XVI SOUTH WEST ATLANTIC

XVI-52 North Brazil Shelf LME

S. Heileman

The North Brazil Shelf LME extends along northeastern South America from the boundary with the Caribbean Sea to the Parnaíba River estuary in Brazil (Ekau & Knoppers 2003). It has a surface area of about 1.1 million km^2, of which 1.69% is protected, and contains 0.01% of the world's coral reefs and 0.06% of the world's sea mounts (Sea Around Us 2007). The hydrodynamics of this region is dominated by the North Brazilian Current, which is an extension of the South Equatorial Current and its prolongation, the Guyana Current. Shelf topography and external sources of material, particularly the Amazon River with its average discharge of 180,000 m^{3}s^{-1} (Nittrouer & DeMaster 1987), exert a significant influence on the LME. This is complemented by discharge from other rivers such as Tocantins, Maroni, Corantyne, and Essequibo. A wide continental shelf, macrotides and upwellings along the shelf edge are some other features of this LME. Book chapters and reports pertaining to the LME include Bakun (1993), Ekau & Knoppers (2003), UNEP (2004a, 2004b).

I. Productivity

The North Brazil Shelf LME is considered a Class I, highly productive ecosystem (>300 gCm^{-2}yr^{-1}), with the Amazon River and its extensive plume being the main source of nutrients. Primary production is limited by low light penetration in turbid waters influenced by the Amazon, while it is nutrient-limited in the clearer offshore waters (Smith & DeMaster 1996). Primary productivity on the continental shelf has been found to be greatest in the transition zone between these two types of waters, occasionally exceeding 8 gCm^{-2}day^{-1} (Smith & DeMaster 1996). In addition to high production, the food webs in this LME are moderately diverse. Brazil's coral fauna is notable for having low species diversity, yet a high degree of endemism.

Oceanic Fronts (Belkin *et al.* 2008)(Figure XVI-52.1): Major fronts within this LME are associated with outflow from the Amazon River and, to a lesser extent, that of the Orinoco River. The Amazon plume initially turns northwestward and flows along the Brazil coast as the North Brazil Current. Off the Guiana coast, between 5°N and 7°N, the North Brazil Current retroflects and flows eastward. This retroflection develops seasonally and produces anticyclonic rings of warm, low-salinity water that propagate northwestward toward Barbados, the Lesser Antilles Islands and eventually the Caribbean Sea. The second major source of fresh water is the Orinoco River plume. Most thermal fronts are associated with salinity fronts related to freshwater lenses and plumes originated at the Amazon and Orinoco estuaries. Such fronts are relatively shallow, sometimes just a few meters deep. Nonetheless, these fronts are important to many species whose ecology is related to the upper mixed layer. Fresh lenses generated by the Amazon and Orinoco outflows persist for months, largely owing to the sharp density contrasts across TS-fronts that form their boundaries (in case of fresh, warm tropical lenses, the temperature and salinity contributions to the density differential reinforce each other).

North Brazil Shelf LME SST (Belkin 2008)(Figure XVI-52.2):
Linear SST trend since 1957: 0.22°C.
Linear SST trend since 1982: 0.60°C.

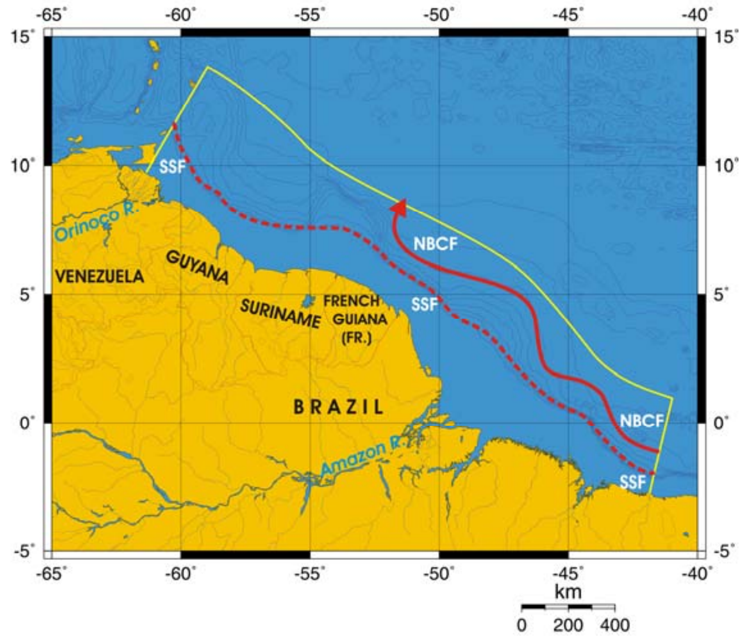

Figure XVI-52.1. Fronts of the North Brazil Shelf LME. Acronyms: NBCF, North Brazil Current Front. SSF, Shelf Slope Front (most probable location. Yellow line, LME boundary. After Belkin *et al.* (2008).

The North Brazil Shelf's thermal history over the last 50 years started with a long-term cooling that culminated in the all-time minimum of 27.3°C in 1976, followed by warming until present. Using the year of 1976 as a true breakpoint, a linear trend would yield a 0.9°C increase over 30 years, which would place the North Brazil Shelf among moderate-to-fast warming LMEs. The North Brazil Shelf thermal history is decorrelated from the adjacent South Brazil Shelf. This can be explained by decoupling of their oceanic circulations. Indeed, the North Brazil Shelf is strongly affected by the North Equatorial Current and Amazon Outflow, whereas the South Brazil Shelf is affected by sporadic inflows of Subantarctic waters from the south and also by offshore oceanic inflows from the east.

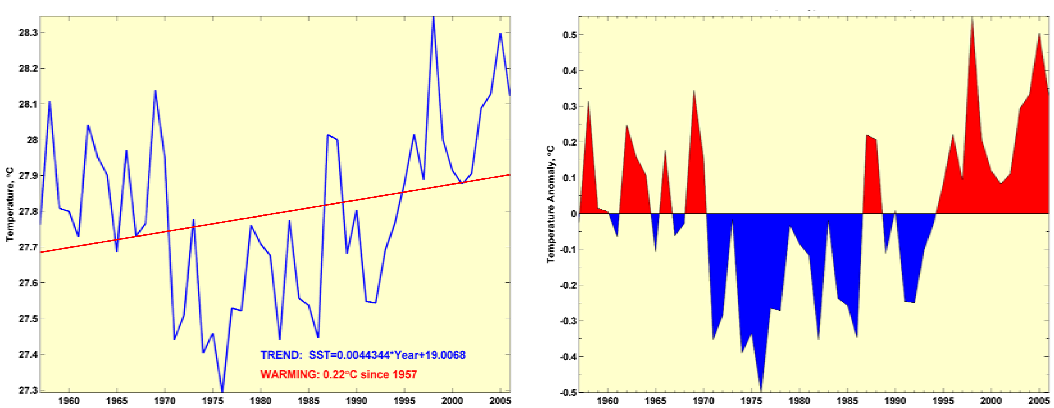

Figure XVI-51.2. North Brazil Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

North Brazil Shelf LME Chlorophyll and Primary Productivity: The North Brazil Shelf LME is a Class I, highly productive ecosystem (>300 $gCm^{-2}yr^{-1}$)(Figure XVI-51.3).

