study by CCAD/IUCN (1999a) showed that the number of artisanal fishermen has increased but fish production has decreased. The resultant lower incomes from fishing have led to extreme poverty in some communities. The expansion of aquaculture in the Gulf of Fonseca is creating social tensions as the farmers are restricting the access of artisanal fishermen to traditional fishing areas (CCAD/IUCN 1999a).

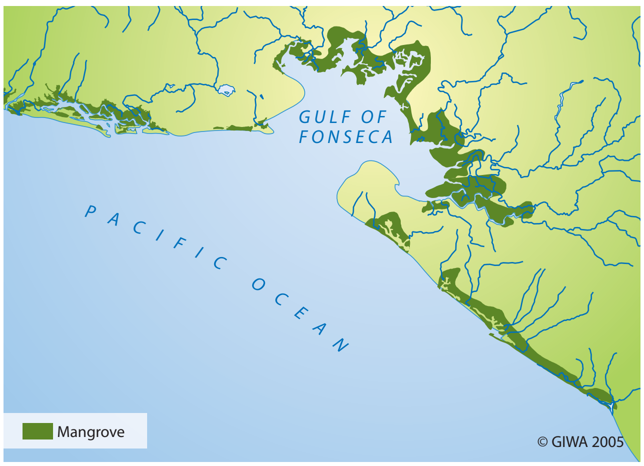

Figure 17 Remaining mangrove areas (in purple) in the Gulf of Fonseca.
(Source: CCAD/IUCN 1999b)

No health impacts associated with habitat modification have been reported. The construction of dams and reservoirs for hydroelectric generation causes habitat fragmentation and increases the water surface area where tropical disease vectors can develop. Habitat degradation is effecting rural populations that depend on wetland and marine resources for their subsistence. The social and community impacts are expected to increase in severity due to the continued modification of ecosystems.

Conclusions and future outlook

The extent and structure of coastal ecosystems has changed as a result of human activities. Mangrove and several other forest communities, especially in flooding lowlands, have been overexploited since the second half of the 20th century and they are now on the brink of collapse. These ecosystems have lost the capacity to provide basic necessities for human well-being. Increased sedimentation, primarily as a result of deforestation, is modifying the aquatic ecosystems of the sub-system. Loss of mangrove forest is the best documented case of habitat destruction in coastal areas. Urbanisation has also affected both mangrove and other forests, and will continue to increase in significance due to high population growth rates, particularly in coastal areas. The future outlook is uncertain and will depend on the success of current and future conservation and sustainable initiatives.

IMPACT Unsustainable exploitation of fish and other living resources

The unsustainable exploitation of fish and other living resources was assessed in the Central Equatorial Pacific and Pacific Colombian sub-systems. There has been an increase in fishing effort in both the industrial and artisanal sectors, particularly for high-value species such as shrimp and tuna. Overfishing and the use of destructive fishing gear have resulted in a decline in recruitment and the degradation of the habitat of some commercial species.

Marine fisheries account for 92% of the total catches in the sub-system (FAO 2002b). Panama is the leading fishing country with 77% of the total volume, followed by Costa Rica with 11.6% (Table 18). The main commercial fisheries include tuna and small schooling fish, such as the California sardine (*Sardinops sagax*) and anchovy (*Engraulis* spp.). There is also an upwelling area off Panama where a locally important stock of the Central Pacific anchovy (*Cetengraulis mysticetus*) is exploited (WCMC 1996).

Fishing is one of the main sources of income for inhabitants in the coastal area of the Pacific Colombian sub-system. The major fishing ports on the Pacific coast are Tumaco, Guapi, Buenaventura, Nuqui and Solano Bay (INDERENA 1992). The fisheries industry is comprised of three sectors: industrial, artisanal and aquaculture. The artisanal and industrial sectors account for 53.9% and 46.1% of total catches, respectively (INDERENA 1992).

Table 18 Total marine catches in the countries of the Central Equatorial Pacific sub-system.

Country	Pacific Ocean (tonnes)				Average production (tonnes)	%
	1995	1997	1999	2001	1995-2001	
Costa Rica	15 846	25 409	23 555	32 917	24 431	11.6
El Salvador	10 747	9 089	7 841	16 065	10 935	5.20
Guatemala	3 838	1 490	8 930	2 450	4 177	1.98
Honduras	864	4 002	1 702	3 044	2 403	1.14
Nicaragua	4 500	5 432	9 662	8 304	6 974	3.34
Panama	151 219	147 295	111 140	230 390	160 011	77
Total sub-system	**187 014**	**192 717**	**162 830**	**293 170**	**208 931**	**100**

(Source: FAO 2002b)

Overexploitation

Central Equatorial Pacific

The increasingly large catches of fish have become unsustainable. In Nicaragua, for example, annual catches increased from 4 235 tonnes in 1984 to 23 259 tonnes in 1998, and in Honduras they increased by 250% over the same period (Pratt & Girot 1999). Coastal species such as lobster, snail and sea urchin are considered depleted. The Central Pacific anchovy is fully or overexploited in Panama (WCMC 1996). The increase in catches of anchovy and the Californian sardine will lead to the collapse of these fisheries (FAO 1997). A significant proportion of tuna production is by foreign fleets, such as those from South Korea, Japan, the United States and Venezuela (Sea Around Us Project 2002).

Most shrimp populations in the sub-system are considered by the FAO to be fully or overexploited. In Costa Rica, the majority of pelagic and coastal benthic fish species are also overexploited. Catches of shark, marlin, sailfish and some species of tuna have decreased steadily since the 1950s. Today, some 85% of pelagic production is caught beyond the Economic Exclusive Zone (EEZ) (Sinergia 69 unpublished).

In the Gulf of Fonseca, some molluscs and crustaceans associated with mangrove and rocky ecosystems are overexploited by the artisanal fishery, and several others such as the oyster *Ostrea iridescens,* Green lobster (*Panulirus gracilis*) and the crab *Menipe frontalis* are at their limit of exploitation (CCAD/IUCN 1999a).

Pacific Colombian

According to FAO (2004c), catches of marine fish, crustaceans, molluscs and other marine living resources decreased in Colombia between 1992 and 2000 (Figure 18). Catches of fish in the continental waters of the Choco region have also steadily declined. The current rate of exploitation of fishing resources is considered unsustainable in the sub-system.

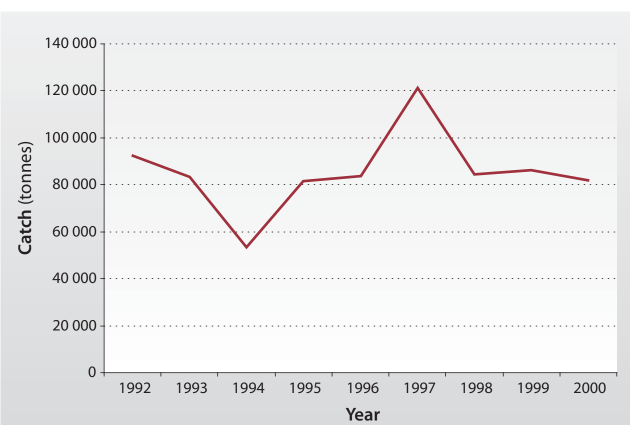

Figure 18 Total catches of coastal marine resources in the Pacific Colombian sub-system.
(Source: FAO 2004c).

The report on the State of Marine and Coastal Resources of Colombia (INVEMAR 2003c) reported that catches of mackerel, snappers and sharks decreased in 2001, whereas catches of tuna and other fish increased. Catches of Blue crab (*Cardisoma guanhumi*) increased from 37 tonnes in 2000 to 716 tonnes in 2001. High-value resources such as jumbo shrimps (*Penaeus* sp.) decreased from 2 686 tonnes in 1999 to 4 tonnes in 2001, and other shrimps from 3 826 tonnes to 1 575 tonnes between 2000 and 2001. Mollusc production decreased from 864 tonnes to 7 tonnes between 1997 and 2001. Squid catches decreased from 295 tonnes in 1996 to 76 tonnes in 2001 and clams decreased from 10 tonnes in 2000 to only 1 tonnes in 2001. Unfortunately, there is a lack of fisheries data to investigate the long-term trends of fish catches and stocks. A risk analysis of the Pacific artisanal fisheries concluded that several species of fish, molluscs and crustaceans are at a high risk of overexploitation (Rueda et al. 2003).

There are around 15 000 artisanal fishermen along the Pacific coast of Colombia. In recent years, there has been an increase in fishing effort, most likely caused by the high level of unemployment in rural areas. There has been migration from rural inland areas to the coast in search of food, security and an income (INPA 2000). The increased coastal population puts further pressure on fisheries resources which, in turn, decreases the *per capita* supply of protein.

During the 1970s, the trade in marine turtle skins resulted in the death of thousands of Olive Ridley turtles (*Lepidochelys olivacea*). The turtles were caught mainly to the south of Buenaventura and towards the border with Ecuador (MMA 2002a). From March until June during this period, between 500 and 3 000 turtles were slaughtered every day (Olarte 1987 in MMA 2002a). Only a small part of the turtle was used (neck and pectoral fins); only 7 kg of a 50 kg turtle (MMA 2002a). In 1996, the use of turtle exclusion devices (TEDs) was made obligatory for the Pacific trawl fleet and the retention of captured turtles was prohibited (FAO 2003).

Excessive by-catch and discards

Central Equatorial Pacific

The shrimp trawl fishery has the highest rate of discards due to the use of non-selective fishing gear. The catching of shrimp larvae for shrimp ponds is reducing the recruitment of several commercial species and threatening the long-term sustainability of both aquaculture and artisanal fishing, as observed in the Gulf of Fonseca. Shrimp aquaculture requires 4 billion post-larvae annually; for every shrimp post-larvae caught, nine larvae of other commercial species are discarded. Discards can include larvae of up to 30 different organisms (CCAD/IUCN 1999a). There are no assessments of marine mammal by-catch, although Palacios & Gerrodette (1996) suggest it is similar to other parts of the Pacific coast of South America.

Several demersal species are caught as by-catch in the artisanal fishery of El Salvador and Guatemala. The depletion of these stocks is extremely detrimental to the sharks that prey on them (Sea Around Us Project 2002). In the Gulf of Fonseca, the shark fishery is showing signs of depletion, especially species of the genus *Carcharrinus* and *Spyrna.* Other species at their exploitation limit include several species of the families Lutjanidae, Scianidae, Centropomidae and Serranidae (CCAD/IUCN 1999a).

Pacific Colombian

Shrimp trawling nets and gillnets are considered the main threat to marine turtles in Colombian waters. Approximately 8 230 marine turtles were captured by the trawling fleet in 1998 (Duque-Goodman 1998 in MMA 2002a), including the Olive Ridley turtle and Black turtle (*Chelonia agassizzi)*, 23-65% of which died (MMA 2002a). Some studies on by-catch from the shrimp trawling fishery in the Colombian Caribbean demonstrated that the ratio of fish caught to shrimp is 10-12:1, with 75% of the fish discarded (Santodomingo & Rueda 2003). Although similar studies have not been carried out on the Pacific coast of Colombia, information on shrimp trawling in Ecuador, south of Colombia, shows the same rate of discards as on the Caribbean coast of Colombia (Little & Herrera 1991). Purse seine gear, which was intensively used between 1985 and 1999, was also found to have significant by-catch; the target species account for only 32% of the catch (Santodomingo & Rueda 2003).

Destructive fishing practices

Central Equatorial Pacific

There is no quantitative information on the use of destructive fishing gear in the sub-system. Some national reports presented during the preparatory meeting of the Plan of Action for the Protection of the Marine Environment and Coastal Zones of the North East Pacific (2001) provided information about the use of dynamite and barbasco (fish poison from the roots of *Lonchocarpus nicou*) by artisanal fishermen in estuaries. The use of fine mesh nets for shrimp larvae is particularly common in the Gulf of Fonseca (CCAD/IUCN 1999a). All these methods are illegal and forbidden throughout the sub-system.

Pacific Colombian

There is no available information on destructive fishing practices in Colombia other than on trawl nets used by the shrimp trawl fleet. In 2000, the Pacific trawl fleet comprised 64 vessels operating in shallow waters and 34 industrial vessels operating in deep waters (Ustate 2002). The full effect of trawling nets on benthic communities is unknown.

Decreased viability of stocks through pollution and disease

Central Equatorial Pacific

Díaz & Fernández (1994) found that fishing activity in the Gulf of Nicoya (Costa Rica) has decreased by over 50% due to wastewater and other pollutants discharged by the Grande de Tárcoles River basin. There are no records in other areas of the sub-system of sickness in fish and marine organisms caused by pollution. Decreased catches are mainly attributed to overfishing and the influence of El Niño events.

Pacific Colombian

Landings of shrimp have changed dramatically in the last five years. The viability of the stock is affected by both overfishing and white spot disease, a virus that has impacted shrimp farms since 1999 causing a downturn in the profitability of the aquaculture sector (González 2002).

