# XIV-48 Pacific Central-American Coastal: LME #11

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The Pacific Central-American Coastal LME extends along the Pacific Coast of Central America, from 22ºN off Mexico down to 4ºS. It is shared by Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia and Ecuador. The LME covers a surface area of nearly 2 million $km^2$, of which 1.42% is protected, and includes 0.22% of the world's coral reefs and 0.78% of the world's sea mounts (Sea Around Us 2007). Re-circulating coastal currents and milder temperatures than those of the adjacent California Current and Humboldt Current LMEs characterise this LME (Bakun *et al*. 1999). Much of the Pacific Central-American Coastal LME is influenced by the seasonal movements of the Inter-tropical Convergence Zone (Bakun *et al*. 1999). The region is vulnerable to the ENSO phenomenon, which affects productive activities, infrastructure, natural resources and the environment in general. The climate varies from tropical to temperate, with a dry period during the winter months. During the rainy season from May to September, rivers discharge significant volumes of freshwater and suspended solids into the coastal areas of this LME (Windevoxhel *et al*. 2000). Extreme ocean depths are reached very close to the coast due to a narrow and steep continental shelf. Book chapters and reports on this LME are by Bakun (1999), Bakun *et al*. (1999), Lluch-Belda (1999) and UNEP (2006).

## I. Productivity

The Pacific Central-American Coastal LME could be considered a Class I, high productivity ecosystem (>300 $gCm^{-2}yr^{-1}$). Several mechanisms, other than the classic eastern ocean upwelling produced by Ekman transport, are important sources of nutrient enrichment in this LME. The mechanisms include equatorial upwelling, open ocean upwelling driven by wind stress curl, and episodic downwind coastal upwellings forced by mountain gap winds from the Caribbean, as well as the mechanism underlying the Costa Rica Dome structure (Bakun *et al*. 1999). In addition, nutrient inputs also come from river run-off along the tropical areas of this LME (FAO 1997). Upwelling plumes extending offshore are located off the three major mountain ranges of the region (Bakun *et*. *al*. 1999). An extensive minimum oxygen layer exists off Mexico and Central America (Wyrtki 1965, Bianchi 1991), with oxygen levels low enough to have major effects on the composition and migration of the biological communities (Bakun *et al*. 1999). The large-scale monthly mean ocean temperatures remain above 26ºC throughout the year and, as a consequence, the marine fauna of this LME is tropical and distinctly different from the predominantly temperate fauna of the California and Humboldt systems (Bakun *et al*. 1999). Threatened species such as turtles and sharks are of particular concern in the region.

***Oceanic Fronts*** (Belkin and Cornillon 2003; Belkin et al. 2009): Most fronts within this LME (Figure XIV-48.1) are generated by coastal upwelling. Some fronts off the Pacific coast of Central America originate from quasi-regular bursts of topographically generated winds blowing from the Caribbean across Central America toward the Pacific Ocean. Local orography tends to channel these winds and make their direction exceptionally stable and predictable, especially in the Gulf of Tehuantepec where these winds result in formation of upwelling zones and fronts that bound them extending far offshore (Belkin & Cornillon 2003). This is the only place in the World Ocean where such fronts are observed.