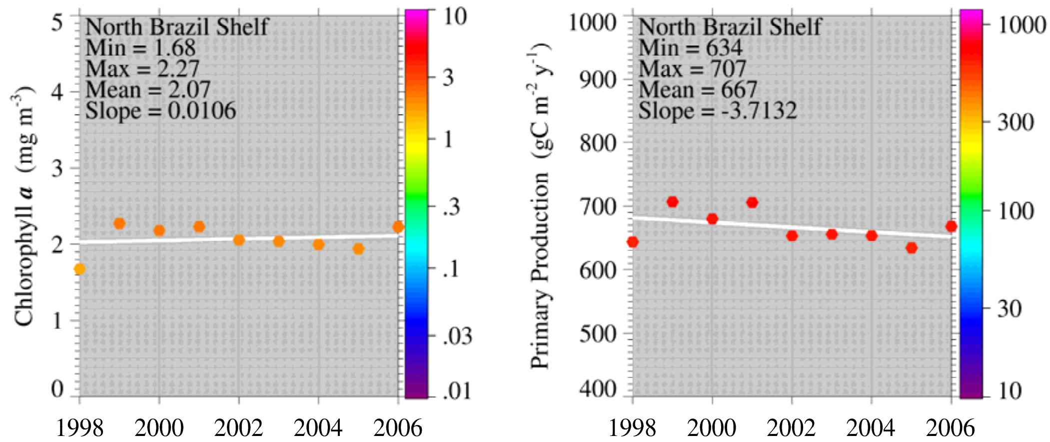

Figure XVI-51.3. North Brazil Shelf LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The multispecies and multigear fisheries of the North Brazil Shelf LME are targeted by both national and foreign fleets (FAO 2005 and see below). Major exploited groups include a variety of groundfish such as weakfish (*Cynoscion* sp.), whitemouth croaker or corvina (*Micropogonias furnieri*) and sea catfish (*Arius* sp.). The shrimp resources, such as southern brown shrimp (*Penaeus subtilis*), pink spotted shrimp (*P. brasiliensis*), southern pink shrimp (*P. notialis)*, southern white shrimp (*P. schmitti*) as well as the smaller seabob (*Xiphopenaeus kroyeri*) support one of the most important shrimp fisheries in the world. Tuna is also exploited, and although its catch weight is relatively small, its value is significant. Total reported landings in this LME underwent a steady increase from 1950 to just over 290,000 tonnes in 2004 (Figure XVI-52.4) and the value of the reported landings reached US$532 million (in 2000 US dollars) in 2004 (Figure XVI-52.5).

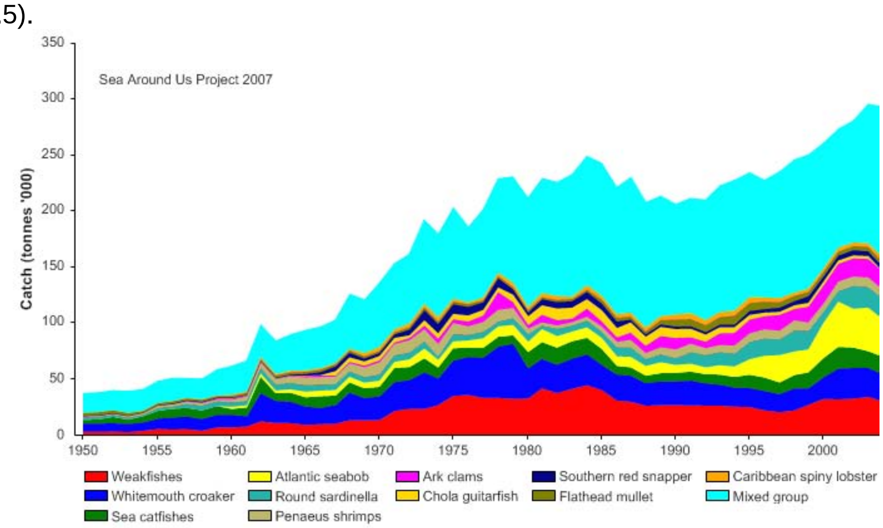

Figure XVI-52.4. Total reported landings in the North Brazil Shelf LME by species (Sea Around Us 2007).

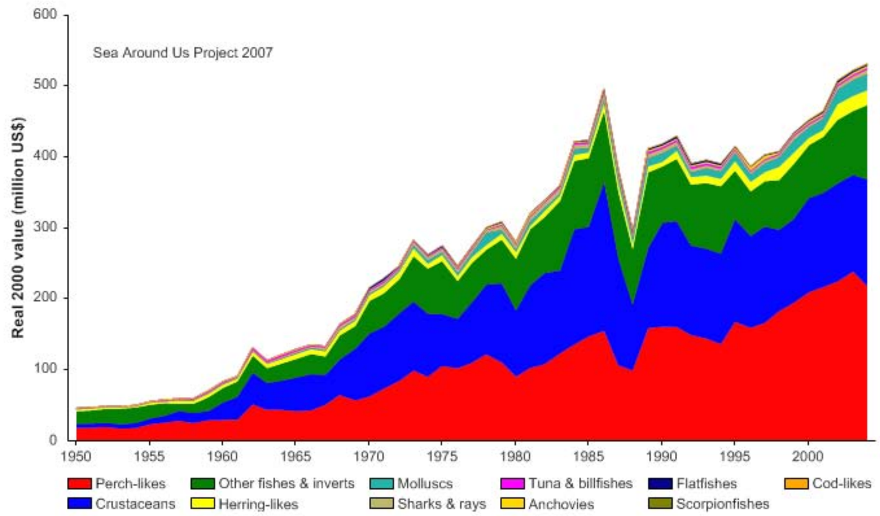

Figure XVI-52.5. Value of reported landings in the North Brazil Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is low, currently at 3% of the observed primary production (Figure XVI-52.6). Brazil has the largest share of the ecological footprint in this LME, followed by Venezuela and Guyana.