Impact on biological and genetic diversity

Central Equatorial Pacific

Several alien species, notably cichlids, have been introduced for freshwater aquaculture. In Nicaragua, the main species used in aquaculture is Nile tilapia (*Oreochromis niloticus*). The Rainbow trout (*Oncorhynchus mykiss*) is raised in El Salvador, Panama and Costa Rica. In the Panama Canal basin, several alien species of fish, such as the Common carp (*Ciprinus carpio*) and the Peacock bass (*Cichla ocellaris*), are found in the Chagres River and several species of *Tilapia* have been reported in Lake Gatún. Their impact on biological and genetic diversity is inadequately documented. It is known, however, that several alien species are highly adaptive and compete successfully with local fauna. Various species of the genus *Tilapia* have become widespread in some coastal areas. Fisheries authorities have established procedures for the use of alien species in the aquaculture industry.

Pacific Colombian

The introduction of alien species either intentionally for farming or unintentionally via ballast waters is poorly studied in Colombia. Around 96 species of fish are known to have been introduced into Colombian waters, especially species of the families Salmonidae, Cyprinidae and Cychlidae (Alvarado & Gutiérrez 2002).

Socio-economic impacts

Fishing is one of the most important economic activities on the coast, providing a major source of employment and income. The depletion of fish stocks will have a direct impact on coastal populations, reducing income and increasing unemployment, thus weakening social stability and food security.

There are no reports of human health impacts caused by the unsustainable exploitation of the fisheries. Around 28% of children under five years old are undernourished in the Central Equatorial Pacific sub-system with protein deficiencies. The consumption of fish per person is relatively low (between 2 and 10 kg/year). Fishing resources have the potential to provide cheap and high quality protein.

The shrimp trawl fishery in shallow waters was the most important fishery until the mid-1980s when it reached its Maximum Sustainable Yield (MSY). However, overexploitation, pollution and the development of forestry have reduced its importance (INPA 2000). During the second half of the 1980s, fisheries authorities restricted fishing activities until an assessment of the resource was undertaken. As a result of this assessment, an annual closed season for the shrimp trawl fishery has been implemented since 1991. The shrimp trawl industry now focuses on fish and other more abundant resources with lower operational costs (INDERENA 1992).

Conclusions and future outlook

The fisheries resources of the Eastern Equatorial Pacific region are significantly depleted. The industrial fishing sector targets small, schooling fish, which are used in fishmeal and oil production (Sea Around Us Project 2002). Tuna, especially yellowfin, skipjack and albacore, are also targeted. The large pelagic fisheries are exploited at their MSY along the coast of the majority of the region. The overexploitation of fishing resources is adversely affecting coastal and marine ecosystems. Coastal areas support an intensive shrimp trawl fishery which impacts benthic communities and has significant quantities of by-catch and discards. In the Central Equatorial Pacific, around 52% of artisanal fisheries production and 36% of the shrimp trawling fishery is from the Gulf of Fonseca. Operational costs have increased due to the reduction in the availability of resources. The long-term food security of the coastal population is jeopardised by the reduction in fisheries resources.

Fisheries management is failing to control fishing effort and illegal fishing. Unreliable statistics affect the credibility of assessments and prevent fisheries managers from making informed decisions. Future conditions will depend on the successful implementation of Pacific Agenda 21 (see Annex III) and several other conservation and development projects.

IMPACT Global change

Global change in the region may increase the severity of El Niño events, including longer and more widespread droughts. Extreme climatic conditions significantly impact economic activities and social well-being in the region. The El Niño of 1997-1998 increased the frequency of cyclones in Mexico and the Caribbean, with hurricanes reaching the Pacific side of Central America. These conditions may increase in frequency and intensity as a consequence of global climate change. According to Intergovernmental Panel on Climate Change (IPCC) projections, the region's average temperature will increase by 0.5-2°C and the sea level will rise by 25-50 cm between 1990 and 2100. No information was available about the issues of increased UV-B radiation, and changes in ocean CO_2 source/sink function.

Changes in the hydrological cycle

Central Equatorial Pacific

According to IPCC, the effects of global change on the countries of the sub-system are likely to be more intense on the Pacific side of Central America where sea surface water temperatures are expected to increase and rainfall to decrease. There will be prolonged droughts, especially during the El Niño. A summary of the national reports by Girot & Jiménez (2003) is shown in Table 19.

Table 19 Different sceneries of global change in the Central Equatorial Pacific sub-system in 2100.

Country	Changes in temperature (°C)	Changes in rainfall (%)	Months with most severe changes	Affected zones
Guatemala	+3.5 °C Increase of dry season	-30%	July-September	Motagua Valley toward Cochunatamos sierra and Southeast of the country
Honduras	+0.9 a +3.7 °C	-8% a -37%	May-June	Gulf of Fonseca slope
	+0.8 a + 3.3 °C	-8% a -36%	November-April	Southeast of the country and Coco basin
El Salvador	Increase of dry season +2.5 a +3.7 °C	-36.6% a +11.1%	January-March	All the country
Nicaragua	+3.0 °C	- 36.6%	Annual variations	Pacific: North of Chinandega and León
Costa Rica	+3.8 °C	-63.0%	March-May	Guanacaste
	+3.2 °C	-69.0%		North and Northeast zones
	+3.5 °C	-49,0%		South of the country
Panama	+0.8 °C	-1,8%	Annual variations	Coastal Pacific basins

(Source: Girot & Jiménez 2003)

In Nicaragua, the annual mean temperature will increase from 27-28°C to 30-31°C in the Pacific areas of Chinandega and León, and rainfall will decrease by 36.6%. Annual rainfall will be less than 500 mm in most of the Central Equatorial Pacific and 800-1 000 mm in the south. By 2100, cities on the Pacific slope will have a 25% water deficit and a reduction in rainfall of 21% (Girot & Jiménez 2003). In Honduras, a vulnerability analysis of water resources shows a significant reduction in the discharges of the river basins of Choluteca and Humaya. For the Choluteca River, under a scenario of a 1-2°C temperature increase and 10-15% increase in rainfall, run-off during the rainy season will increase by 18-20%. In contrast, discharges will decrease by between 31% and 21% if there is a reduction in rainfall of 10-15% and a temperature increase of 1°C (SERNA in Girot & Jiménez 2003). In Guatemala, according to IPCC scenarios, potential temperature and rainfall changes will have the largest impact on an area containing 40% of the cloud forests, resulting in increased river discharges (MARN Guatemala 2001). In El Salvador, the forecasted intensification of dry periods by 2100, in combination with high population growth, could have severe impacts on the availability of water for the country's ecosystems and population (MARN in Girot & Jiménez 2003).

Pacific Colombian

The average water availability in Colombia is estimated to be 57 000 m^3/person/year (IDEAM 2001) and average annual rainfall and surface run-off is more than three and six times the global average, respectively. It may, therefore, be inferred that global change has not significantly affected the hydrology of the Pacific Colombian sub-system. However, Pérez et al. (2005) found positive trends in minimum and average temperatures throughout Colombia and a reduction in the discharge of the major river basins. This was linked to a shift in the annual cycles of several climatic variables. Such findings demonstrate that climatic changes are beginning to affect the hydrological regime of the Pacific Colombian sub-system.

It is unknown how changes in ocean circulation may influence the sub-system but it is evident that ocean induced events such as the El Niño and/or La Niña change the rainfall regime; such events are expected to occur more frequently and intensely due to global warming (IPCC 2001).

Sea-level change

Central Equatorial Pacific

Sea-level change will affect large areas of the sub-system. The estuaries in Costa Rica, El Salvador, Honduras and Nicaragua are particularly vulnerable. The shoreline and the intertidal zone will widen in these areas. Some countries have estimated the impact of the sea-level rise predicted under IPCC scenarios, presenting the results at the Fifth Annual Session of the Commission on Sustainable Development. In Costa Rica, seawater will penetrate inland by 150 m at Puntarenas, flooding 105 ha (60% of the urban area). If the sea level rises by 1 m, the sea will reach up to 500 m inland, flooding 300 ha (90% of the urban area) (MINAE 2000). In El Salvador, it is estimated that around 10% (149 km^2) of its territory would be flooded if the sea level rises by 13 cm and up to 27.6% (401 km^2) if it rises by 1.1 m (MARN El Salvador 2000). In Panama, sea-level change will result in flooding, the displacement of wetlands, increasing coastal erosion and the salinisation of estuaries and aquifers. Storms will become more frequent, intertidal areas will increase in area and sedimentation patterns will change resulting in the flooding of low-lying areas (ANAM 1994). So far, there is no authoritative evidence of sea level change in the sub-system.

Pacific Colombian

Recent studies have highlighted the vulnerability of the sub-system to sea level rise (INVEMAR 2003a). Tumaco and Buenaventura are considered at high risk. The annual rate of sea level rise is estimated to be 2-5 mm (Lozano & Pabón 2005).

Socio-economic impacts

There are severe economic, health and social impacts associated with natural disasters. They often result in migration, disease epidemics, a loss of income and employment, human injuries and mortality, and damage to property. There is no available data which links socio-economic problems in the sub-system with global changes. However, severe social and economic impacts are expected to result from the increasing frequency and intensity of extreme climatic events.

Sea-level rise will impact coastal infrastructure and economic activities, such as tourism. Global warming is expected to cause the tropicalisation of the marine environment which will alter the distribution and composition of marine resources, significantly impacting the regional fisheries. The increased severity of El Niño periods will have disastrous effects on the economy of the countries in the region. Higher surface water temperatures will change the productivity of upwelling areas, thus affecting the food web of the region's ecosystems.

The sectors impacted by global change are thought to be agriculture, fishing and hydroelectricity, particularly during El Niño events. In 1992, a drought period necessitated the restriction of electricity, which confirmed that El Niño can have major effects on the economy of the region (Carvajal et al. 1997). Poveda & Rojas (1997) reported a significant increase in the cases of malaria and other endemic diseases during El Niño events. This is attributed to higher temperatures, which shorten the larvae period of mosquitoes, and to a reduction in water flow, which favours the formation of pools and small lagoons where mosquitoes breed (Carvajal et al. 1997).

Diarrhoea, cholera, hepatitis and other diseases increase their geographic distribution and prevalence following natural disasters. OPS/OMS (1999) noted that following disasters, water-related diseases become epidemics. For example, after Hurricane Mitch in 1998 there were 1 451 cases of cholera in Nicaragua, with a mortality rate of 2.4%. The hurricane severely disrupted the freshwater supply system. An increase in diarrhoea, typhoid fever and other diseases also occurs when sanitation problems increase during droughts, especially during El Niño events (WFP/FAO 2002).

Conclusions and future outlook

The IPCC predicts that global climate change will increase rainfall during the rainy season and prolong drought periods during the dry season. The reduction of river discharges will increase the size of arid zones. Coastal cities will experience greater water shortage. Climatic change will increase the intensity and change the trajectory of storms and hurricanes.

The governments of the region recognise the potential impact of climate changes but actions to limit the vulnerability of their countries to these changes are rarely implemented. They are yet to accurately assess the impact of climate change on aquatic ecosystems under different scenarios. Aquatic productivity is expected to decrease as it does during current El Niño events. Although there is insufficient information about the potential changes in ocean circulation in the region, it is known that during El Niño events upwellings collapse when the thermocline sinks, resulting in extreme impacts on the productivity of marine ecosystems and the fisheries.

The sectors most affected by global change are expected to be agriculture, fishing and hydroelectric generation. Climate change may increase the prevalence of malaria, which is already experienced during El Niño events. According to IPCC projections, the effect of El Niño events on ecosystems, the economy and human well-being will increase in the future. The severity of the impacts will depend on the level of implementation of mitigatory programmes, which are still in their infancy.

Priority concerns for further analysis

The above assessment of the environmental and socio-economic state of the region identified the priority GIWA concerns based on an integrated evaluation of the impacts. The priorities established by the GIWA Task team constitute the basis of the Causal chain analysis which led to the development of policy options which aim to address and mitigate the causes of the environmental and socio-economic impacts.

The assessment of the major concerns shows that the environmental quality of the transboundary waters of the Eastern Equatorial Pacific region is deteriorating. This situation is not expected to improve by 2020 due to rapid population growth and economic development. The aquatic concerns are ranked below in priority order.

Southwest Mexico

Pollution was considered by the regional team to be the priority concern of the Southwest Mexico sub-system. In 2002, nearly one-quarter of the beaches tested in Mexico failed to meet WHO standards. SEMARNAT suspects that untreated municipal wastewater is responsible for a significant portion of coastal water pollution. Many municipalities fail to treat, or under-treat, wastewater before discharging it into Mexico's inland and coastal waters. The tourism boom in Mexico's coastal regions benefits coastal economies while harming coastal ecology. Coastal tourism development is outpacing the development of both sewer infrastructure and wastewater treatment. The increase in visitors and associated construction is increasing point and non-point sources of pollution. In addition to harming bathers, coastal water pollution negatively impacts commercial fisheries, coral reefs, other aquatic ecosystems, the quality of diving, and other forms of tourism. The problem of beach pollution in Mexico is complicated by the fact that there are many sources of pollution, and each of these sources is subject to economic, technical and political constraints that will determine the effectiveness of any particular intervention.