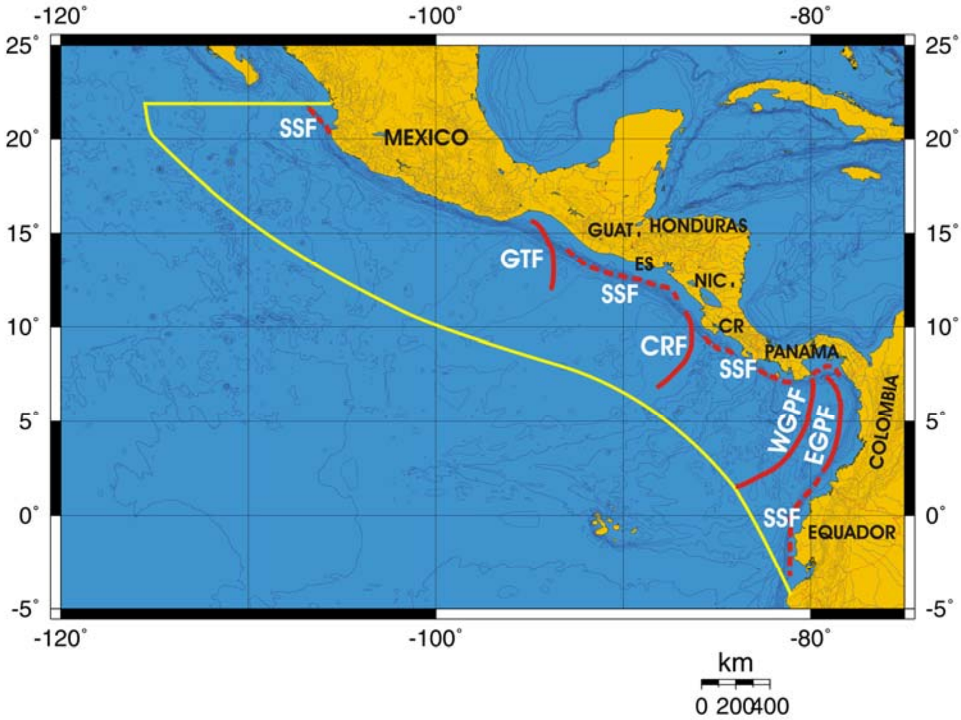



**Figure XIV-48.1. Fronts of the Pacific Central-American Coastal LME. CR, Costa Rica; CRF, Costa Rica Front; EGPF, East Gulf of Panama Front; ES, El Salvador; GTF, Gulf of Tehuantepec Front; GUAT, Guatemala; NIC, Nicaragua; SSF, Shelf-Slope Front (most probable location); WGPF, West Gulf of Panama Front. Yellow line, LME boundary. After Belkin et al. (2009).**

***Pacific Central-American Coastal LME SST*** (Belkin 2009)(Figure XIV-48.2)
Linear SST trend since 1957: 0.29°C.
Linear SST trend since 1982: 0.14°C.

The Central-American Pacific LME experienced moderate warming over the last 50 years. However, the thermal history of this LME was non-monotonous. The cooling phase culminated in the two minimums, in 1971 and 1975, both associated with major La Niñas ((National Weather Service/Climate Prediction Center, 2007), after which the SST rose by approximately 1°C over the next 30 years. The absolute minimum of 1975 was synchronous with absolute minima in two other East Pacific LMEs: California Current LME and Gulf of California LME. The minimum also was roughly synchronous with the absolute minimum of 1974-1976 on the other side of the Central American Isthmus, in the Caribbean LME. The warming phase was accentuated by two sharp peaks, in 1983 and 1997, both associated with major El Niños (National Weather Service/Climate Prediction Center, 2007). Similar peaks (warm events) were also observed in other East Pacific LMEs, namely the Humboldt Current, Gulf of California, and California Current. The warm event of 1992, concurrent with a strong El Niño, was less conspicuous in this LME compared with other East Pacific LMEs. In general, all significant maxima and minima of SST observed in this LME are associated with El Niños and La Niñas respectively (National Weather Service/ Climate Prediction Center, 2007). This strong correlation is not surprising giving the location of this LME in the Eastern Tropical-Equatorial Pacific, where El Niños' and La Niñas' effects are most conspicuous.

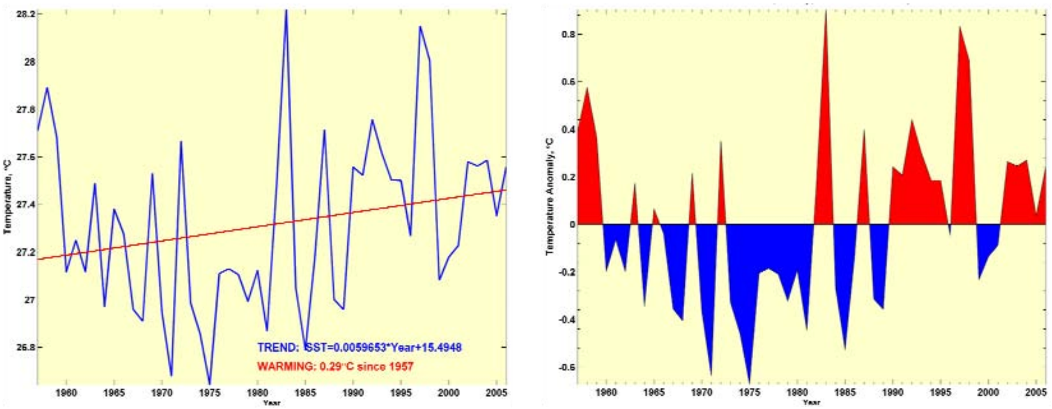



**Figure XIV-48.2. Pacific Central-American Coastal LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).**

***Pacific Central-American Coastal LME Chlorophyll and Primary Productivity:*** The Pacific Central-American Coastal LME is a Class I, high productivity ecosystem (>300 $gCm^{-2}yr^{-1}$)(Figure XIV-48.3).