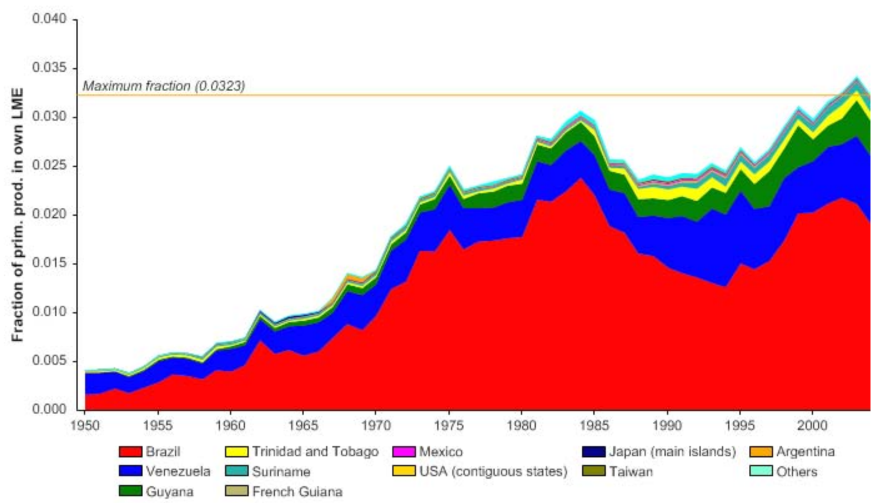

Figure XVI-52.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the North Brazil shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

From the mid 1980s, the mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) has undergone a steady decline (Figure XVI-52.7, top), a trend indicative of a 'fishing down' of the food webs (Pauly *et al.* 1998) in the LME, while the flatness of the FiB over the same period (Figure XVI-52.7, bottom) implies that the increase in the reported landings have not compensated for the decline in the mean trophic level. A detailed study of ecosystems in the region by Freire (2005) has found similar trends using local catch data.

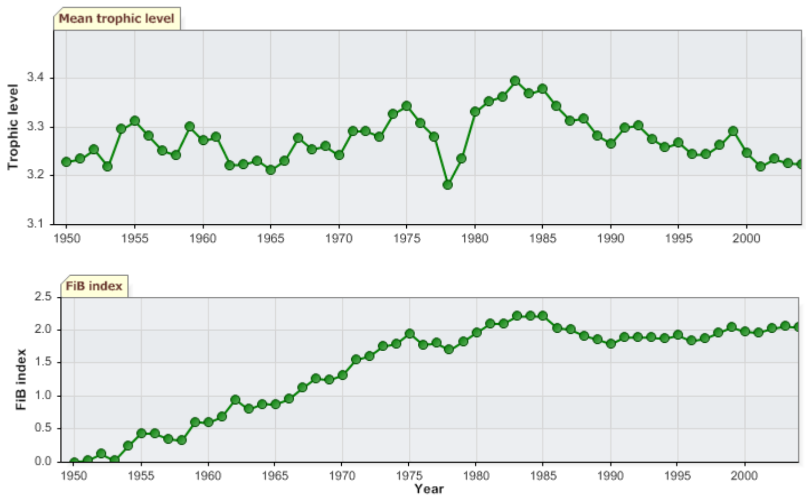

Figure XVI-52.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the North Brazil Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that over 60% of commercially exploited stocks in the LME are either overexploited or have collapsed (Figure XVI-52.8, top). However, 70% of the reported landings come from fully exploited stocks (Figure XVI-52.8, bottom).

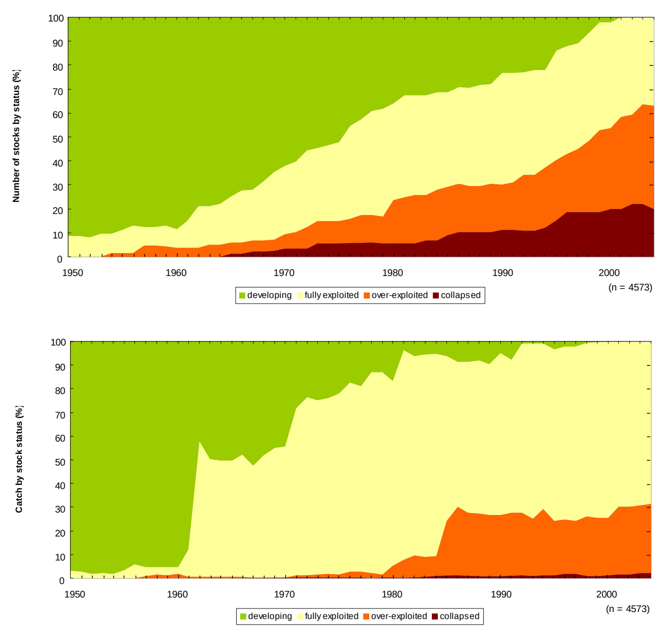

Figure XVI-52.8. Stock-Catch Status Plots for the North Brazil Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

Detailed analysis of the fisheries in this LME confirms this diagnosis of severe overexploitation. There is evidence that some of the fisheries may be fully exploited or overexploited in relation to MSY, particularly some of the groundfish stocks. Where assessments have been undertaken, there are clear signs of overexploitation of the southern red snapper (*Lutjanus purpureus*) resource (UNEP unpubl), with declining catch rates and a decrease in the size of this species (Charuau *et al*. 2001, Charuau & Medley 2001). Recent trends in catch per unit effort and other analyses indicate that the corvina is now overexploited in some areas, with the low stock levels of this species being commensurate with exploitation levels beyond the MSY level (Alió *et al*. 2000, Alió 2001). Similarly, lane snappers (*L*. *synagris*), bangamary (*Macrodon ancylodon*) and sharks are also showing signs of overexploitation (Alio 2001, Ehrhardt & Shepard 2001a). Moreover, a decrease in the average size of some groundfish species has raised sustainability issues (Booth *et al*. 2001, Chin-A-Lin & IJspol 2001). The increasing capture of small individuals is potentially compromising recruitment to the spawning stock (Souza 2001). For instance, in Brazil, immature southern red snappers comprise over 60% of the catch of this species (Charuau *et al*. 2001). Trawl and Chinese seines harvest bangamary at ages far below the age at maturity (Ehrhardt & Shepherd 2001a).

In general, all the shrimp species in the region are subjected to increasing trends in fishing mortality (Ehrhardt 2001) and the fishery is generally overcapitalised (Chin-A-Lin & M. IJspol 2001). Stocks of brown and pink spotted shrimp may be close to being fully exploited (Charuau & Medley 2001, Ehrhardt 2001, Ehrhardt & Shepherd 2001b, Negreiros Aragão *et al*. 2001), with the latter being overexploited in some areas (Ehrhardt & Shepherd 2001b). There has been a general downward trend in the abundance of brown and pink shrimps, particularly during the late 1980s and throughout the 1990s. The trends in fishing mortality were not high enough to have created the very conspicuous decline in abundance, which implies that environmental factors (seasonal river run-off and rainfall) may be more significant than fishing in determining recruitment in these species.