Central Equatorial Pacific

Freshwater shortage was selected as the Central Equatorial Pacific sub-system's priority concern. Water availability in the sub-system is strongly influenced by climatic variability. The intensity and duration of El Niño induced droughts and the size of the area affected is increasing. Anthropogenic activities are also affecting water availability. The sub-system has one of the highest deforestation rates in the world which exacerbates erosion processes in river basins. As a result, rivers carry large amounts of sediment downstream which is reducing the storage capacity of rivers and lakes, thus modifying stream flow and increasing flooding. Population growth and urbanisation are increasing water demand beyond sustainable limits. Water availability *per capita* has reduced by almost 62% since the 1950s. Many of the major urban areas of the sub-system depend on groundwater supplies which are already overexploited. Higher aridity is predicted in the long-term, with the risk of water shortages becoming severe.

Pollution is considered as the second priority concern. Around 95% of municipal wastewaters released into the water bodies of the sub-system are untreated, resulting in microbiological pollution downstream and in coastal marine areas. Agricultural run-off containing agro-chemicals is degrading freshwater ecosystems and causing eutrophication in coastal waters. Wastewater from industries is also introducing organic matter, suspended solids and nutrients (nitrates and phosphates). The low level of sanitation coverage and the widespread use of latrines are leading to the contamination of aquifers. Pollution is increasing the prevalence of diarrhoeic diseases, the main cause of morbidity and infant mortality.

Global change will affect the availability of freshwater in the sub-system. Rainfall is expected to be more intense during the rainy season and droughts more severe during the dry season. The heavily populated parts of the Pacific slope are the most vulnerable to droughts and changes to river flows. However, global climate change is not studied in the Casual chain analysis or Policy options analysis because the causes are also global issues that can not be resolved through regional action in the Eastern Equatorial Pacific alone but requires concerted efforts by the international community. The influence of future climate change on this region is still poorly understood and requires further investigation.

Pacific Colombian

Unsustainable exploitation of fish and other living resources was selected as the priority concern of the Pacific Colombian sub-system. Despite most of the fisheries in Colombia being small scale and/or subsistence, the current level of exploitation is unsustainable. Although total catches have increased recently, catches of some traditionally targeted species, such as mackerel and sharks, have declined (INVEMAR 2003c, FAO 2004c). The abundance of some coastal shellfish such as clams, squid and snails has decreased significantly. Similarly, stocks of freshwater commercial species are significantly depleted (IIAP 2001b). Additionally, the uncontrolled exploitation of marine turtles continues. As stocks of traditional species become exhausted, fishing effort targets other more abundant species to maintain income levels and food security. Although the aquatic living resources are unsustainably exploited on the coast of the Colombian Pacific sub-system, the coast is less populated than some areas of Colombia and therefore the environmental problems are mainly localised. It is therefore not too late to implement mitigation measures in order to reduce the pressure on fisheries resources.

Pollution was identified as the second priority concern. Pollution is the principal cause of freshwater shortage in the sub-system. The main sources of pollution are untreated domestic and industrial effluents, hydrocarbon spills and agricultural run-off (Calero et al. 1995, Peña 1995, IDEAM 2002). However, organic matter and other pollutants carried by water bodies are rapidly dispersed due to the high rate of water exchange (Calero et al. 1995, IDEAM 2002). Fees and fines have been imposed on enterprises and the urban sector in order to reduce the pollution load of water bodies.

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 involved a step-by-step process that identified the most important causal links between the environmental and socio-economic impacts, their immediate causes, the responsible human activities and economic sectors and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis (CCA) recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. The CCA uses a relatively simple and practical analytical model. For further details of the methodology, please refer to the GIWA methodology chapter.

Based on the results of the assessment (see priority concerns above), the CCA of the Eastern Equatorial Pacific region was conducted for the priority concerns of each sub-system. The analysis considered the following sub-systems for each priority concern:

- Freshwater shortage in the Central Equatorial Pacific sub-system
- Pollution in the Central Equatorial Pacific and Southwest Mexico sub-systems
- Unsustainable exploitation of fish and other living resources in the Pacific Colombian sub-system

Freshwater shortage

Although the Central Equatorial Pacific sub-system has abundant water resources, they are unevenly distributed, with some countries having a surplus and others having deficient supplies. In 2002, the discharge of

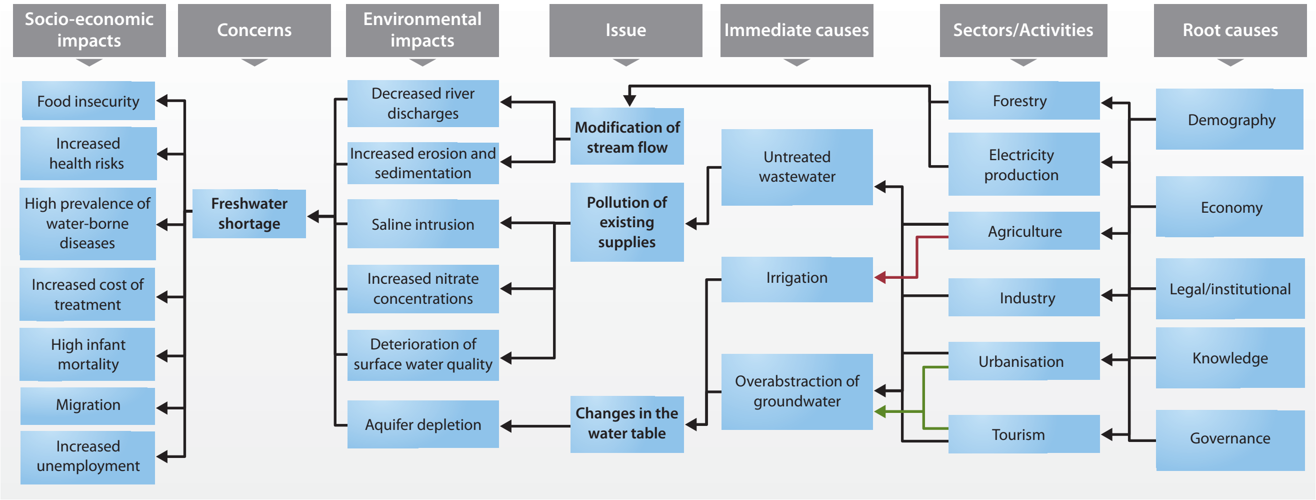

Figure 19 CCA diagram Freshwater shortage in the Central Equatorial Pacific sub-system.

the Lempa River – shared by El Salvador, Guatemala and Honduras – was 42% below the historic average (SNET 2002). Approximately 70% of the total population and 80% of the economic activities are located in areas with a shortage of freshwater. About one-quarter of the population in the sub-system did not have access to safe freshwater in 2000.

During the Causal chain analysis, the issue of pollution of freshwater supply is emphasised because it is the issue best documented in the sub-system. The information regarding the other two issues is somewhat limited, not current and tends to focus on specific localities and rivers.

Figures 19 and 20 show the causal links between the environmental and socio-economic impacts of the freshwater and pollution concerns, the immediate causes, the responsible economic sectors, and the root causes that determine the behaviour of these sectors.

Immediate causes

Climatic variability

Despite all countries of the Central Equatorial Pacific sub-system having abundant water resources and extracting relatively limited quantities, some areas experience water scarcity during the dry season when river flows are considerably reduced. During the El Niño, river flows are notably smaller, exacerbating the effects of a normal dry season.

Land-use changes and practices

Deforestation and inappropriate agricultural practices in the catchments have affected run-off and river flow patterns. These practices have increased sedimentation, reducing the capacity of freshwater bodies including reservoirs, thus increasing the extent and frequency of floods. The reduction in water availability has also been attributed to the loss of fog forests in the upper sections of the basin. The removal of natural forest cover may also be affecting both the recharge rate and water quality of aquifers (Ballesteros 2003).

River diversion and groundwater abstraction

River discharges are affected by dams, which interrupt the natural flow of nutrients to coastal waters. Groundwater is the main source of freshwater in the sub-system and aquifers in most countries are unsustainably exploited. For example, the aquifers that supply Managua (Nicaragua), San José (Costa Rica) and San Salvador (El Salvador) are overexploited (Lezama-López 2003). According to the International Hydrological Programme of UNESCO, groundwater abstraction in 2010 is expected to be nine times the rate in 1950. Illegal connections consume a large proportion of the water available for the cities of the sub-system. Groundwater use will increase as the quality of surface water deteriorates in the future.

Discharge of untreated wastewater

Freshwater supplies are contaminated in several major basins of Central America, including the Lempa River and the Grande de Tárcoles River basin. According to PNUMA (2001), 95% of the municipal wastewater generated in the sub-system enters natural water bodies without appropriate treatment. El Salvador is particularly affected as the main sources of freshwater, the Lempa River and lakes Ilopango and Coatepeque, are highly polluted by wastewater discharges. In the Lempa River, a two-year study found that 95% of samples contained *E. coli* (Levin 2002). Industries, particularly coffee production, also discharge large amounts of wastewater without treatment.

Agricultural run-off

The sub-system has one of the largest rates of pesticide consumption in Latin America (2 kg/person), which contribute to the deterioration of surface and ground water quality. Aquifers in the metropolitan area of Alajuela, Cartago and Guanacaste contain increasing concentrations of nitrates originating from fertilisers and septic tanks (Reynolds & Fraile 2002). Urban and agricultural run-off are responsible for polluting the Managua aquifer that provides freshwater to 1.2 million people.

Root Causes

Demography

The demographic trends of the last four decades have led to increasing demand for freshwater resources for drinking water, agricultural production and industrial processes, among other uses. Urbanisation has intensified and concentrated demand in areas that have limited freshwater availability. The following demographic trends are driving freshwater shortage issues in the sub-system:

- Over the past 30 years, the population of the sub-system has increased by 98%, from 19.3 million to over 37 million. The population density increased over the same period from 39 to 66 inhabitants/km^2. The population of the sub-system will continue to grow rapidly, reaching 40 million within the next decade.
- The population is concentrated in specific areas. In general, the population occupies only a quarter of the sub-system's territory with 70% inhabiting the Pacific slope. The urban area is expected to increase from 596 km^2 to 913 km^2 by 2030 if current urbanisation trends continue.
- Urban populations increased by 29% over the period of 1975-2000. About 75% of the population will live in urban areas by 2030 as a consequence of natural population growth, longer life expectancy and migration from rural areas. Most rural populations are poor and migrate for economic reasons, while others are environmental refugees fleeing from natural disasters (OPS/OMS 2001a). The larger urban population will increase further the pressure on water and

sanitation services. The influx of immigrants into urban areas has created an illegal land market and the establishment of illegal settlements which have no freshwater supply or sanitation services.

The Lempa River basin is the most densely populated and intensively exploited area of the sub-system. Its population was 4.7 million inhabitants in 2001, of which 3.9 million live in the Salvadorian part of the basin. The population is expected to double in the next 25 years (Granados in Llort & Montufar 2003). The majority of economic activity and the two major urban centres (San Salvador and Santa Ana) of El Salvador are located in the Lempa River Basin. These socio-economic characteristics are exerting extreme pressure on the freshwater resources of the basin.

Freshwater supply and sanitation services

The current water distribution systems are obsolete and highly inefficient. The countries of the Central Equatorial Pacific sub-system lack the economic resources needed to adopt water efficient technologies. Water supply and sanitation services are subsidised. As a consequence, insufficient revenues are generated to maintain current and invest in new technologies, and the population has no incentive to save water. Most countries in the sub-system depend on foreign imports rather than developing their own technologies that are culturally compatible and suitable for their local environmental conditions. The Pan-American Health Organization has stated that technical solutions used to solve water supply problems in rural areas are not always appropriate for either the local communities or the environment.

The development of both freshwater supply and sanitation coverage is not keeping pace with population growth. The health of the increasing number of people without access to these basic services is at risk. Some urban areas such as the capitals of most countries in the sub-system (e.g. Panama, San José, San Salvador, Managua and Tegucigalpa) have grown in a disorganised manner. They are characterised by the occupation of fringe urban areas by a rural migrating population or by people displaced from neighbouring countries. In these cities, where public services do not cover even the formal population, urban development will increase pressure on the aquifers that are already depleted.

The average freshwater supply coverage in the sub-system was 78% in 2000, of which 69% was through the network and 9% through easy access (OPS/OMS 2001a), which, in most cases, increases human heath risks. Besides the low level of coverage, several cities in the sub-system have deficiencies in treatment processes, forcing the population to boil water for direct consumption. Only a small proportion of rural communities apply chlorine to water for disinfection. In most countries, water supply is not continuous (between 27% and 98% of the systems), with a supply only available for 6-20 hours/day because of the poor condition of the equipment. This is especially true in rural areas. Almost 40% of water systems have leaks due to the poor maintenance of the network and the use of obsolete technology. In Costa Rica, only 50% of the water abstracted is actually charged to users, with the other half being consumed through illegal connections or wasted as a result of dilapidated pipelines (Ballesteros 2003). Illegal connections increase the costs of operation and maintenance, and create an additional problem in quantifying water losses.