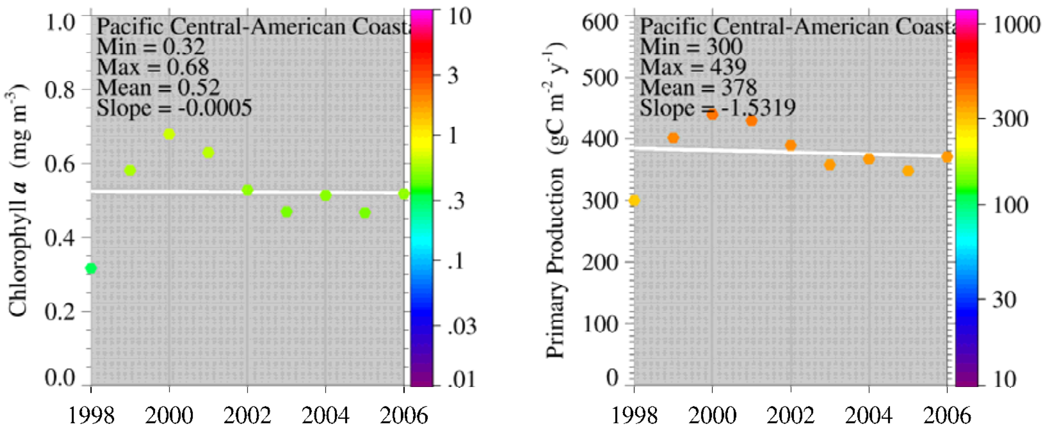



**Figure XIV-48.3. Pacific Central-American Coastal LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hude. Sources discussed p. 15 this volume.**

## II. Fish and Fisheries

The Pacific Central-American Coastal LME is rich in both pelagic and demersal fisheries resources. The most valuable fisheries in the region are offshore tunas and coastal penaeid shrimps. More than 50% of the shelf catches consists of small coastal pelagic species such as anchoveta (*Engraulis ringens* and *Cetengraulis mysticetus*), South American pilchard (*Sardinops sagax*) and the Pacific thread herring (*Opisthonema libertate*), most of which are used for fish meal and fish oil. Artisanal shark fisheries also operate in El Salvador and Guatemala. In addition to the capture fisheries, aquaculture of penaeid shrimp is an important economic activity.

Total reported landings have risen, with some fluctuations, to peak landings of 730,000 tonnes in 1994 (Figure XIV-48.4). The species composition of the landings has also fluctuated, particularly between anchovies and South American pilchard. These fluctuations coincide with the most important El Niño events and are related to the dramatic and simultaneous inter-decadal regime shifts in marine fish populations in other Pacific LMEs associated with El Niño (Bakun 1999, Lluch-Belda 1999). Fluctuations in the value of the reported landings correspond with the landings, with a peak of US$548 million (in 2000 US dollars) recorded in 1994 (Figure XIV-48.5).

It should be cautioned, however, that the underlying landing statistics in this LME, particularly those reported by the countries south of Mexico, strongly underestimate the true catch (see, e.g., Wielgus et al. 2007 for Columbia) and represent, in several instances, a bias toward landings of exported species (e.g., lobsters, shrimps), while those sold on local markets by artisanal fishers are often ignored (see also Bakun *et al*. 1999).