Excessive bycatch and discards and destructive fishing practices are severe, and are of concern throughout the LME. The shrimp bycatch issue is well known in the region, where the bycatch/shrimp ratios are typically between 5 and 15:1 (Villegas & Dragovich 1984, Marcano *et al*. 1995). Many commercial species, predominantly young individuals, comprise the bycatch, most of which is discarded dead at sea. Several species have practically disappeared from the bycatch, indicating a dramatic shrinking of their populations, notably in the case of sharks (Charlier 2001). The operation of trawlers in shallow areas also causes extensive physical damage to benthic habitats and their communities (Charlier 2001). The use of explosives and poisons on the reefs (bleach for capturing octopus) and mangroves (toxic chemicals to capture crabs), capture of immature individuals through diving as well as the use of nets to catch lobsters, which drag sediments, animals and calcareous algae from the sea floor, have also been reported in this region (UNEP 2004a).

III. Pollution and Ecosystem Health

Pollution: Overall, pollution was found to be moderate, but severe in localised hotspots near urban areas. Most of the pollution is concentrated in densely populated and industrialised coastal basins, and not widespread across the region. Water quality in the coastal areas is threatened by human activities that give rise to contamination from sewage and other organic material, agrochemicals, industrial effluents, solid wastes and suspended solids (EPA/GEF/UNDP 1999).

Effluents from industries are released, sometimes untreated, into the water bodies. Contamination by mercury as well as by chemical agricultural wastes is the main source of chemical pollution in the Amazon Basin (UNEP 2004b). Gold is exploited in all the countries of the region and mercury from gold mining operations is dispersed into the air. It is assumed that the largest part ends up in rivers, transforms into methyl-mercury and other chemical compounds and concentrates along the food chain. Mercury contamination could, on the longer-term, become a hazard for the coastal marine ecosystem and for human health, if suitable measures to limit its use are not implemented. There is also the potential risk of pollution from oil extraction, both in the coastal plain and the sea.

Agricultural development is concentrated along the coast and includes intensive cultivation of sugarcane, bananas and other crops. This involves the application of large quantities of fertilisers and pesticides, which eventually end up in the coastal environment. Sugarcane plantations along the coast are also suspected to contribute persistent organic contaminants, which are widely used in pest control, to the coastal habitats (UNEP 2004b).

As a result of the coastal hydrodynamics in this LME, the potential for transboundary pollution impacts is significant. River outflow is deflected towards the northwest and influences the coastal environment in an area situated west of each estuary. It has been estimated that 40-50% of the annual Amazon run-off transits along the Guyana coast (Nittrouer & DeMaster 1987). In fact, Amazon waters can be detected as far away as the island of Barbados (Borstad 1982). As a result, most of the coastal area of the Brazil-Guianas region has been described as an 'attenuated delta of the Amazon' (Rine & Ginsburg 1985). This implies that contaminants in river effluents, particularly those of the Amazon, could be transported across national boundaries and EEZs.

Habitat and community modification: Human activities have led to severe habitat modification in this LME. Mangroves, which dominate a major part of the shoreline, have been seriously depleted in some areas, for example, in Guyana, where mangrove swamps have been drained and replaced by a complex coastal protection system (EPA 2005. Likewise, on the Brazilian coast, the original mangrove area has been significantly reduced by cutting for charcoal production and timber, evaporation ponds for salt and drained and filled for agricultural, industrial or residential uses and development of tourist facilities (Marques *et al*. 2004). In Brazil, erosion also threatens coastal habitats and some coastal lagoons have been cut off from the sea.

In the past, the coral reefs were mined for construction material. Currently, they are exposed to increased sedimentation due to poor land use practices and coastal erosion, chemical pollution from domestic sewage and agricultural pesticides, overfishing, tourism and development of oil and gas terminals (Maida & Ferreira 1997). Additionally, there has been some coral bleaching associated with climate variation (Charlier 2001).

Trawlers often operate without restriction in the shallower areas of the shelf, over ecologically sensitive areas inhabited by early life stages of shrimp. The environmental impact of such activities is likely to be high, considering the intensity of shrimp trawling operations in these areas (Ehrhardt & Shepherd 2001b). Evidence from other regions suggests that precautionary measures should be undertaken in environmentally sensitive areas of the continental shelf (Ehrhardt & Shepherd 2001b). Trawlers also catch significant quantities of finfish as bycatch, of which dumping at sea is still a widespread practice in the region (FAO 2005). This is especially damaging to the stocks when the bycatch includes a significant portion of juvenile fish. In Suriname, small-scale fishers have reported the incidence of 'dead waters', in shallow areas, following fishing activity by trawlers (Charlier 2001). These dead waters were scattered with dead fish in larger amounts than could have been discarded by the trawlers. Vast areas were devoid of live fish, as they had apparently died or moved out of the area. Such mortality could be the result of local oxygen depletion, caused by the re-suspension of anoxic sediment combined with the presence of organic matter dumped from the vessels.

Growth of the local human population and pressures associated with urban and industrial development will continue to threaten the health of the LME. The problems are, however, potentially reversible, considering that there is a greater public and governmental awareness about environmental issues and several measures at national and regional levels are being taken to address some of these problem.

IV. Socioeconomic Conditions

Brazil (states of Amapá, Pará, Maranhão), French Guiana, Guyana, Suriname and the southeastern part of Venezuela border this LME. A high percentage of the total population consists of indigenous communities. Human uses of the coastal zone include subsistence agriculture, fisheries, exploitation of clay and sand and limited ecotourism. Marine fisheries constitute an important economic sector in the region, providing foreign exchange earnings, employment and animal protein. A significant portion of the region's population depends upon fishing for its survival and is unable to substitute other sources of animal protein for fish protein (UNEP 2004b). In Guyana, the fishery sector is of critical importance to the economy and to social well-being. The economic contribution of Guyana's fisheries has grown dramatically in recent years, contributing about 6% to GDP and employing about 10,000 persons (FAO 2005). Furthermore, fish protein is the major source of animal protein in Guyana, with per capita consumption of about 60 kg in 1996, more than four times the world average (FAO 2005). In general, unsustainable overexploitation of living resources as well as environmental degradation may result in threats to the food security of fishers and loss of employment, as well as loss of foreign exchange to the countries of this LME. Because of shrinking resources and degradation of habitats, a number of development projects have been implemented to support local communities.

V. Governance

Fisheries management issues in the countries bordering the North Brazil Shelf LME are complicated because of the variety of gears used, and the multi-species and multinational nature of the groundfish fisheries. This situation is further complicated by the paucity of data pertaining to the biology and productivity of the region's fish stocks and catch and fishing effort. As a consequence, confidence in stocks assessments is low (Booth *et al*. 2001). The countries have ongoing programmes for environmental and natural resource management and coastal zone management and most have established several national marine parks and protected areas.

The countries are parties to several international environmental agreements, for example CBD, UNFCCC, UNCLOS, MARPOL and Ramsar Convention on Wetlands. Brazil, Guyana, Peru, Suriname and Venezuela, along with Bolivia, Colombia, Ecuador and Peru have developed a project for support by GEF: 'Integrated Management of Aquatic Resources in the Amazon' For the Brazilian Amazon River Basin. The project, approved for Work Program Entry in June 2005, recognises the close linkages between integrated water resource management and the protection of marine habitats. The general objective of this project is to strengthen the institutional framework for planning and executing, in a coordinated and coherent manner, activities for the protection and sustainable management of the land and water resources of the Amazon River Basin, based upon the protection and integrated management of transboundary water resources and adaptation to climatic change.