Economic

The assessments by OPS/OMS (2001a) for Latin American and the Caribbean are also valid for this sub-system. Both reports highlighted the differing situations facing the countries, but noted that they share the following economic problems:

- Substantial resources are required to improve the current infrastructure and to improve the level of freshwater supply coverage.
- Service charges do not cover operational and maintenance costs. As a consequence, governments subsidise water supplies.
- Difficulties estimating operational and maintenance costs as a result of distortions introduced by governmental subsides, and inefficient management and technical deficiencies.
- Subsidies do not benefit the population directly but, instead, hide operational and management inefficiencies.
- The lack of realistic tariff rates and jurisdictional uncertainty discourages private investment in sanitation and wastewater treatment.
- The privatisation of public services reduces the possibility of improving the level of wastewater treatment coverage and the introduction of integrated water resources management. In several cases of privatisation, environmental costs are charged to users and the government assume an intermediary role.
- Management lacks an enterprise approach.
- There is a vulnerability to political pressures.
- Current statistics show that a high proportion of the population use *in situ* sanitation solutions, which involve environmental risks. For example, if latrines are located in porous soils, leachates may contaminate aquifers.

Legal/Institutional

Most countries in the sub-system have a weak legal and institutional framework for water management which results in overlapping responsibilities and a duplication of effort. There is a lack of control and surveillance during the implementation of current regulations

(Dourojeanni 2001). Some regulations, particularly those regarding permissible limits for individual substances or groups of substances, have been modernised. Others are obsolete or incomplete (UNEP/GPA 2001) as they do not include provisions for new approaches and administration procedures, such as those necessary for a sustainable development approach. The legislation considers water quantity separately from water quality. They are also managed by different institutions, making it difficult to implement a holistic approach at the institutional level (Escobar 2003). Environmental policies regarding water management are predominantly sectorial and fail to take into account the multiple uses of water.

Most water services in the sub-system are managed by centralised governmental agencies which lack the capacity to maintain and update the distribution networks and equipment, as well as to monitor the quality of the water supplied. Incipient decentralisation processes suffer from inadequate governmental support for the transfer of responsibilities for water management to local governments. Traditionally, local stakeholders were not consulted in the management of water resources. The lack of a multidisciplinary approach leads to inter-institutional conflicts. There is an absence of an integrated policy for population distribution, urban development and the provision of water services. An integrated river basin management approach to shared river basins has not been sufficiently adopted.

Knowledge

Countries in the sub-system lack water monitoring programmes and environmental, social and economic impact assessment processes. There is a dearth of knowledge regarding water quality and the effect of pollutants on ecosystems and their biota. Most of the countries lack the economic and technological resources necessary for strengthening the territorial agencies responsible for undertaking studies on biophysical, hydro-geological, meteorological and other environmental parameters. The monitoring of water quality is inadequate as it only focuses on a few indicators (Ramírez & Espejel 2001). These knowledge deficiencies are impeding the development of a better management framework that incorporates the particularities of the sub-system's environment. The Workshop of Experts on Municipal Liquid Wastes in Latin America, held in September 2001 in Mexico (UNEP/GPA 2001), identified the absence of monitoring and surveillance of water quality as a major obstacle to combating pollution in the region and recommended the standardisation of water quality criteria (Ballesteros 2003).

There is a lack of public awareness of water issues and the associated socio-economic impacts, particularly regarding sanitation. There is no culture of water conservation in the population of the sub-system. This prognosis is evidenced by the use of inappropriate farming practices which result in severe impacts on the water cycle, the lack of treatment for industrial and domestic wastes, and the disregard by the public for their impact on the environment. Other than the consumptive benefits of water, there is little recognition or valuation of the indirect benefits water provides through ecosystem goods and services.

Pollution

Microbiological contamination was considered to be the priority pollution issue in the Central Equatorial Pacific and Southwest Mexico sub-systems. In the Central Equatorial Pacific sub-system, chemical pollution was also considered to be a priority.

Immediate causes

Discharge of untreated municipal wastewater

The failure to appropriately dispose of excrement and the use of latrines and septic wells in porous soils contribute significantly to the load of microbiological pollution. The low levels of wastewater treatment in both sub-systems results in around 95% of wastewater reaching the Pacific Ocean with a high load of organic matter, nutrients and microbial pollutants (PNUMA 2001). Livestock production may also contribute considerable microbiological pollution to the surface waters of the Central Equatorial Pacific sub-system. High concentrations of pathogenic micro-organisms associated with water pollution have been recorded in water bodies and on beaches in the Central Equatorial Pacific and Southwest Mexico sub-system. Many of these beaches are important for the tourism industry; the pollution can discourage visitors and cause health problems for bathers.

Agricultural run-off

Agricultural run-off is the main source of chemical pollution due to the large-scale use of pesticides in agriculture, especially for export production. High concentrations of pesticides have been found in several coastal sites in water, sediments and biota, posing risks for humans and other living organisms.

Industrial and mining run-off

Heavy metals are introduced into water bodies from mining washes and industries. Other chemicals are discharged in small concentrations within wastewater. Heavy metals, such as lead, copper and chromium, have been reported in sediments and surface waters in several countries in the Central Equatorial Pacific sub-system, particularly Panama, Nicaragua and Costa Rica.

Root causes

Population demography and economic development

Today, half of the Central Equatorial Pacific sub-system's population is urban and by 2030 the proportion is expected to increase to three-quarters. The coverage of sanitation services has not expanded sufficiently to cope with the increasing quantities of wastewater produced by the swelling urban population. The growing population and export market requires more food which is leading to the application of more agro-chemicals and, thus, increased chemical pollution.

The tourism boom in Mexico's coastal regions is benefiting the economy but harming coastal ecology. The growing numbers of visitors and associated development are increasing the volume of point and non-point sources of pollution (Rivera-Arriaga & Villalobos 2001) and placing additional pressure on sewer infrastructure and wastewater treatment facilities. The negative environmental impacts of untreated wastewater are particularly apparent in and around the coastal tourist cities of Acapulco, Ensenada, Veracruz, and Xihuatanejo (Ascencio pers. comm.). In cities such as these, largely uncontrolled coastal tourism development has put enormous pressure on the ability of the ecosystems to absorb municipal waste.

Technology

The major cities in the Central Equatorial Pacific have dilapidated wastewater treatment systems (OPS/OMS 2001a). In Guatemala, only 15 municipalities treat wastewater, and only 4 out of 16 plants in the metropolitan zone are functioning (FAO 2004a). Design flaws have frequently led to new systems failing soon after installation.

Industrial processes often involve the use of antiquated technology. Political will to force or encourage industry to adopt cleaner technologies is lacking. Industry managers are also uninformed about new technological alternatives and there is a lack of facilities for the recycling of industrial wastes. Guidelines on agricultural best practice including techniques to reduce the use of agro-chemicals and to improve soil management are not disseminated to farmers.

Mexico's water treatment infrastructure is significantly less advanced than that of other nations in the Organisation for Economic Cooperation and Development (OECD), as well as other countries in Latin America. At least 20% of the existing treatment facilities in Mexico are non-operational and a significant percentage of those in operation are performing below their capacity (OECD 2003). While over 76% of the Mexican population is connected to sewer systems, only 26% is connected to wastewater treatment facilities (OECD 2003); the wastewater is therefore discharged directly into the ocean or inland waterways without treatment.

Economy

Low tariff rates for water and underinvestment in sanitation infrastructure are the principal causes of the lack of basic sanitation services in the Central Equatorial Pacific sub-system. In Panama, water and sanitation services are subsidised resulting in the authorities receiving insufficient revenues to invest in the expansion of sanitation services. As a consequence, investment was limited to maintenance during the 1990s. Privatisation of sanitation services has led to the improvement of waste collection rather than sewage treatment or water supply. In fact, there is no example of wastewater treatment services being privatised. There is a lack of economic incentives to encourage industries to adopt environmentally friendly technologies and practices. In terms of disincentives, polluters are not taxed appropriately for the environmental damage that their activities cause. In the Southwest Mexico sub-system, federal authorities lack the appropriated mechanisms to collect fines from local governments. Such fines could be used for maintenance or for the construction of new wastewater treatment plants.

Legal/Institutional

All countries in the sub-system are failing resolve their pollution problems, in part due to financial problems and in part due to the unwillingness of governments to regulate economic activities for fear of constraining development. There is a lack of common coastal and marine policies with specific environmental objectives that address pollution issues. This has resulted from an inappropriate institutional framework and the application of freshwater criteria to marine environmental legislation. The countries within the sub-system have differing marine policies, except those related to maritime aspects such as traffic and national security. Institutional weaknesses and a lack of coordination among the different governmental sectors hinder the implementation of legislation and environmental management instruments (e.g. environmental impact assessments, management plans and environmental auditing). Industries and agriculture are regulated by a weak and uncoordinated legal framework. In most countries, the institutions responsible for river basin management only focus on water distribution and consumption, have overlapping responsibilities and rarely encourage stakeholder participation in the decision making process. The control and surveillance of pollution is undertaken by a variety of institutions. River basins and the coastal zone are managed autonomously by different institutions (Escobar 2002).

The legal regime and the institutional organisation of several countries in the Central Equatorial Pacific sub-system have been characterised by Jouravlev (2001):

- In Costa Rica, legislation is disarticulate and, in part, obsolete (Ballesteros 2003). In several cases, laws and decrees are conflicting or are not implemented due to a lack of institutional capacity.
- In El Salvador, the diversity of laws related to water resources creates confusion in defining responsibilities. In fact, there are numerous laws but few that have specific regulations needed for implementation. To solve these problems a new Law of Waters is being developed.
- Guatemala does not have a general water law but secondary laws partially regulate issues related to water, its use and conservation.
- In Honduras, until recently, the responsibilities for implementing regulations regarding water management were dispersed between several institutions. However, important advances in water management have been achieved, including the creation of the National Council for Sustainable Development (CONADES) and the Secretary of Natural Resources and Environment (SERNA). The Framework Law of Waters, currently in development, will provide a modern, legal, technical and institutional basis for the integrated management of water resources.
- In Nicaragua, the integrated management of water continues to be fragmentary and lacking in coordination (MARENA in FAO 2002a).
- In Panama, institutions in charge of water management do not have an integrated legal framework. The lack of appropriate technical knowledge and economic constraints impede the implementation of current regulations.

In Southwest Mexico, SEMARNAT, Comision Nacional del Agua (CNA) and other regulatory bodies have achieved increasing success in controlling large volume industrial polluters whose wastes flow into federal waterways. These agencies have direct jurisdiction over facilities affecting federal waters and are able to enforce fines for exceeding pollution targets. They have even shutdown the worst offenders. Despite these improvements, pollution levels are still high due to a lack of direct control over municipal pollution sources. Under the Mexican Constitution, municipalities are responsible for the maintenance of their water systems and are largely autonomous from state and federal authorities (Constitucion Nacional de Mexico 1992). Therefore, attempts to regulate municipal pollution have been largely ineffective as the government has little enforcement power to collect fines from municipalities who exceed federal pollution limits, and no power to directly fine those who pump their waste into these municipally controlled waters.

The Mexican federal government and several international NGOs have invested in the construction of sewers and treatment facilities. However, the strong legal provisions guaranteeing municipal autonomy prohibit federal authorities from funding the ongoing maintenance and upkeep of these investments. This means that in communities with limited economic resources, funding of waste treatment services is often a low priority. These aspects of municipal water control have resulted in the breakdown of many recent environmental initiatives. While many state and municipal governments have turned to outside contractors to run their wastewater treatment operations (called operating agencies), major sanitation-related decisions are often made by municipal officers. These decisions are frequently based on political considerations that have little relevance to the long-term water and sanitation needs of a community.

Many pollution problems impact downstream communities and ecosystems, especially those on the coast. There is insufficient investment in upstream sewage infrastructure which could reduce the impact on the economy and public health of many other communities sharing the same watershed. These problems are exacerbated by the sheer number of municipal governments.

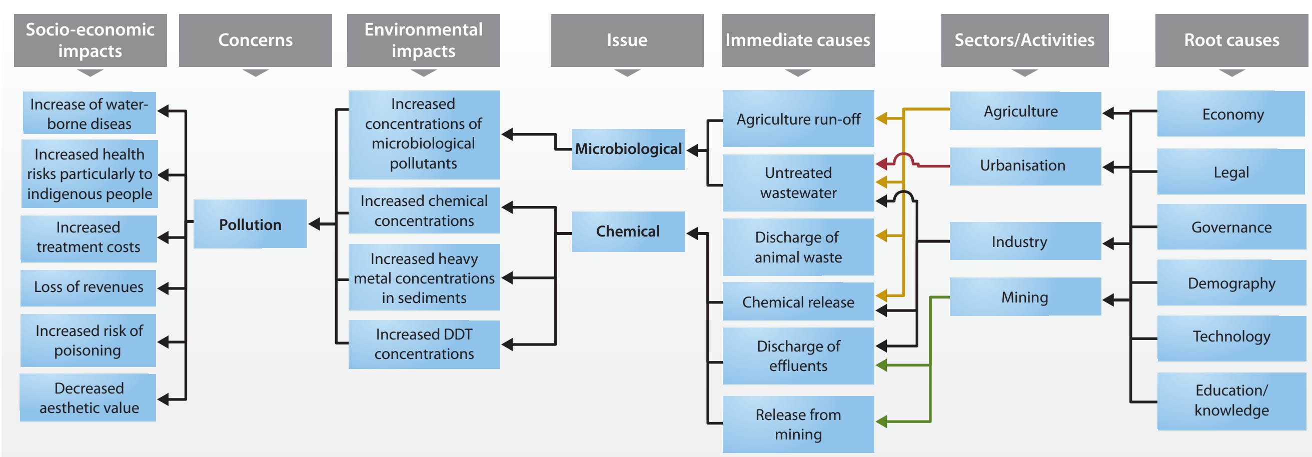

Figure 20 Diagram showing the Causal chain analysis of microbiological and chemical pollution in the Central Equatorial Pacific and Central Mexican sub-systems.