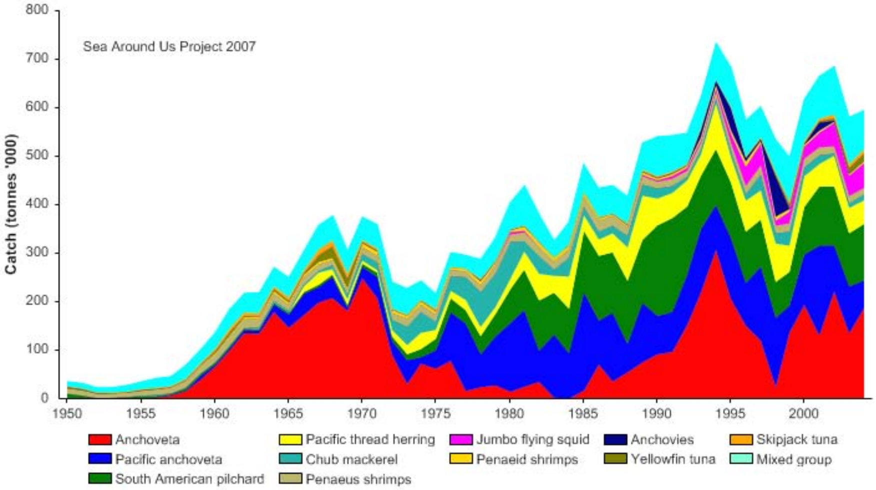



**Figure XIV-48.4. Total reported landings in the Pacific Central-American Coastal LME by species (Sea Around Us 2007).**

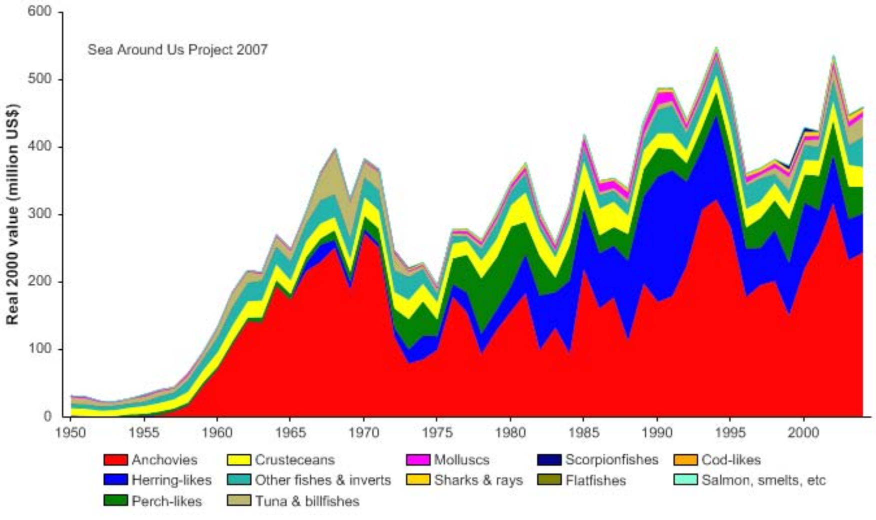



**Figure XIV-48.5. Value of reported landings in the Pacific Central-American Coastal LME by commercial groups (Sea Around Us 2007).**

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME reached 5% of the observed primary production in 2002 (Figure XIV-48.6). Mexico, Ecuador, El Salvador, Peru and Panama account for most of the ecological footprint in this LME.

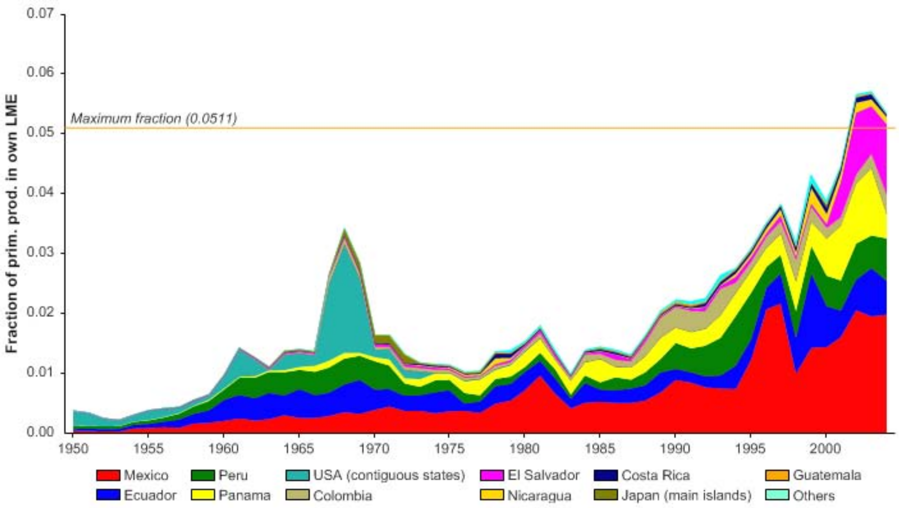



**Figure XIV-48.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Pacific Central-American Coastal LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.**

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) is relatively low, and shows a declining trend until the mid 1980s, after which a slight increasing trend became apparent (Figure XIV-48.7 top). The FiB index has increased, indicating that 'fishing down' (Pauly *et al*. 1998) occurring in the LME would be masked by either the geographic (offshore) expansion of the fisheries (Figure XIV-7.7 bottom) or the incompleteness of the underlying statistics as indicated above.