The first phase of the project will involve strategic planning and institutional strengthening, including the development of a TDA of the Basin and preparation of a Framework SAP. Brazil has applied for the GEF biodiversity project ‘Strengthening the Effective Conservation and Sustainable use of Mangrove Ecosystems in Brazil through its National System of Conservation Units’. The aim of the project is to develop conservation and sustainable management of mangrove ecosystems in Brazil to conserve globally significant biodiversity and key environmental services and functions important for national development and the well-being of traditional and marginalised coastal communities.

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XVI-53 East Brazil Shelf LME

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The East Brazil Shelf LME encompasses that part of the Brazilian coast from the Parnaíba Estuary in the North to Cape São Tomé in the South (Ekau & Knoppers 2003). It covers a surface area of about 1.1 million km^2, of which 0.86% is protected, and contains 0.33% of the world's coral reefs and 0.58% of the world's sea mounts (Sea Around Us 2007). The South Equatorial Current, which splits into the North Brazil Current and the southward-flowing Brazil Current, dominates the LME. Coastal upwelling of nutrient-rich South Atlantic Central Waters characterises the area south of Abrolhos Bank in spring and summer (Summerhayes *et al*. 1976). About 35 rivers, the largest of which are the Jequitinhonha, Mucuri, Doce and Paraíba do Sul rivers, drain into the coastal areas. Estuaries include São Francisco and Paraíba. Apart from the Abrolhos Bank, this LME has a narrow continental shelf. A tropical climate characterises this LME. LME book chapters and articles pertaining to the South Brazil Shelf LME include Bakun (1993), Ekau & Knoppers (2003), UNEP (2004).

I. Productivity

The East Brazil Shelf LME is a typical oligotrophic system, poor in nutrients and phytoplankton biomass, except in areas of upwelling where primary production is enhanced (Gaeta *et al*. 1999). The oligotrophic character of the eastern shelf system and its diverse food web structure is in clear contrast to the Southeast-South shelf system (Ekau & Knoppers 1999). The LME can be considered a Class II, moderate productivity ecosystem (150-300 gCm^{-2}yr^{-1}). Highest biomass and densities of pico-, nano-, micro- and macro-plankton typify the southern coast and the Abrolhos Bank (Susini-Ribeiro 1999). The macro-zooplankton is dominated by calanoid and cyclopoid copepods. Mesopelagic species dominate the ichthyofauna community in waters more than 200 m deep. On the Abrolhos Bank, demersal ichtyoplankton species, largely herbivorous fish, dominate the system possibly relying on the primary production of benthic algae. The Abrolhos Bank and the Vitória-Trindade Ridge form a topographical barrier to the Brazil Current, inducing fundamental changes and spatial variability in physical, chemical and biological features over the shelf and along the shelf edge (Castro & Miranda 1998, Ekau & Knoppers 1999).

Oceanic Fronts (Belkin *et al.* 2008)(Figure XVI-53.1): This LME includes the bifurcation of the westward South Equatorial Current near Cabo de São Roque (5.5°S; Belkin *et al*. 2008) that gives rise to two currents and associated fronts: the northward North Brazil Current Front (NBCF) and the southward South Brazil Current Front (SBCF). Within this LME the SBCF is most noticeable in salinity; it becomes distinct as a temperature front from the South Brazil Bight southward (see South Brazil Shelf LME). The NBCF is year-round, best defined in austral winter; it extends along the coast into the North Brazil Shelf LME. The Southern Bahia Front (15°S-19°S) and the Cabo Frio Front (20°S-24°S) are caused by wind-induced upwelling and are best developed during austral summer and fall, from January through June.

East Brazil Shelf LME SST (Belkin 2008)(Figure XVI-53.2):

Linear SST trend since 1957: 0.57°C.
Linear SST trend since 1982: 0.30°C.

Figure XVI-53.1. Fronts of the East Brazil Shelf LME. Acronyms: NBCF, North Brazil Current Front; SBCF, south Brazil current Front; SSF, Shelf Slope Front (most probable location). Yellow line, LME boundary. After Belkin *et al.* (2008).

Like the adjacent South Brazil Shelf, the East Brazil Shelf experienced a long-term warming at a slow-to-moderate rate. The most significant event since 1957 was a 1°C warming in 1981-84, similar to and concurrent with the South Brazil Shelf warming. Both LMEs are linked by shelf-slope along-frontal currents that transport SST anomalies from one LME to another; therefore the observed synchronism can be explained by advection, although large-scale atmospheric forcing spanning both LMEs also could have played a role.

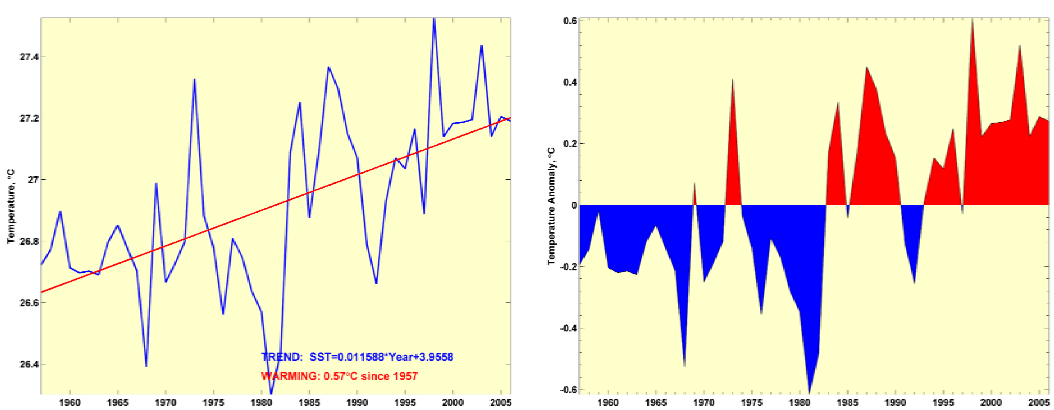

Figure XVI-53.2. East Brazil Shelf LME annual mean SST (left) and SST anomalies (right) , 1957-2006, based on Hadley climatology. After Belkin (2008).

East Brazil Shelf Chlorophyll and Primary Productivity: This LME is a Class II, moderate productivity ecosystem (150-300 gC$m^{-2}yr^{-1}$)(Figure XVI-53.3).