Knowledge

In the Central Equatorial Pacific sub-system, available information is dispersed, sparse and not current, which restricts the understanding of the real situation. Limited research and technological development hinders progress in addressing pollution issues. In the Southwest Mexico sub-system, local municipal governments lack personnel with the necessary technical expertise to create and maintain complex wastewater treatment networks. Additionally, politicians poorly understand wastewater and pollution issues and their effects on public health and local economies. This often leads to political decisions that do not recognise the environmental and social benefits that could be obtained through investments in pollution control.

Unsustainable exploitation of fish and other living resources

The unsustainable exploitation of fish and other living resources was considered to be the priority concern in the Pacific Colombian sub-system. The Causal chain analysis focuses on the issue of overexploitation as it is having the most severe impacts, but also considers destructive fishing practices and excessive by-catch and discards.

Immediate causes

Excessive fishing effort

The current level of fishing effort is unsustainable. According to FAO (2004c), catches of marine fish, crustaceans, molluscs and other marine living resources decreased in Colombia between 1992 and 2000.

Destructive fishing practices

The use of destructive fishing gear has resulted in a decline in recruitment and the degradation of the habitat of some commercial species. Today, shrimp trawling nets and gillnets are considered the main threat to marine turtles in Colombian waters.

Excessive by-catch and discards

Although there have been no studies of the level of by-catch in the Pacific Colombian, based on studies in territories within close proximity of the sub-system, it is believed that large quantities of fish are caught as by-catch in the shrimp trawling industry and the majority are discarded.

Root causes

Technology

On the Colombian Pacific coast, non-selective and destructive fishing gear is employed in the artisanal and industrial fisheries. Such gear is used to increase short-term profits, but at the expense of the long-term sustainability of fish stocks. As the distribution of fish species has changed and stocks of traditionally exploited species have declined, the fishing industry has began to exploit stocks which are further offshore using new technologies.

Economy

Investment in the fisheries sector is aimed at increasing catches of species valuable on the international market; there are few incentives to supply local demand.

Legal/Institutional

There is a lack of harmonisation between national and international fisheries policies. Although Colombia has a legal framework for the

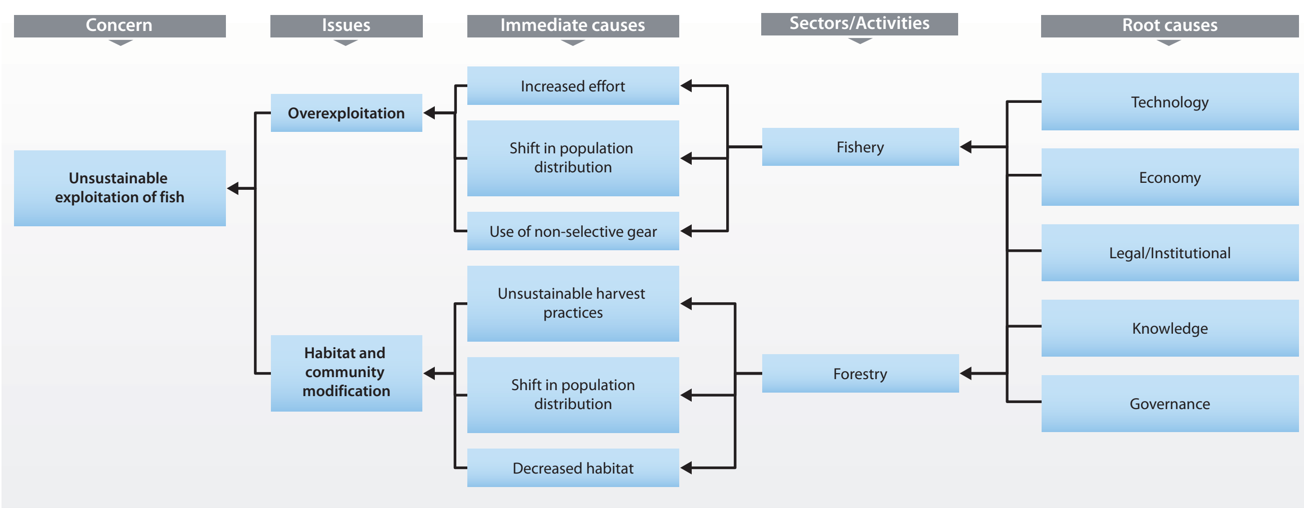

Figure 21 Diagram of the Causal chain analysis of overexploitation in the Pacific Colombia sub-system.

management of natural resources, there is a lack of inter-institutional coordination, resulting in the weak implementation of existing environmental laws. Domestic and foreign fishing fleets are able to avoid legislation due to weak enforcement. Limited stakeholder participation in decision making processes often results in the unsuccessful implementation of fisheries policies.

Knowledge

There is a lack of detailed information about the exploitation and status of fishing resources in Colombia. Although recent data has shown a decreasing trend in the catches of some important species, the long-term effects on fish stocks are unknown. The fisheries are irregularly monitored and there is limited surveillance of aquatic ecosystems (INVEMAR 2003c). The quantity and impact of by-catch and discards produced by the fishing industry in the sub-system, as well as the distribution and influence of introduced species, has not been studied.

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.

Recommendations made by the GIWA regional experts of the Eastern Equatorial Pacific region during the two preparatory meetings coincide with those developed by international forums on water management (UNEP/GPA 2001) and those recommended in the Environmental Plan of Central America (PARCA). The latter established a set of principles to strengthen environmental management and harmonise the approaches, policies and management instruments of the member states of Central America. Box 1 shows the immediate actions recommended by the Latin American Workshop on Wastewater Management (2001).

Box 1 Immediate actions recommended by the Latin American Workshop on Wastewater Management. Mexico 10-12th September, 2001.

1. **Technological:**
- Implement re-use practices; and
- Optimise water use.

2. **Financing**
- Establish financial strategies based on regional, national and river basin priorities;
- Devise self-funding sources; and
- Rating systems that include subsidies aimed at promoting higher coverage of water and sanitation services in deprived areas.

3. **Technical training**
- Training to improve supervision, management and assessment capabilities;
- Personnel training and institutional strengthening in different geographic areas of the sub-system; and
- Develop an emergency response capacity in preparation for potential natural hazards.

4. **Environmental education/dissemination/awareness-raising**
- Promote transparency in public information, such as service quality indicators and environmental quality indicators; and
- Encourage the active participation of the media, civil society and the ministries of education in awareness-raising activities.

5. **Research**
- Develop water and sanitation services and environmental quality indicators;
- Formulate regulations for water supply and waste management based on local knowledge and stakeholder participation;
- Carry out a Latin American diagnosis of management priorities, taking into consideration each country's capacity;
- Undertake case studies in tropical and dry areas;
- Promote the adoption of new management instruments; and
- Evaluate the contribution of diffuse pollution in comparison with isolated pollution.

6. **Legislation/rules**
- Promote land-use planning as an instrument;
- Up-date the laws on water; and
- Promote the spreading and overlapping of administrative roles with regard to water as a resource.

7. **Other**
- Planning (basin-wide); and
- Formulation of public policies at the state level which recognise water as a strategic resource.

Southwest Mexico

Problem definition

Pollution has been identified as the priority concern of the Southwest Mexico sub-system due to the high levels of microbiological pollution recorded in inland and coastal waters and biota. This is attributed to the discharge of untreated wastewater in the river basins of the sub-system. The tourism industry is being adversely affected by polluted beaches and the health risks of microbiological pollution.

Only 26% of Southwest Mexico's population is connected to wastewater treatment (OECD 2003). The sewage infrastructure that does exist is commonly non operational, with most wastewater discharged directly into the ocean or inland waterways without treatment. Coastal tourism development is further increasing the pressure on sewer infrastructure. Regulatory agencies have achieved increasing success in controlling large volume industrial polluters whose wastes flow into federal waterways. However, pollution levels are still high due to a lack of direct control over municipal pollution sources and weak enforcement power which prevents the collection of fines from municipalities who exceed federal pollution limits. Local municipal governments lack technical expertise and financial capacity to create and maintain wastewater treatment networks.

A variety of options to improve the quality of coastal waters along Mexico's tourist beaches were considered. The policy options aim to address the root causes of microbiological pollution in the Southwest Mexico sub-system and are therefore grouped under the various types of root cause.

Policy options

Technology and economy

Rehabilitate existing, and construct new, wastewater treatment facilities

The government of Mexico must recognise wastewater treatment as a priority issue and allocate greater funds for building new and maintaining existing wastewater treatment facilities. In many cases, facilities need to be rehabilitated in order to operate at their designed capacity levels. Investment in sewer systems and wastewater treatment facilities is currently co-funded by federal, state, and local sources. Further funding is often received as loans from various development banks. Since the federal government does not have the legal power to earmark funds for specific purposes, a simple increase in grant funding from the federal level to municipalities is unlikely to leverage funds for the operation and maintenance of treatment facilities. One option would be for the Federal government to match investment made by local governments in treatment facilities with a grant.

Local circumstances define the most appropriate technology and implementation strategy. The financial and technical limitations of local communities must be considered so that the facilities can be operated and maintained locally. There are a wide variety of conventional and less-conventional municipal wastewater treatment technologies available. Large treatment facilities consume a lot of energy, generate large quantities of excess sludge that must be disposed of or used, and require relatively sophisticated equipment that requires highly skilled personnel. Alternatively, technologies such as lagoons, treatment wetlands, anaerobic treatment, and reuse schemes are more sustainable and cost-effective wastewater treatment options. Lagoons and stabilisation ponds are biological treatment options with low operational costs (UNEP 2000). Educating municipal decision makers regarding the various conventional and non-conventional wastewater treatment options will enable them to choose the most appropriate facility for their community.

Introduce a fee-and-rebate system for municipal wastewater

Mexico's current difficulties in enforcing fines on municipalities are an obstacle to developing a system of rebates and fees. A comprehensive study of the feasibility of implementing such a scheme in Mexico is necessary. Box 2 outlines the methodology of a fee-and-rebate system.

Box 2 Fee-and-rebate system

In a fee-and-rebate system, the government sets a threshold pollution level for a municipality or industrial plant. Municipalities receive a rebate for each unit below the threshold or a fee (replacing the fine) for each unit above the threshold. The fees can be used to pay for the rebates. In essence, municipalities choosing to pollute forego the rebate opportunity, and thus face higher costs for polluting. Annex IV gives further details of the proposed fee-and-rebate system.

Demography

Reduce excess water use

Consumers tend pay water rates that are far below the true cost of water extraction and delivery, and, as a result, tend to overuse water. In addition, urbanisation is tending to increase water use, requiring the expansion of wastewater treatment infrastructure (Veenstra et al. 1997). Several strategies can be employed to reduce water consumption. The two main methods are education programmes and a fee-and-rebate system applied to the end-users of water.

By reducing water consumption, less water drains into the sewage system and is needed to be treated, thus reducing costs and the pressure on existing treatment facilities (UNEP 2000). However, the waste becomes more concentrated as domestic waste production per capita remains fairly constant but the concentration of contaminants varies with the amount of water consumed (Veenstra et al. 1997). The effectiveness of this policy option varies according to the local water supplier and only applies to municipalities with existing wastewater treatment infrastructure.

Knowledge

Formulate and implement education and information strategies

Education and information strategies inform the public and government officials about the problems caused by pollution. Increased technical assistance is required for municipalities in the development, operation and maintenance of wastewater treatment infrastructure. The following groups could be targeted by education campaigns:

- *Public officials:* Educating public officials about the costs of water pollution allows them to make more informed and effective decisions related to the control of water pollution.
- *The public:* The coastal population should be aware of the impact of water pollution on the tourism industry, their health and livelihood.
- *Small businesses:* The waste discharged by larger industries has been reduced considerably in response to Federal initiatives. Smaller businesses, which discharge pollutants directly into municipal sewer systems, need to be targeted by education campaigns in order to reduce their contribution.

Publicly rate municipalities for their level of compliance with wastewater treatment standards

Decision makers will be more likely to take action to improve wastewater management if there is lobbying by the public. Grading municipalities according to their level of compliance with water pollution standards and publicising this information will engage the public and allow them to identify which municipalities are failing to maintain adequate water standards. This will foster competition among municipalities which will ultimately improve standards. Introducing a public rating system that applies to all Mexico's larger municipalities will reduce opposition to the current beach pollution rating system. Rating upstream communities allows coastal municipalities to identify the sources of pollution and apply political pressure on polluters.