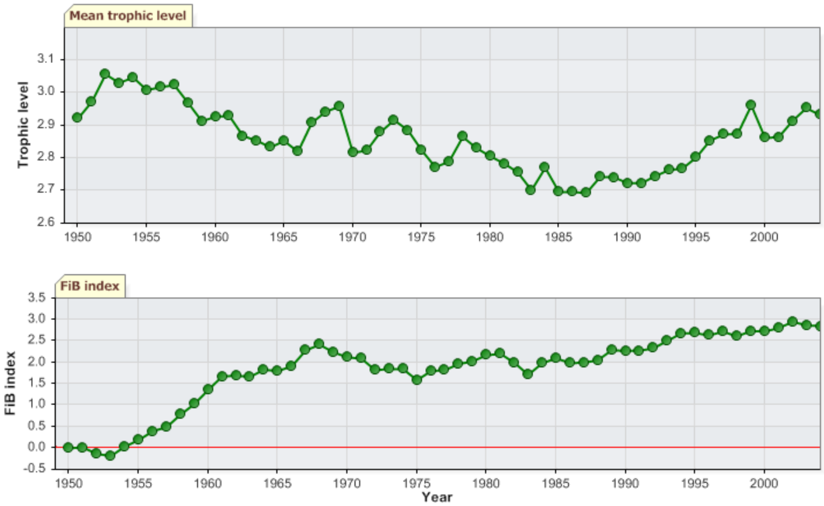
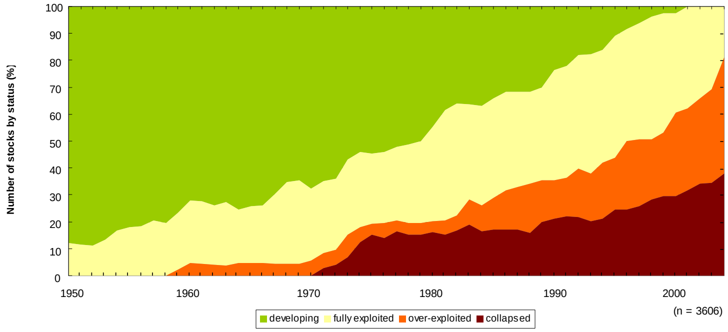



**Figure XIV-48.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Pacific Central-American Coastal LME (Sea Around Us 2007).**

The Stock-Catch Status Plots indicate that the number of collapsed and that overexploited stocks are rapidly increasing in the LME (Figure XIV-48.8 top). Approximately 40% of the reported landings are supplied by fully exploited stocks (Figure XIV-48.8 bottom).



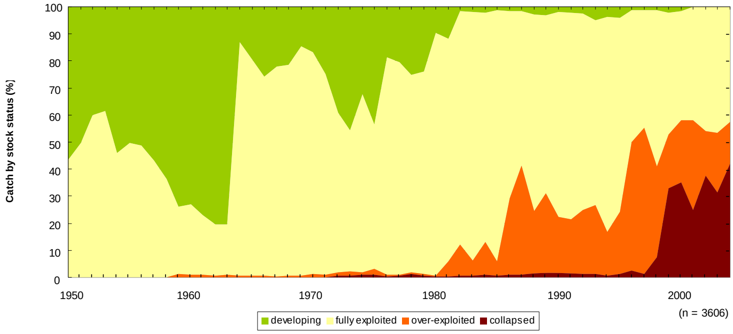




**Figure XIV-48.8. Stock-Catch Status Plots for the Pacific Central-American Coastal LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).**

In general, overexploitation was found to be moderate in this LME, although it was severe in Colombian waters (UNEP 2006), with several traditionally fished stocks showing signs of overfishing. For example, most of the shrimp stocks are considered to be overexploited (Bakun *et al*. 1999, FAO 2005a), although the reported landings of shrimp trawlers have not substantially declined. In Costa Rica, the landings of the shrimp trawler fleet increased between 1993 and 2002. However, closer examination reveals that the increase was due to larger catches of finfish, suggesting that when the shrimp stocks were reduced, greater fishing effort was focused on high-value fish (FAO 2005a). Fishery resources in the Gulf of Nicoya have come under heavy pressure from the rapid growth of the small-scale fleet in the past 20 years. As a result, there has been a reduction in the catch per unit effort of the most valuable species and the sizes of fish and shrimp caught.