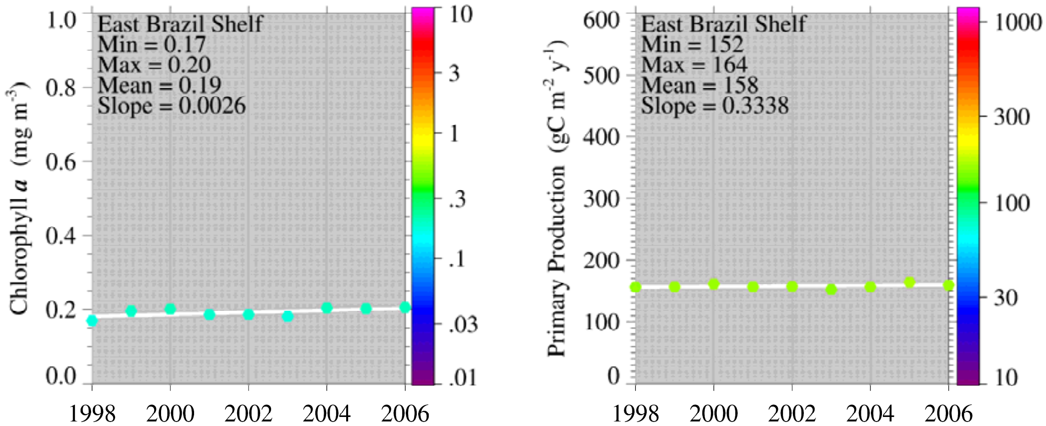

Figure XVI-53.3. East Brazil Shelf trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The fisheries are mainly artisanal although commercial fisheries for lobster, shrimp and southern red snapper are significant in the states of Ceará, Rio Grande do Norte and Espírito Santo (Ekau & Knoppers 1999). Tuna (mainly bigeye) are fished in offshore areas and landed mainly in Rio Grande do Norte and Paraíba. Total reported landings in the LME increased to 300,000 tonnes in 1973 with Brazilian sardinella (*Sardinella brasiliensis*) accounting for two-third of the landings, but have decline over the past three decades, recording 130,000 tonnes in 2004 (Figure XVI-53.4). However, a large quantity of fish bycatch from shrimp trawlers is not included in the underlying statistics and, there are reasons to believe that a substantial fraction of the landings from small artisanal fisheries (predominantly fishes) may not be included in the statistics as well (Freire 2003). The high likelihood of misreporting in the underlying statistics makes 'ecosystemic' diagnosis of catch trends difficult if not impossible (see below).

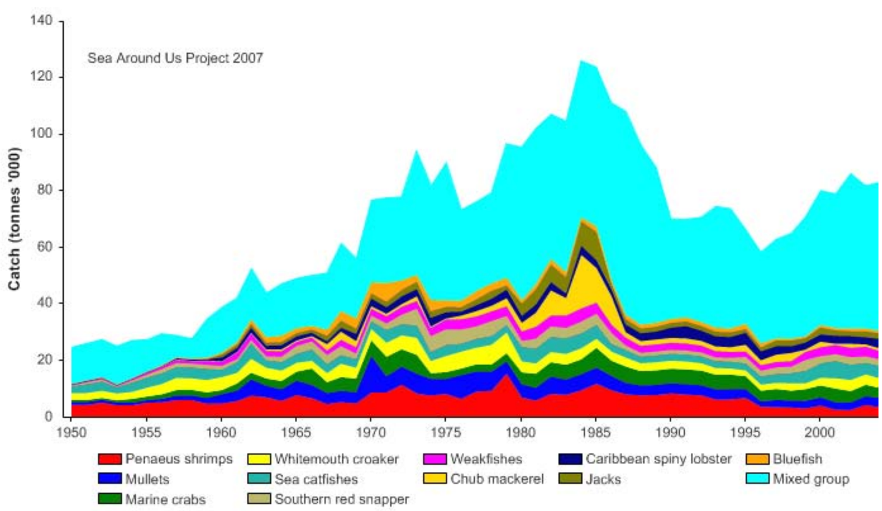

Figure XVI-53.4. Total reported landings in the East Brazil Shelf LME by species (Sea Around Us 2007).

The value of the reported landings peaked at US$400 million (in 2000 US dollars) in 1986, with landings of crustaceans accounting for the largest share (Figure XVI-53.5).

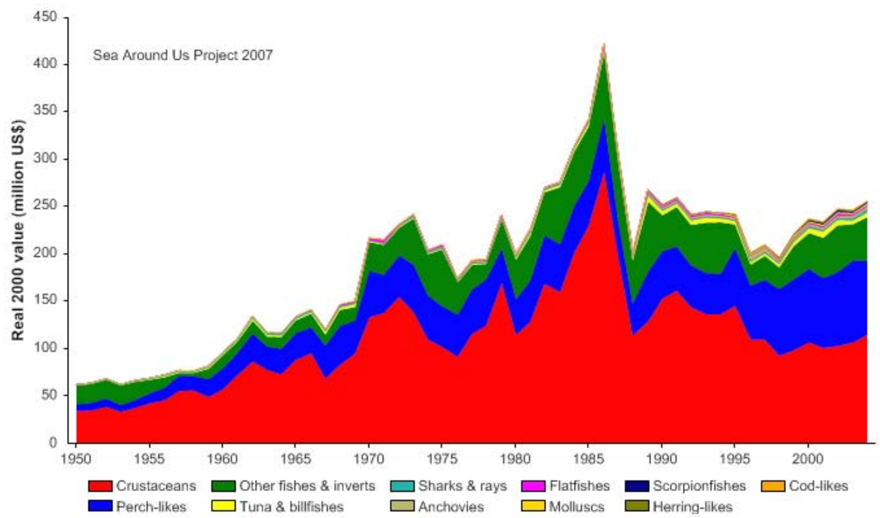

Figure XVI-53.5. Value of reported landings in the East Brazil Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings for the LME approached 5% of the observed primary production in the early 1970s, and has fluctuated between 3 to 5% in recent years (Figure XVI-53.6). This is probably an underestimate due to the large under-reporting of catch in the region (see above). Brazil account for almost all of the ecological footprint in this LME, which has little foreign fishing (Figure XVI-53.6).

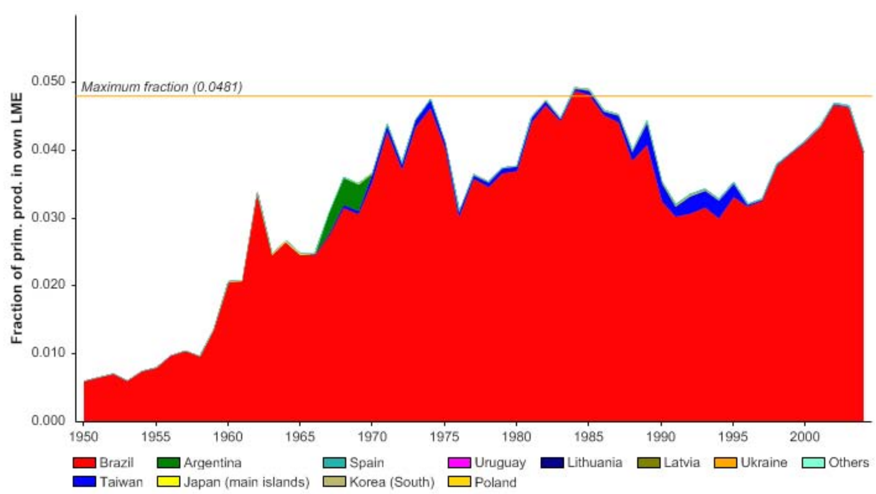

Figure XVI-53.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the East Brazil Shelf Sea LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI, Pauly & Watson 2005) has increased steadily (with variation) from around 3.2 in the early years to 3.4 in recent years (Figure XVI-53.7, top).. As for the FiB index, the expansion of the fisheries in the

1950s and 1960s is represented by an increase in the FiB index, though it has since been on a generally flat trend (Figure XVI-53.7, bottom).