Legal/Institutional

Create autonomous water districts

This policy option involves the creation of independent wastewater districts consisting of representatives from the relevant municipalities. Despite the involvement of municipal governments, the water district itself should be a separate legal and political entity, with the exclusive responsibility of managing water treatment operations. By removing decisions regarding water treatment from the normal political structures of local municipal governments, federal funding can be targeted at developing treatment infrastructure.

Reform the pollution-related legal framework

Some reform of the Mexican legal framework could provide additional power to regulatory agencies to more effectively control water pollution and guarantee municipal investment in waste treatment infrastructure and operations. These legal reforms fall into two general categories: those designed to make current regulations more effective; and those designed to increase stakeholder participation in waste management.

While the direct regulation of polluters and municipalities is an important control instrument, it creates a dynamic in which polluters are opposed only by federal bureaucrats, not by those harmed by pollution. The victims of pollution can be empowered by being able to take legal action against non-complying industries or municipalities, i.e. to create a system of class-action civil law suits (Zilberman pers. comm.).

Central Equatorial Pacific sub-system

Definition of the problem – Freshwater shortage

Freshwater shortage was considered as the priority aquatic concern of the Central Equatorial Pacific sub-system. Although the sub-system has abundant water resources, they are unevenly distributed and seasonal droughts affect extensive areas, especially during El Niño years. The discharges of several rivers have reduced (Vörösmarty et al. 1998). The high rate of deforestation is increasing erosion and the quantity of suspended sediment in freshwater systems, thus modifying stream flow in several areas of the sub-system. Human activities are polluting both surface- and groundwater supplies in many of the sub-system's river basins. Because groundwater is the main source of freshwater supply, many aquifers are overexploited in the sub-system.

Population growth and urbanisation have led to increasing demand for freshwater resources and the concentration of demand in areas that have limited freshwater availability. Because water supply and sanitation services are subsidised, insufficient revenues are generated to maintain current and invest in new technologies, and the population has no incentive to save water.

Most countries in the sub-system have a weak and outmoded legal framework for water management which does not provide for the incorporation of new criterion and approaches. Institutions weakly implement current legislation, are vulnerable to political pressures, lack trained personnel and have limited budgets. There is a lack of an integrated river basin approach to water management. Traditionally, local stakeholders were not consulted in the management of water resources. Countries in the sub-system lack water monitoring programmes and public awareness of water issues is limited. The indirect benefits that water provides through ecosystem goods and services are rarely valuated.

Countries of the region agreed during the Central American Dialogue about Water, Food and Environmental Sustainability (San Jose, Costa Rica, 2001) to adopt specific policies related to water management (see Annex III). The policy options developed by the regional team of the Central Equatorial Pacific sub-system, presented below, directly address some of the priority root causes identified during the Causal chain analysis.

Policy options

Demographic

Integrate territorial planning with water management

Urban planning regulations are not always enforced in the countries of the sub-system. Even if they are enforced, these regulations usually concentrate on territorial planning rather than addressing freshwater shortage issues. This option would support the countries of the sub-system, using economic and technological instruments, in developing their own policies, legislation and regulations regarding urban planning, which integrate territorial issues (i.e. migration, urban sprawl) with water management.

Promote new development centres in rural areas

Urban water supply services are unable to provide for the increasing numbers of migrants from rural areas. The promotion of new development centres in rural areas, which take into consideration existing activities, may reduce migration to cities. This can be achieved by decentralising productive activities in order to create employment and by improving social security in rural areas, particularly medical care, education, appropriated family planning, water supply and other basic services.

Knowledge

Strengthen and establish further monitoring programmes

The sub-system lacks a monitoring system for the control and surveillance of water quality. This is important for assessing the extent of freshwater shortages and defining the current and potential supply capacity required for urban development. This option would establish financing mechanisms for governmental institutions to develop programmes that monitor the factors determining land occupancy and its affect on water availability and quality, as well as the impact on aquatic ecosystems. The countries of the region need international support in order to initiate urban development programmes which include provisions for regulating water quality and availability. Studies are also required to establish the carrying capacity of the ecosystems at the sub-system level. Databases should be created for decision makers to access policy relevant and current information so that they can develop and adopt appropriate policies.

Develop and implement environmental awareness programmes

The public lack an awareness of water issues and the associated socio-economic impacts, and there is no culture of water conservation. There is a need to recognise the value of water for economic development, particularly when formulating development strategies. There is insufficient information and guidance regarding available techniques for reducing water pollution and treating water. By establishing, promoting and implementing environmental awareness training programmes at the regional level this option aims to develop a culture of water conservation. Awareness programmes should increase environmental consciousness of the importance of a healthy environment and the impact of humans on water resources. This supports the implementation of integrated management plans. To create a water conservation culture in the long-term, formal education programmes should include key environmental issues in their curricula, including those related to water.

Governance, legal and institutional

Reorganise the water sector

Most countries in the sub-system have a weak legal and institutional framework for water management with overlapping responsibilities and a duplication of effort. Some regulations are obsolete or incomplete as they omit provisions for new approaches and administration procedures. The legislation considers water quantity separately from water quality, and river basin and coastal management are not integrated (Escobar 2002).

The water sector needs to be reorganised in the short-term (OPS/OMS 2001a). The modernisation of the water sector should include the separation of operational and oversight powers, based on an appropriate strengthening of the legal and institutional framework. Several countries in the sub-system have policies and a legal framework for water management; others are in the process of developing them and require support. The following options should be considered within an ecosystem-based management approach:

- Promote the exchange of successful and unsuccessful experiences regarding water policies, laws and regulations among the countries of the sub-system.
- Apply common water standards and quality criteria in the countries sharing an international river basin.
- The review of national and regional legal frameworks for water management by a multitude of stakeholders.
- Strengthen the current legal framework based on this review and international recommendations, with an aim of improving the

efficiency and effectiveness of institutions responsible for water management. The reform of the legal framework is necessary in order to improve institutional governance in the region.

- Integrate coastal area and river basin management.
- Implement integrated river basin management to reduce the negative effects on freshwater quantity and quality caused by various water users in different countries sharing a river basin.
- Strengthen the agencies responsible for water management in order to improve water use efficiency and water quality in the long-term.

Technology and economy

Finance the maintenance and expansion of water services by introducing water rates

Currently, insufficient revenues are received to up-date technologies because the governments of the sub-system subsidise water supply and sanitation services. Overuse and waste of water is indirectly promoted by subsides for water supply services. Privatisation agreements do not stipulate that the company purchasing the public service has to strive for greater water efficiencies, adopt cleaner technology or control leaks and other water loses from the distribution network.

The introduction of realistic water rates that reflect the costs of maintenance and the expansion of water services will promote the efficient use of the sub-system's limited water resources. This will provide greater revenues to invest in new appropriated technologies and to develop a water monitoring programme. To improve the acceptability of the increased charges, public awareness of the importance of water conservation needs to be raised. Water users should be charged for the costs of environmental remediation and river basin management according to the quantity of water used, the impact of its activities on the environment, and the mitigation measures it has adopted to minimise this impact. Incentive frameworks are required to encourage the private and public sector to adopt sustainable practices.

Definition of the problem – Pollution

Pollution was considered as the second priority concern of the Central Equatorial Pacific sub-system. Due to the low level of wastewater treatment, pathogenic microorganisms, solid wastes and heavy metals are present along the coasts and in the water bodies of the entire sub-system (PNUMA 2001). Low tariff rates for water and underinvestment in sanitation infrastructure have resulted in a lack of basic sanitation services for the rapidly expanding urban population. At least 12 different diseases have been linked to polluted water in the sub-system (PNUMA 2001).

The intensification of agricultural production to feed the growing population is leading to more agro-chemical pollution. Political will and economic incentives to force or encourage industries and agriculture to adopt more environmentally friendly technologies/practices are lacking. Polluters are not taxed appropriately for the environmental damage that their activities cause.

Legislation and environmental management instruments are often not implemented due to an inappropriate institutional framework and a lack of coordination among the different governmental sectors. River basin management focuses predominantly on water distribution and consumption and stakeholder participation in the decision making process is rarely encouraged. There is a lack of accurate and timely information.

Countries of the sub-system have developed different legal mechanisms to address pollution problems. Annex III outlines some of the regional agreements that include provisions for addressing pollution, such as the Central American Ecological Summit of 1994 and the Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the North-East Pacific (Antigua Convention) adopted in Guatemala, 2002 (see Annex III).

Policy options

Economy

Invest in treatment infrastructure

Substantial investment is required to rehabilitate treatment systems and increase the level of sanitation coverage. The countries of the sub-system do not have sufficient economic resources to develop such facilities. Economic and technological support is required from donors to rehabilitate existing treatment systems and/or to construct new facilities in the countries of the sub-system.

Adopt the polluter pays-principle

Polluters are not charged for the environmental costs their activities cause. Economic sectors are, therefore, given little incentive to adopt cleaner technologies or to treat their wastes in order to reduce the pollutant loads they contribute. Instead, governments subsidise wastewater treatment and agro-chemicals resulting in limited investment in sanitation and more pesticide contamination, respectively.

This option would identify the sectors responsible for pollution and impose load-based charges. The polluter pays-principle can be adopted by implementing realistic tariff rates for wastewater discharges. The principle should be developed based on environmental goals and objectives agreed upon by multiple stakeholders.

Legal/institutional

Review and reform national and regional legal frameworks

There are weak, and in some cases obsolete, legal frameworks and a lack of coordination between the different sectors and institutions responsible for environmental management, many of which have overlapping mandates. International best practice is not considered in national regulations, nor are new approaches related to the use of water. There is little or no coordination between river basin and coastal-marine institutions, limiting the possibility of integrated river basin and coastal area management.

This option proposes the review of national and international legal frameworks for water management in order to reform institutional frameworks at the national level. Based on this review, a regional legal framework should be developed to apply in each country according to their particularities, and water quality regulations should be standardised. National regulations should be based on those inspired by the Antigua Convention (2002).

Strengthen the capacity of the agencies responsible for water management

Existing regulations are ineffectively implemented and enforced. Management instruments and institutional capacity are insufficiently evaluated using, for example, environmental impact assessments and environmental management programmes. Institutional weaknesses, the failure to implement legislation and limited monitoring are the main root causes of pollution in the sub-system. Therefore, institutional strengthening is a priority issue at the regional level.

This option proposes strengthening the agencies responsible for water management by creating mechanisms and opportunities for institutional cooperation in order to adopt a holistic approach to water management, in which the particularities of both coastal and marine areas are considered. The strengthened capacity of the institutions will allow them to implement programmes aimed at controlling and monitoring pollution in coastal and marine areas. In particular, the Network of National Institutions should be established, and coordinated by the Central American Commission for Maritime Transportation in collaboration with UNEP.

Knowledge

Develop and implement environmental awareness programmes

This option would establish, promote and implement environmental training programmes at the regional level. Educational programmes increase the environmental awareness of the population about the importance of waste management. Environmental issues should be included in formal education curricula.

Strengthen information management

Information about water quality is dispersed, not up-to-date and used within specific sectors, thus impeding a holistic understanding of the overall status of water resources. This option proposes the improvement of information exchange mechanisms in the sub-system by strengthening and updating the Regional Network for Resources Monitoring and other initiatives related to water management and surveillance in the sub-system. The countries need to cooperate and share data regarding the water regime of the sub-system. To support the implementation of the Plan of Action for the Protection of the Marine and Coastal Environment of the North East Pacific, there needs to be monitoring and surveillance of pollution from land-based sources. The knowledge base would be improved by monitoring the pollution load of coastal waters.

Pacific Colombian sub-system

Definition of the problem

During the environmental and socio-economic impact assessment of the Pacific Colombian sub-system, it was established that the unsustainable exploitation of fish and other living resources was the principal concern. Despite most of the fisheries in Colombia being small scale and/or subsistence, the current level of exploitation is unsustainable; catches of some traditionally targeted species have declined (INVEMAR 2003c, FAO 2004c). Stocks of freshwater commercial species are also significantly depleted (IIAP 2001b).

On the Pacific Colombian coast, non-selective and destructive fishing gear is used to increase short-term profits at the detriment of fish stocks and marine ecosystems. As the distribution of fish species has changed and stocks of traditionally exploited species have declined, the fishing fleet has began to exploit stocks which are further offshore using new technologies. The fisheries sector concentrates on certain valuable species to supply the export rather than domestic fish market. Existing laws related to the fisheries are weakly enforced allowing domestic and foreign fishing fleets to avoid legislation. There is lack of institutional cooperation, fisheries statistics and stakeholder participation to aid and improve the effectiveness of decision making processes.

Colombia has developed several programmes aimed at addressing the environmental problems affecting its Pacific coast, such as Pacific Agenda 21 and the Project Biopacífico. The policy options proposed in this document should be considered as complementary actions to those recommended in these initiatives. In a broader scope, Colombia has signed several protocols and agreements with other countries of the South East Pacific to address transboundary pollution problems, notably the Convention for the Protection of the Marine Environment and Coastal Areas in the South East Pacific, and the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the South Pacific, which are briefly described in Annex III. The Policy options analysis focuses on mitigating the root causes identified in the CCA, including technology, knowledge, economic and governance drivers.