Numerous species of demersal fish are under heavy fishing pressure from the shrimp fisheries, in which they are commonly taken as bycatch (Bakun *et al*. 1999). The shark stocks in the Gulf of Fonseca are also showing signs of depletion. Other overexploited stocks include several species of Lutjanidae, Sciaenidae, Centropomidae and Serranidae (CCAD/IUCN 1999). In the Gulf of Fonseca, some molluscs and crustacean species are overexploited by the artisanal fishery and several others such as the tropical rocky oyster (*Ostrea iridescens),* green lobster (*Panulirus gracilis*) and crab (*Menipe frontalis*) are fully exploited (CCAD/IUCN 1999).

Likewise, the level of bycatch and discards and the use of destructive fishing practices were assessed as generally moderate, but severe in Colombian waters (UNEP 2006). Several hundred species of demersal fish, especially early life history stages, are taken as bycatch in the shrimp trawl fishery, which also has the highest rate of discards. Many of these bycatch species have potential economic value, but do not sustain major commercial fisheries in the region (Bakun *et al*. 1999). Nonetheless, their effective level of exploitation could be high as a result of pressure from the shrimp fishery, which probably inhibits the development of fisheries for these species (Bakun *et al*. 1999). Furthermore, the juveniles of about 30 different groups are discarded during the catching of shrimp larvae for aquaculture in the Gulf of Fonseca (CCAD/IUCN 1999). This is of particular concern since it is likely affecting the recruitment of several commercial species and threatening the long-term sustainability of both aquaculture and artisanal fisheries. No assessment of marine mammal bycatch has been conducted, although Palacios and Gerrodette (1996) suggested that the rate could be as high as that in other parts of the Pacific coast of South America.

The current level of fisheries exploitation is unsustainable, and overexploitation is expected to worsen (UNEP 2006) as a result of increasing coastal populations and further increases in fishing effort in the traditional fisheries. However, there is a potential for the development of fisheries for other species such as mid-sized pelagics and other oceanic species as well as deepwater shrimps (Bakun *et al*. 1999). Among the most pressing needs is the development of systems for improved data collection and monitoring, since the fisheries catch statistics in the bordering countries are generally poor and unreliable (Bakun *et al*. 1999). Future conditions will depend on the effective implementation of conservation and development projects directed towards the environmental sustainability of the region.

### III. Pollution and Ecosystem Health

***Pollution***: Population growth, poorly planned urban development, tourism and industrial and agricultural activities exert significant pressures on the Pacific Central-American Coastal LME, partly as a result of the associated discharges of waste into the aquatic environment (IDEAM 2002). Although pollution was found to be generally moderate in this LME, it was assessed as severe in some localised areas, including in the transboundary Gulf of Fonseca (UNEP 2006). Land-based pollution is potentially more damaging in the coastal waters because of the numerous sheltered bays and gulfs in which pollutants are not easily dispersed. About 95% of the wastewater produced in the bordering countries is untreated and reaches the Pacific Ocean with high loads of organic matter, nutrients and other pollutants (PNUMA 2001). The limited available information indicates accumulation of pesticides, heavy metals and other pollutants in coastal areas, with unknown impacts on the marine biota. High concentrations of pathogenic micro-organisms have been recorded in some areas (CPPS 2000). For example, in Puntarenas, Costa Rica, total coliform bacteria concentrations between 16 - 20 million MPN[1]/100 ml and between 2 - 9.2 million MPN/100 ml for faecal coliforms have been reported (Wo-Ching & Cordero 2001).

Wastewater discharges and agriculture run-off are the main source of anthropogenic nutrient enrichment in the LME. Fertiliser consumption increased from 76 kg $ha^{-1}$ in 1990 to about 131 kg $ha^{-1}$ in 2000 in the countries in the central part of the LME. It is

[1] MPN: Most Probable Number

estimated that the coastal waters in the region receive 120,300 tonnes nitrogen $yr^{-1}$ and around 14,500 tonnes phosphorus $yr^{-1}$ (PNUMA 2001). The high rate of deforestation, poor agricultural practices and associated increase in erosion and runoff also contribute to elevated nutrient levels to this LME (PNUMA 2001). As a consequence, eutrophication is evident in coastal areas of e.g. Panama (Panama Bay), Nicaragua (Corinto, El Realejo, Estero Chocolate, La Esparta, El Real), El Salvador (Jiquilisco Bay) and Costa Rica (Gulf of Nicoya) (PNUMA 2001). Harmful algal blooms (HABs) associated with eutrophication have also been observed (Rubio *et al*. 2001). These factors combined with the input of wastewater, are producing a significant amount of suspended solids and high sedimentation in some coastal areas (CCAD/IUCN 1999, Rubio *et al*. 2001, Sánchez 2001).