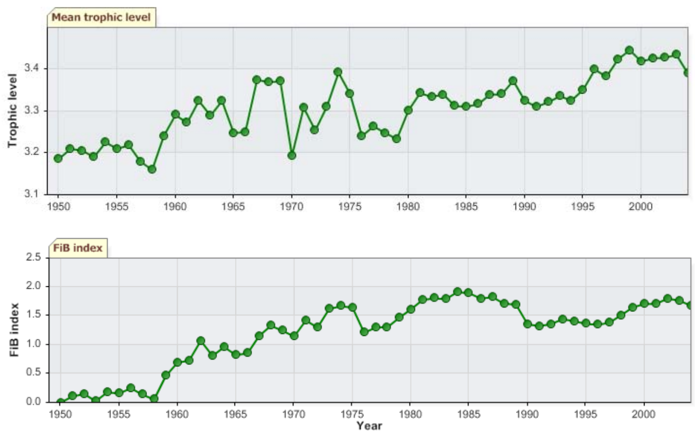

Figure XVI-53.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the East Brazil Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that over 70% of commercially exploited stocks in the LME are either overexploited or have collapsed (Figure XVI-53.8, top). With regard to the contribution to the reported landings biomass, approximately 60% of the landings are supplied by overexploited and collapsed stocks (Figure XVI-53.8, bottom). However, given the quality of the underlying catch statistics (see text), this diagnosis is tentative.

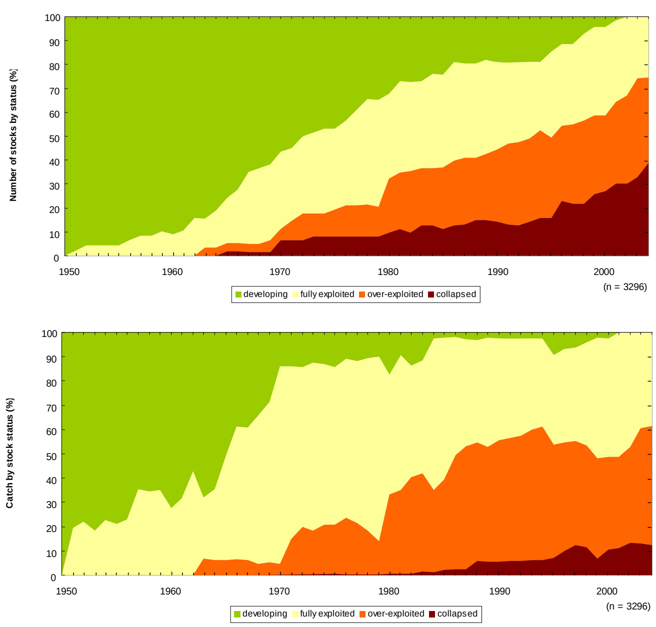

Figure XVI-53.8. Stock-Catch Status Plots for the East Brazil Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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 volume, for definitions).

Overexploitation is considered to be severe in this LME, with both artisanal and commercial fishing contributing to the significant decrease of the region's fish stocks. Several valuable species (e.g., shrimp, lobster, tuna, crabs and mussels) are fully exploited or exploited above MSY (FAO 1997, UNEP 2004. As a result, declining fish catches are evident in several areas (e.g., Paiva 1997, Hilsdorf & Petrére 2002) and overfishing has drastically reduced the stocks of some commercially important fish or eliminated them from the catches. In fact, marine and estuarine fisheries for red snapper, prawns and mangrove crabs have declined as a result of overfishing.

Excessive bycatch and discards range from slight to severe (UNEP 2004. Non-selective fishing methods are used extensively and up to 30% of fisheries catches in the northeast areas consists of accidental captures and/or discards. In the oceanic fisheries, bycatch comprises 80% of the catch (on the Sergipe and Alagoas coast this can reach 90%) with discards amounting to 60% of the catch. Small-meshed nets used in commercial shrimp trawling capture a number of non-target species, such as finfish, lobster, crab and turtle. This bycatch, which is normally returned dead to the sea, can reach up to 8 kg for each kilogram of shrimp captured. Destructive fishing practices are moderate to severe (UNEP 2004). Trawling has also destroyed many habitats. The use of bombs and poison is seen in most estuaries in the state of Sergipe while the use of explosives is common along the entire Bahia coast.

Measures aimed at recovery and sustainability of the principal species may help to address overexploitation in the LME (FAO 2005). However, improved fisheries statistics are necessary for the development of fisheries management plans. Fisheries statistics continue to be a difficult issue in Brazil, due to several factors including the lack of institutional stability among the regulatory agencies in charge of the fisheries sector (Freire 2003), the multitude of common names used for reporting landings (Freire & Pauly 2005), the large geographical extension of the coast, the uneasy coexistence of artisanal and commercial fisheries and the large number of species and landing sites related to the artisanal fisheries (Paiva 1997).

III. Pollution and Ecosystem Health

Pollution: Pollution is a growing concern, especially around densely populated and industrialised coastal areas where hotspots have been identified. In general, pollution was found to be moderate in this LME, but severe in localised hotspots (UNEP 2004, UNEP unpubl). The main sources of marine pollution are linked to land-based activities, especially unplanned coastal development and tourism and recreation centres, as well as ocean transport and industrial activities (e.g., Suape industrial port complex in the State of Pernambuco) and agriculture. As a result of the disposal of untreated sewage in coastal areas, microbial contamination is evident in the estuaries and coastal waters near major cities. In fact, beaches located downstream of densely populated urban centres are likely to be contaminated by faecal coliform bacteria in concentrations above the threshold limit (FEMAR 1998). Estuaries, bays and lagoons encircled by large urban areas show varying degrees of eutrophication from sewage and other organic pollution, increased sediment loads and limited water circulation (FEMAR 1998, Kjerfve *et al*. 2001). Low oxygen levels (<3 mgl^{-1}) occur in estuaries and coastal lagoons and significantly affect coastal embayments (Lacerda *et al*. 2002). As a result, fish kills due to low concentration of dissolved oxygen associated with the proliferation of harmful algal blooms are not uncommon in some areas (Sierra de Ledo & Soriano-Serra 1999).