Policy options

Technology

Transfer of sustainable technologies

The fisheries industry in the sub-system has poor access to modern technologies. The transfer of sustainable technologies can be accomplished through cooperation among national agencies and between municipalities and other regional and local administration institutions.

Knowledge

Enhanced information management and education programmes

There is a need to widely disseminate key, policy relevant scientific findings to individuals and institutions responsible for fisheries management. This requires the active participation of, and cooperation between, the scientific community and local stakeholders. Education campaigns and training courses for local authorities can improve their understanding of scientific findings. Local authorities need access to up-to-date fisheries statistics.

Training courses for community and fishing association leaders may improve the adoption rate of sustainable fishing practices. They are often responsible for the implementation and oversight of appropriated practices and have the power to change the behaviour of fishers. Since education is the responsibility of the government, this approach requires the strengthening of the formal education sector so that it considers environmental issues, including those related to the fisheries. This option would initiate ethno-education focused towards sustainable development and the rational exploitation of living resources (clean production and eco-efficiency). Education should be directed at local communities rather than productive sectors since the current legal framework regulates the activities of the latter.

Governance

Further implement integrated coastal zone management (ICZM)

Coordinate institutional systems by adopting integrated coastal zone management. Colombia has made significant progress regarding this approach including the establishment of the Integrated Management Unit of Guapi Iscuande. Local authorities need to be monitored by regional and national agencies to ensure governmental fisheries strategies are implemented. In parallel to this, the capacity of local authorities needs strengthening regarding the management of fisheries resources.

Strengthen the self-regulation of coastal communities

Strengthen the self-regulation processes of coastal communities so that they receive greater responsibilities which are currently exclusive to the government. For this purpose, responsibilities must be assigned independently of the current political-administrative framework, as geographic boundaries of coastal communities often do not correspond with political boundaries. It is expected that self-regulation will lead to the increased participation of local communities, especially those of Afro-Colombian and indigenous origin, in decision making and implementation. This will legitimise their administrative structures. This proposal follows the results obtained by Ostrom (2000) and is in accordance with the community participation mechanisms stipulated in the National Constitution. The option may prove difficult to implement as local leaders may be unwilling to participate in the process and there may be resistance to change by the authorities. Fishing associations should also be strengthened so the interests of the industry are considered.

Conclusions and recommendations

Southwest Mexico

Pollution was considered to be the priority concern by the regional team. Microbiological pollution was found to have the most severe impacts due to its affect on the tourism industry and the health of the population. Untreated wastewaters from inland and coastal sources enter coastal waters where they degrade marine ecosystems, thus affecting tourism and the commercial fisheries. Some of the sub-system's important tourism beaches are the most polluted in Mexico resulting in the dissuasion of tourists. The contamination of surface- and groundwater has reduced the availability of freshwater for human consumption. Diseases associated with microbiological pollution are highly prevalent in the sub-system.

Sewer and treatment infrastructure, which is commonly dilapidated, has been unable to cope with the increasing quantities of wastewater produced by the booming coastal tourism industry and rapidly growing population. While regulatory agencies have made progress in controlling large volume industrial polluters whose wastes flow into federal waterways, they do not have the jurisdictional power to control municipal pollution sources. Technical and financial deficiencies often prevent local municipalities from developing and maintaining wastewater treatment networks.

Recommendations

Near-term recommendations:

- Formulate and implement education and information strategies;
- Publicly rate municipalities for their level of compliance with wastewater treatment standards; and
- Rehabilitate existing, and construct new, wastewater treatment facilities.

Medium-term recommendations

- Introduce a fee-and-rebate system for municipal wastewater.

Long-term recommendations

- Create autonomous water districts; and
- Reform the pollution-related legal framework.

In conclusion, pollution abatement is a major challenge for Southwest Mexico. Increased understanding among public and policy makers of the causes and effects of pollution, the establishment of communication networks among the stakeholders of a river basin, the creation of incentives as well as penalties for polluters, and greater civil legal powers will shift the political situation in favour of environmental protection. A healthy environment will improve the well-being of the sub-system's population.

Areas for further study

There is a general lack of information and data regarding wastewater management and the transboundary effects of water-related pollution in the coastal zone. This is presenting a significant obstacle to selecting and implementing appropriate policies. The following studies are recommended:

- Initiate studies to quantify the economic impact of coastal water pollution; and
- Conduct a survey of local public officials regarding their attitudes to pollution control.

Central Equatorial Pacific sub-system

The countries of the sub-system are inextricably linked by hydrological processes. Water is a vector transporting not only a wide variety of valuable resources but also problems from one country to another. For example, deforestation in Nicaragua is affecting aquatic ecosystems in

Honduras, Guatemala and Costa Rica due to increased rates of erosion resulting in sedimentation downstream and in coastal areas.

Freshwater shortage and pollution were considered to be the most severe transboundary aquatic concerns in the Central Equatorial Pacific sub-system. Both concerns are interlinked as the discharge of untreated wastewater is contaminating surface- and groundwater, thus reducing the availability of water suitable for human uses. At the same time, population growth and economic development have led to increasing demand for water resources. Water availability per capita has declined by almost two-thirds between the 1950s and 1990s.

With the exception of Panama City, the other capitals and large cities depend primarily on groundwater supplies. In Managua, San José, San Salvador and the valleys of Choluteca and Tegucigalpa the level of groundwater abstraction is exceeding the natural recharge rate of the aquifers. Water supply infrastructure is not satisfying demand and is beset with operational and maintenance failures. Because water supply and sanitation services are subsidised, insufficient revenues are generated to maintain current and invest in new technologies, and the population has no incentive to save water.

These human dimensions to water availability are set against a backdrop of variable climatic conditions throughout the sub-system, with some parts of the region suffering from intense periods of drought with a marked reduction in river flow. The intensity of rainy periods and the severity of droughts are expected to increase in the future. Water scarcity will depress the agriculture sector, the cornerstone of the sub-system's economy, increasing unemployment and migration, and causing food insecurity. Tourism, an increasingly important industry, will also be severely impacted by water shortages.

Municipal wastewater is the major source of pollution in the sub-system; 95% is discharged without treatment. Only 60% of the population has access to sanitation services, which are frequently latrines. ADD and other water-related diseases are the main cause of the high rates of morbidity and mortality in the sub-system.

The root causes of this situation include deficient environmental policies, institutional failures, biased sectorial approaches, resistance to change, the use of obsolete technology, outmoded regulations, and the lack of inter-institutional integration and stakeholder consultative processes.

Recommendations

In order to address pollution in the coastal areas of the Central Equatorial Pacific sub-system, a first step would be the implementation of regional instruments of cooperation such as the Plan of Action for the Protection of the Marine Environment and Coastal Areas of the North East Pacific. The institutions responsible for the management of water and the control of pollution were found to lack administrative and organisational capacity. The selected policy options, therefore, address these institutional inadequacies as a prerequisite.

In the case of freshwater shortage, the following policy options are recommended:

- Develop and implement environmental awareness programmes; and
- Reorganise the water sector.

In the case of pollution, the following policy option is recommended:

- Develop and implement environmental awareness programmes.

Pacific Colombian sub-system

Unsustainable exploitation of fish and other living resources was selected as the priority concern of the Pacific Colombian sub-system. The current level of exploitation is unsustainable; stocks of some traditionally targeted species and coastal shellfish have been depleted. Freshwater commercial species are also less abundant today. The fishing industry tends to target a limited number of species which are valuable on the international market. Despite stocks of these species becoming exhausted, total catches have been maintained or even increased as fishermen are targeting more abundant species in order to sustain their income levels and food security. This has been achieved by the use of new technologies which allow fishermen to exploit stocks which are further offshore in deeper water. They are also using non-selective and destructive fishing gear to increase short-term profits at the detriment of fish stocks and marine ecosystems. It is weak enforcement rather than a lack of laws and regulations that is allowing domestic and foreign fishing fleets to operate illegally. The various institutions responsible for fisheries management inadequately cooperate and fail to involve stakeholders in the decision making process. The lack of fisheries statistics prevents managers from having an accurate understanding of the state of the fisheries.

Colombia has developed several programmes aimed at addressing the environmental problems affecting its Pacific coast, such as Pacific Agenda 21 and the Project Biopacífico. The policy options proposed in this report should be considered as complementary actions to those recommended in these initiatives.

Recommendations

The analysis of the policy options established that under current conditions of environmental management and governance the most feasible option for implementation is:

- Enhanced information management and education programmes.

Following the implementation of the above option, which would result in direct benefits for the management of natural resources, it is also recommended to implement the option:

- Strengthen the self-regulation of coastal communities.

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Annexes

Annex I
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Annex II
Detailed scoring tables

I: Freshwater shortage

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

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	2	35
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	3	55
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	10
Weight average score for Economic impacts		**2.55**	
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	40
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	10
Weight average score for Health impacts		**2.0**	
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	30
Degree of severity	Minimum Severe 0 1 2 3	2	50
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	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	1.85
5. Eutrophication	1	10		
6. Chemical	2	25		
7. Suspended solids	1	5		
8. Solid wastes	2	15		
9. Thermal	0	0		
10. Radionuclides	0	0		
11. Spills	2	10		

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	50
Degree of severity	Minimum Severe 0 1 2 3	2	40
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	10
Weight average score for Health impacts		**2.0**	
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	45
Degree of severity	Minimum Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	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	40	Habitat and community modification	2
13. Modification of ecosystems or ecotones, including community structure and/or species composition	2	60		

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	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	30
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)	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	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		**2.0**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	40	Unsustainable exploitation of fish	2.25
15. Excessive by-catch and discards	2	30		
16. Destructive fishing practices	2	20		
17. Decreased viability of stock through pollution and disease	0	5		
18. Impact on biological and genetic diversity	1	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	25
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	25
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)	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	35
Degree of severity	Minimum – Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	25
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	57	Global change	1.57
20. Sea level change	1	43		
21. Increased UV-B radiation as a result of ozone depletion	0	0		
22. Changes in ocean CO_2 source/sink function	0	0		

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

Annex III
Regional agreements, conventions and projects

Central American Ecological Summit on Sustainable Development (Cumbre Ecológica Centroamericana para el Desarrollo Sostenible), Managua, Nicaragua, 13th October, 1994.

The Presidents of the Republics of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, and the Representative of the First Ministry of Belize, met at the Central American Ecological Summit on Sustainable Development. They made the following commitments, among others:

Water

To prioritise policies and legislation regarding the management and conservation of hydrological resources, including, among others, the strengthening of the legal and institutional framework, and coordination mechanisms between the authorities in charge of the management and administration of water resources either for human consumption, irrigation or electricity generation. Commitments were made for respective authorities to update studies about Central American basins in order to prepare specific projects for their sustainable use and management.

Pollution control

A two year period was allowed for the countries of the region to implement mechanisms for the monitoring and control of pollution. The Central American Commission of Environment and Development is responsible for the gradual implementation of the commitments, the establishment of decentralisation mechanisms for surveillance and control, and the promotion of public participation in these processes.

A Dialogue about Water, Food and Environmental Sustainability, San Jose, Costa Rica, 1st November, 2001.

Conclusions and commitments:

1. Foment integrated water resources management and take into consideration the social, economic and environmental values in order to improve the quality of life.
2. Adopt integrated water resources management, with the river basins being the planning unit.
3. Promote opportunities for dialogue and participation of communities and private, governmental, agricultural and environmental sectors.
4. Formulate guidelines and policies that will assist in the sustainable use and management of water resources.
5. Develop case studies for implementing the Local Dialogues and activities that involve the sustainable use of water.
6. Develop methodologies to assess the economic value of water resources.
7. Produce a Historical Record of the Meeting and distribute internally within each country.
8. Based on the criteria for determining the locations, each country should provide technical support for the proposed locations.
9. Interact as a Virtual Network by means of an electronic forum for discussion.
10. Compile experiences and good practices in the region in order to exchange information.
11. Design a proposal to be presented in Bonn, which should be regional in nature in order to create a larger impact, although this does not eliminate the possibility of generating pilot projects at the micro-basin level.
12. A regional commission was formed to follow up the commitments of "A Dialogue about Water, Food and Environmental Sustainability."

Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the North-East Pacific (Antigua Convention), Antigua, Guatemala, 18th February 2002.

The aim of this Convention is to establish a regional co-operation framework to encourage and facilitate the sustainable development of marine and coastal resources of the countries of the North-East Pacific for the benefit of present and future generations. The contracting parties recognised the need to protect and preserve the marine and coastal environment of the North East Pacific against all kinds of environmental pollution and degradation. The ecological, economic, social and cultural value of the area was seen as a means of bonding the countries of the region. The scope of application of the Convention comprises the maritime areas of the North East Pacific, defined in conformity with the United Nations Convention on the Law of the Sea. The Secretariat of the Convention is the Central American Commission for Maritime Transportation (COCATRAM) located in Managua, Nicaragua.