Chemical contamination is highly concentrated in some areas of the Pacific coast (Jameson *et al*. 2000). Heavy metals such as lead, copper and chromium have been reported in sediments and surface waters in several countries of the region, especially in Panama, Nicaragua and Costa Rica (Sánchez 2001, Wo-Ching & Cordero 2001). Discharges from agricultural areas are a major source of pollution by persistent toxic substances. The level of pesticides used in the region is one of the highest in Latin America, and their presence has been reported in discharges of several rivers (Rubio *et al*. 2001, Wo-Ching & Cordero 2001). Pesticides have been found in fish, crustacean and mollusc tissue in some areas (Rubio *et al*. 2001).

Over 15 million tonnes of solid waste are produced annually in the region, about 44% of which originates in coastal settlements (PNUMA 2001). However, the collection of solid waste is generally inadequate, or it is disposed of in inappropriate sites or discharged directly into water bodies. Litter accumulation has reduced the aesthetic value of coastal areas and presents a permanent risk for fishing and maritime traffic in the region. Most oil spills are chronic and occur in ports and storage sites. The heavy traffic on the shipping lanes to North and South America and Asia, which parallel almost the entire length of the coastline, increases the threat of oil spills in the LME. Another potential source of oil pollution is the trans-isthmus oil pipeline (PNUMA 1999). Small spills also come from the cities when oils and other hydrocarbons are eliminated through the sewerage system and finally disposed of in coastal areas.

***Habitat and community modification*:** The LME's coast is characterised by its many peninsulas, gulfs and bays, as well as extensive intertidal areas, barriers and well developed coastal lagoons. An important geographic feature is the transboundary Gulf of Fonseca, which is shared by Nicaragua, Honduras and El Salvador. Poorly planned urbanisation and economic development along the Pacific coast is leading to the accelerated degradation and destruction of economically and ecologically important habitats. Habitat modification was found to be moderate in this LME (UNEP 2006). Even protected areas are being affected, with about 35% of protected areas showing some type of deterioration in 2001 from various causes such as sedimentation, mangrove destruction, pollution and overfishing (PNUMA 2001).

Of the coastal habitats in the LME, mangroves are the most affected by human activities and there are reports of mangrove destruction throughout the region (CCAD/IUCN 1999, Rubio *et al*. 2001, Sánchez 2001). Mangrove forests have been cleared for several purposes including aquaculture, agriculture, urban development, firewood, building material and tannin production. Conversion to aquaculture ponds is, however, a major cause of mangrove loss in the region. At least 90% of the shrimp farms have been constructed on former mangrove or salt pond areas. All mangroves in the transboundary Gulf of Fonseca have been affected (CCAD/IUCN 1999). The mangrove area in the Gulf was reduced from 1,049 $km^2$ in 1976 to 691 $km^2$ in 1997. In addition, the Gulf is also polluted by run-off from extensive banana plantations in the coastal areas. In the central parts of the LME, only a small proportion of the mangrove area is relatively stable, the remaining areas being considered vulnerable (wet Pacific coast), in danger (Gulf of Fonseca and the northern dry coast), or critical (the southern part of the dry coast) (PNUMA 2001). About 98% of the estuaries are estimated to be affected by sedimentation, wastewater and agro-industrial residuals. The effects of mangrove destruction include an increase in coastal erosion, higher penetration of the saline wedge in some estuaries, soil salinisation and decrease of biological productivity with direct effects on artisanal fisheries.

The LME's coral reefs have been affected by sedimentation, oil spills, pesticides and trawling activities (Escobar 1996, PNUMA/IUCN 1998). Also, some reefs were severely impacted by the 1982-1983 El Niño event, which caused mass coral bleaching and mortality in all areas (Spalding *et al*. 2001). In Costa Rica, recovery has generally been good and, despite repeated bleaching in 1992 and 1997-1998, coral cover remains high in most areas. In contrast, recovery on many reefs in Panama has been poor. Pollution and habitat and community modification are expected to increase in the future, if the growth of poorly planned coastal urbanisation and development continues (UNEP 2006). This could be compounded by lack of adequate sanitation service and waste treatment and disposal facilities, and requires an increase in the provision of sanitation services as well as the strengthening of measures to prevent and control pollution and habitat degradation in the region. The crucial nature of transboundary issues within this region are demonstrated by the situation in the transboundary Gulf of Fonseca (Bakun *et al*. 1999). Threats to the finely structured habitats of this LME pose important concerns for biodiversity preservation and resource sustainability.