Marine Corridor for the Conservation and Sustainable Development of the South East Tropical Pacific

This corridor was established on 2nd April 2004 and embraces the islands Galapagos (Ecuador), Gorgona and Malpelo (Colombia), Coiba (Panama) and Cocos (Costa Rica). The initiative reinforces cooperation between these countries in order to protect biological diversity.

Large Marine Ecosystems (LMEs) of the world

Several institutions are providing and fostering scientific and technical support for developing countries to establish new policies and actions in order to eliminate the causes of marine environmental degradation, as well as the loss of biodiversity and food security due to over-exploitation. For the Central American Pacific coast, the LME stretches from Cape Corrientes in Mexico in the north to Ecuador in the south, including the basins of Guatemala and Panama and the Peru-Chile trench. The system is located between the California and Humboldt currents.

Conventions, protocols and projects relevant to the colombian pacific sub-system

Convention for the Protection of the Marine Environment and Coastal Areas in the South East Pacific (1981)

This Convention, also known as the Lima Convention, was signed on 12th November, 1981 by Chile, Colombia, Ecuador, Peru and Panama. It was initiated by the United Nations Environment Programme (UNEP). The main objective of the Convention is to promote regional cooperation in the protection of the marine environment and coastal zones of the South East Pacific, emphasizing the economic, social and cultural significance of the South Pacific.

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

This Plan has the same characteristics as other UNEP Regional Seas Programmes. The main objective of this regional cooperation mechanism is to protect the marine environment and coastal areas in order 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. The Plan of Action for the South East Pacific has the following components:

- Environmental assessment: This provides the scientific basis to implement the other components of the Plan. It comprises an assessment of the pollution caused by oil spills; the degree of pollution caused by industrial, mining and agricultural wastes and their effects; and pollution caused by domestic wastes, radioactive pollution, and from the atmosphere, among others.
- Environmental management: Formulation and application of programmes to prevent, monitor, reduce and eliminate pollution.
- Legal component: The development of regional instruments constitutes 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.

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

This Protocol contains regulations regarding protected areas such as common criteria to establish protected areas and the regulation of activities through an integrated environmental management mechanism. Guidelines include, among others, buffer areas; measures to prevent, reduce and control pollution in protected areas; environmental impact assessments; establishing an integrated analysis procedure; scientific and technical cooperation; and promotion of stakeholder participation and environmental education. This protocol was approved by Colombia through Law 12 (1992).

Protocol on the Program for the Regional Study of the "El Niño" Phenomenon in the South East Pacific (ERFEN) (1992)

The member States of the Permanent Commission for the South Pacific (CPPS; Chile, Colombia, Ecuador and Peru) signed this protocol on 6th November 1992 in Callao, Peru. The aim of ERFEN is to forecast ocean-atmospheric changes with sufficient warning time to allow the issue of policies and emergency measures to limit the impact on productive activities such as fishing, agriculture and industry, among others.

Framework Agreement for the Conservation of Living Resources on the High Seas of the Southeast Pacific (Galapagos Agreement 2000)

The member States of CPPS 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 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 located on the 120° W meridian between 5° N and 60° S.

Pacific Agenda 21

Pacific Agenda 21 has adopted a cultural approach to changing the traditional model of communication between governments and Pacific communities. It attempts to deal with social problems involving various stakeholders and to find solutions to problems that threaten the environmental and cultural diversity of the Colombian Pacific region. The objective of Pacific Agenda 21 is to provide a local perspective, through the participation of stakeholders, to long-term policies, plans and programmes for the development of this area, taking into account the ethnic, cultural, social and economic realities of the Colombian Pacific (IIAP 2001a).

Project Biopacifico

This project, implemented by INDERENA and the National Department of Planning, focuses on the Choco biogeographic region. The general objective of the project is to contribute towards the consolidation of a new development strategy, based on scientific knowledge, and to identify options for the management of biodiversity in order to guarantee its protection and sustainable use by local communities. The goals of the project include, among others: i) assessment of the state of the region's biodiversity and the current practices affecting its use and conservation; ii) assessment of the dynamics and effects of agro-ecological systems; iii) development of conceptual and methodological approaches for the valuation of biodiversity and environmental services; iv) strengthening of communication, education and social organisation processes related to the conservation and exploitation of biodiversity; v) training of authorities about policies, planning and decentralized management of biodiversity; vi) training of local people who are involved in conservation and the sustainable use of biodiversity; and vii) institutional coordination with other regional and national plans, programmes and projects (INDERENA 1992).

Annex IV
Fee-and-rebate system (Southwest Mexico sub-system)

Adjustable implementation features of fees and rebates

A fee-and-rebate system for municipal waste can be adapted for specific requirements. There are opportunities to decide on the number and features of municipalities in the programme, the threshold or target level of pollution, and the size of the rebates and fees. In addition, innovative programmes have started to integrate fee and rebate systems with tradable pollution permits.

Which cities to include

A fee-and-rebate system does not have to include every municipality. Given that most municipal waste stems from urban areas and that wide gaps in financial resources exist between urban and rural zones, it is more practical to focus a fee-and-rebate system on larger cities. The population threshold can be set by SEMARNAT. Mexico already has different water infrastructure policies for rural and urban areas. The same distinctions can be retained in the implementation of a fee-and-rebate system.

Setting pollution thresholds

Threshold limits for pollution – where rebates switch to fees – have to be set. The thresholds can be based on the prior history of pollution; the population of the city; or environmental health indicators.

Basing threshold levels on prior history requires every city, regardless of their past history of pollution, to make additional effort to meet the threshold. This method favours cities which have not introduced any pollution abatement methods. These municipalities will usually be able to take advantage of more lower-cost technologies than cities that were reducing water pollution before the implementation of fees and rebates.

Basing allowable pollution levels on a municipality's population provides room for adjustment, and rewards cities who have already made an effort to reduce and/or treat water pollution. Allowing time for municipalities to update their wastewater infrastructure capacity prior to implementation increases the political viability of the fee and rebate structure.

Basing threshold levels on environmental health standards places the main focus on safeguarding the local environment (as opposed to aggregate watershed pollution). Standards have frequently been set in the form of Total Maximum Daily Loads – maximum pollution levels on waterways where the wastewater is discharged. This method places a heavier burden on large cities and does little to reduce the pollution per capita in smaller cities and cities that discharge wastewater into larger waterways. The population of the city and the size of the receiving water body affect the overall pollution levels in waterways. Large cities can reduce wastewater pollution per capita, but have few options to reduce the overall city population.

Setting fees and rebates

When it comes to municipal water pollution, the commitment to a fee-and-rebate system has to be credible and long-term. Cities will make decisions about whether or not to invest in wastewater treatment infrastructure based on expected future returns. Year-to-year uncertainty about the size of the rebates and fees complicates local decisions about investment in water pollution infrastructure, and may deter investment. Nonetheless, this does not mean fees and rebates must remain fixed. It does, however, require advanced warning regarding upcoming changes to the structure of the fee and rebate system.

A five year timetable of fee-and-rebate changes is recommended so that municipalities can calculate the costs and benefits of their investments in wastewater infrastructure. Although the fee changes require some advance notice, the penalties and rebates themselves do not have to be fixed in a given year. Penalties and rebates can be graded. SEMARNAT can charge smaller fees per-pollution-unit to municipalities that exceed the threshold by only a little and larger fees per-pollution-unit for those that significantly exceed threshold levels.

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Eastern Equatorial Pacific 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.

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

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.

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:

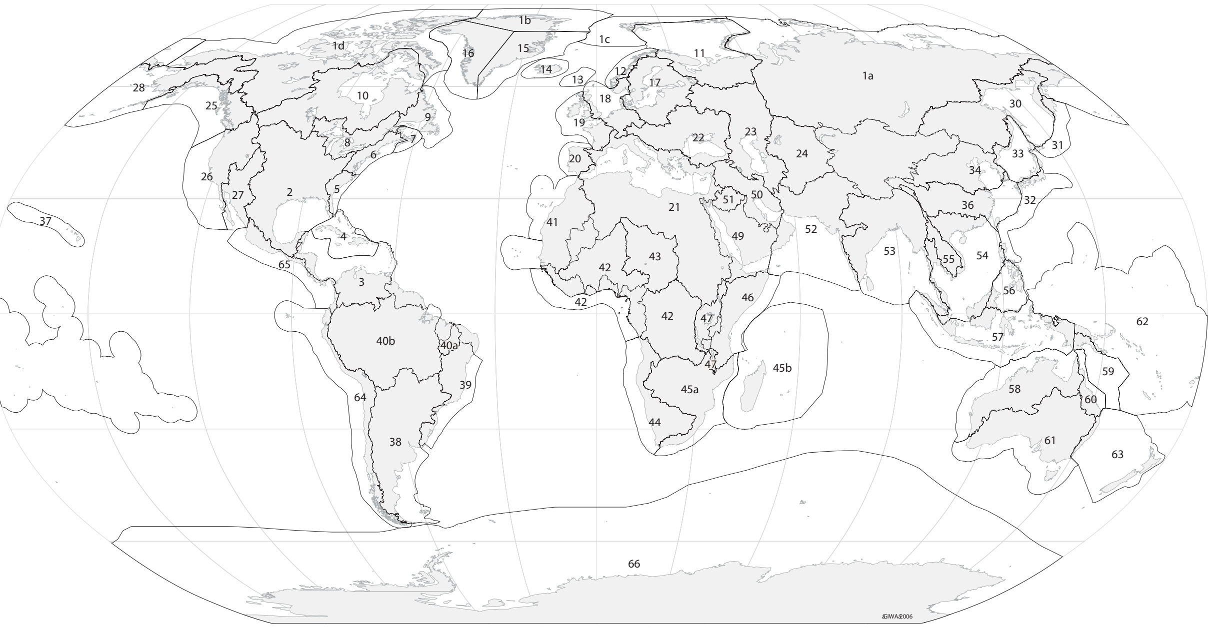
- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater 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)



- 1a Russian Arctic (4 LMEs)
- 1b Arctic Greenland (LME)
- 1c Arctic European/Atlantic
- 1d Arctic North American
- 2 Gulf of Mexico (LME)
- 3 Caribbean Sea (LME)
- 4 Caribbean Islands (LME)
- 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 Sea (LME)
- 21 North Africa and Nile River Basin (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 Bering Sea (LME)
- 30 Sea of Okhotsk (LME)
- 31 Oyashio Current (LME)
- 32 Kuroshio Current (LME)
- 33 Sea of Japan (LME)
- 34 Yellow Sea (LME)
- 36 East China Sea (LME)
- 37 Hawaiian Archipelago (LME)
- 38 Patagonian Shelf (LME)
- 39 Brazil Current (LME)
- 40a Northeast Brazil Shelf (2 LMEs)
- 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
- 49 Red Sea and Gulf of Aden (LME)
- 50 Euphrates and Tigris River Basin
- 51 Jordan
- 52 Arabian Sea (LME)
- 53 Bay of Bengal
- 54 South China Sea (2 LMEs)
- 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 Pacific Islands
- 63 Tasman Sea
- 64 Humboldt Current (LME)
- 65 Eastern Equatorial Pacific (LME)
- 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).

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.

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.

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

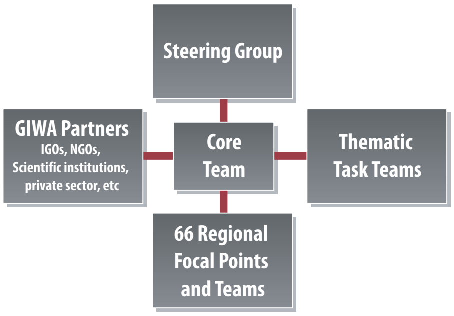


Figure 2 The organisation of the GIWA project.

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.

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.

Global International Waters Assessment

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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**

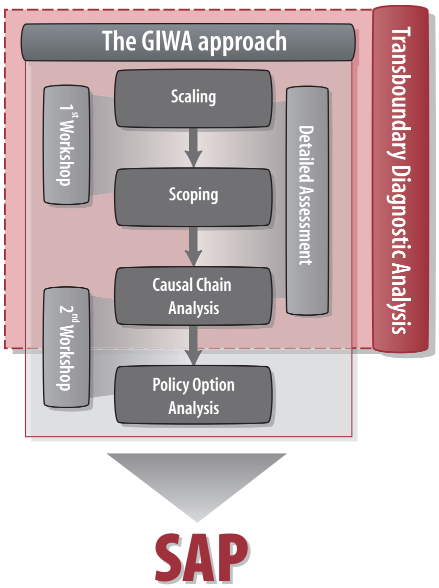

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

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 km^2); 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 km^2; 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 km^2 .	■ 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 km^2;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 assessment of the GIWA Eastern Equatorial Pacific region, which includes parts of Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama and Colombia. Pollution in the Southwest Mexico sub-system, freshwater shortage in the Central Equatorial Pacific sub-system, and the unsustainable exploitation of fish and other living resources in the Pacific Colombian sub-system were considered as the priority concerns. The root causes of these water-related problems are identified and policy options are proposed.

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