## IV. Socioeconomic conditions

In 2002, the total population of the Pacific Central-American Coastal LME region was about 180 million, 80% of which is found in Colombia and Mexico (WRI 2004). Within these countries, some of the most impoverished people have migrated to the coast where they manage to make a meagre living from subsistence fishing and farming. The main economic activities in the coastal zone are tourism, fisheries, aquaculture and agriculture, as well as shipping and industrial activities (Bakun *et al*. 1999). Fish export value is substantial for Mexico, Nicaragua, Panama and Ecuador and the export of frozen crustaceans represents a significant source of foreign exchange. In 2001, the export value of frozen crustaceans was US$281 million in Ecuador, US$450 million in Mexico, US$33 million in Nicaragua and US$80 million in Panama (FAO 2005b). This LME is located on the intercontinental maritime route with intensive commercial exchange and tourist activity through the region. The most important site of maritime traffic is the Panama Canal, with an annual average of 14,300 ships (1990-1998) and income of US$420 million (PNUMA 2001).

Overexploitation, pollution and habitat modification have moderate socioeconomic impacts in the bordering countries (UNEP 2006). Fishing is of high social and economic significance for coastal populations, being a major source of protein, employment and income. However, total catches do not satisfy the local demand because investments are directed towards international markets. This has a direct impact on coastal populations by affecting social stability and creating food insecurity. About 28% of children below five years of age have nutritional problems. A study has shown that the number of artisanal fishers has increased but fish production has decreased (CCAD/IUCN 1999). This is producing lower incomes from fishing and an increase of the population living in extreme poverty. In the Gulf of Fonseca, the increasingly restricted and scarce marine resources associated with ongoing economic activities have had negative social impacts by further marginalising traditional human users of mangroves, wetlands and marine resources (DANIDA 1997).

Pollution and eutrophication in coastal areas also threaten the food security of the coastal communities by affecting the harvesting of shellfish and other living resources. Available information indicates the accumulation of pesticides, heavy metals and other pollutants in coastal areas. Coastal water pollution also has negative impacts on commercial fisheries and tourism and endangers the health of swimmers. A growing number of environmental refugees are encroaching on sensitive areas in need of protection.

### V. Governance

The Pacific Central-American LME coastline is shared by Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia and Ecuador. Each of these countries has laws and institutions related to management of the marine environment and its resources at the national level. However, there is need for the strengthening of local administrations for effective monitoring and management as well as for improved data collection (Bakun *et al*. 1999). Greater awareness is also required among local people and governments of the importance of preserving ecosystem integrity, especially for key coastal habitats like mangrove swamps and coral reefs. The marine environmental initiatives in the region are partly governed by international conventions such as UNCLOS, the UN Fish Stocks Agreement and the FAO Code of Conduct for Responsible Fisheries.

Regional initiatives include the Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific (Antigua/Guatemala Convention), which was signed by Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama in 2002. Key parts of this convention address the high levels of sewage and other pollutants being discharged from urban areas into the Pacific Ocean. Another priority is the assessment of risks from oil pollution and a strategy to deal with such events including an evaluation of the region's access to clean-up equipment and personnel. The Northeast Pacific Regional Seas Programme includes Colombia, Costa Rica, El Salvador, Guatemala, Honduras and Panama and is based on the Antigua/Guatemala Convention. The Central American Commission for Maritime Transportation acts as secretariat for the Northeast Pacific Regional Seas Programme. El Salvador, Honduras, Nicaragua are preparing the project 'Integrated Ecosystem Management of the Gulf of Fonseca' for GEF support. The development objective of the proposed project is to prevent the degradation and maintain the ecosystem integrity of the Gulf of Fonseca through an integrated approach to managing its land and water resources and promoting their sustainable use. The project's global objective is to implement a regional cooperative framework for the management of the Gulf that will result in enhanced environmental protection of international waters and strengthen the conservation of globally significant coastal and marine habitats.

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