Chemical pollution arises mainly from industry and agricultural plantations. Mercury concentrations reach about 2-5 times baseline levels in some hotspots (Seeliger & Costa 1998). Deforestation, coastal plantations and mining have facilitated soil erosion, which has resulted in increasing suspended solids in estuaries and other coastal areas (Knoppers *et al*. 1999a, 1999b).

Oil exploitation and shipping in the coastal zone, although on a lesser scale than offshore oil and gas activities, represent one of the greatest pressures on the coastal environment of this LME (IBAMA 2002). Several small-, medium- and large-scale spills of oil, grease and a number of hazardous substances have been detected in coastal and marine waters (UNEP 2004). Oil spills are becoming more frequent along the northeast coast of Brazil. The refuelling of boats and the washing of ship tanks is normally carried out a few kilometres from the coastline, resulting in the occurrence of tar and sometimes weathered oil slicks in coastal habitats such as sandy beaches and coral reefs.

Habitat and community modification: Human activities in the coastal zone have resulted in moderate to severe habitat modification in this LME, with the East Atlantic Basins and NE Brazil Shelf being the most affected (UNEP 2004, UNEP unpubl). Destruction of mangrove forests for charcoal production, timber, urban and tourist developments, salt production, agriculture and shrimp farms is widespread throughout the region. It is estimated that the area of mangrove swamp on the entire Brazilian coast has been reduced by up to 30% of its original area, with the probability of further reduction (UNEP unpubl). Only in the state of Piauí can significant areas of non-impacted mangrove forest be found. The conversion of the mangrove to shrimp farms has drastically changed the natural and ecological balance of the region's estuaries. The highest rate of mangrove deforestation and conversion to aquaculture occurs on the coast of Rio Grande do Norte, which has lost about 2,000 ha of its original area. The states of Paraíba and Pernambuco are no exception, with almost all of its estuaries having shrimp farms of various sizes. This industry is expanding in Piauí, where the total loss of mangrove has already reached 600 ha.

The coral reefs of Brazil are mostly spread over a distance of 2,000 km between $0^{o}50'$ and 19° S latitude from the state of Maranhão in the North Brazil Shelf LME to southern Bahia. They are the southernmost reefs in the Atlantic Ocean and are characterised by relatively low species diversity and the endemism of the hard coral species, with six endemic species (Castro 1994). The largest and richest reefs of Brazil occur on the Abrolhos Bank in the southern part of the state of Bahia. In the past, the coral reefs of the North Brazil Shelf LME were mined for construction material, but at present they come under a growing number of threats. These include increased sedimentation due to unsustainable land use as well as coastal erosion, pollution from domestic sewage and pesticides from sugar cane plantations, overfishing and use of explosives for fishing, tourism, as well as port and oil/gas terminals development (Amado-Filho *et al*. 1997, Maida & Ferreira 1997, Leão 1999).

In the state of Bahia, an acceleration of generally unplanned urbanisation and indiscriminate use of septic tanks in urban centres have resulted in contamination of groundwater (Marques *et al*. 2004). As a consequence, nutrient enrichment through groundwater seepage has resulted in eutrophication of adjacent coastal areas (Costa *et al*. 2000). This has affected the trophic structure of the reefs in these areas, with increasing turf and macroalgae growth, reduction of available light to coral colonies and competition for space preventing the settlement of new coral larvae. Coral bleaching resulting from high sea surface temperature has also affected the reefs in this LME (Leão 1999). There was extensive coral bleaching in 1998 in North Bahia and the Abrolhos region, with levels of 80% reported in important species such us *Agaricia agaricites*, *Mussismilia hispida* and *Porites astreoides* (Garzón-Ferreira *et al*. 2002). However, all corals recovered after six months. The reefs of the Abrolhos Archipelago have been impacted by coastal zone development, tourism, overexploitation of natural resources and pollution from urbanisation as well as industrial activities, including the exploitation of fossil fuel in deep waters (Amado Filho *et al*. 1997, Coutinho *et al*. 1993, Leão 1996, 1999).

Changes in sediment transport dynamics due to land-based activities are considered one of the most serious environmental issues in this region (IBAMA 2002). The lower São Francisco River and its estuary have suffered significant morphological changes as a consequence of the construction of dams. Significant reduction of sediment/nutrient transport has caused sediment deficit in coastal areas, erosion and modification of ecological niches (Marques 2002). Some marine turtles, such as the green, loggerhead, hawksbill, Pacific ridley and leatherback, marine mammals such as the humpack whale, as well as the marine manatee have suffered significant reductions in their populations and are in danger of extinction (Fundação CEPRO 1996).

IV. Socioeconomic Conditions

The East Brazil Shelf LME is bordered by the Brazilian states of Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia and Espírito Santo. It shows an extremely high social, cultural and economic diversity (UNEP 2004). The estimated population is about 53 million inhabitants, with a large percentage living in urban areas (IBGE 2000). In most states, the increasing concentration of the population and economic activities in coastal cities is notable. For example, the state of Pernambuco has the highest coastal population density in the country (over 800 persons km^{-2}). This is ten times greater than the population density of the rest of the state and twice above the national average (Costa & Souza 2002). A large number of the inhabitants of this region are among the poorest in the country, with a wide social and economic gap separating the few rich and the mass of poor people (UNEP 2004).

The main economic activities are linked to agriculture, livestock farming, fisheries/aquaculture and tourism. The LME's fisheries represent an important source of food and income for coastal communities, although they make a small contribution to the country's GDP. Shrimp farming is also an important economic activity, with farms in the northeastern part representing 75% of the national total. Tourism is one of the most important drivers of coastal development in Brazil, and is expected to expand further during the coming years.

Artisanal fisheries are an important subsistence activity not accounted for in the formal economy of Brazil. Fishing represents a labour-intensive activity, responsible for about 800 000 direct jobs. Approximately four million people depend on this sector. The decline in marine fisheries in the region has been accompanied by reduced economic returns over the years. Severe impacts are seen on the fisheries sector economy, affecting the population that is directly dependent on the sector. Several fishing associations have been closed and the labour force diverted into other sectors, such as tourism. As a consequence of the declining stocks and interruption of industrial fishing activities, unemployment in the seafood processing sector has increased.

The socioeconomic impacts of pollution and habitat modification and loss in the East Brazil Shelf LME include loss of revenue and employment opportunities from tourism and fisheries, loss of property value, increased cost of surveillance, restoration of degraded areas as well as penalties against companies responsible for accidents (UNEP 2004). More frequent are the health impacts related to water-borne diseases such as microbiological and parasitic diseases (Governo do Estado de São Paulo 2002). Increasing gastrointestinal symptoms related to exposure to polluted beaches were described by Ciência e Tecnologia a Serviço do Meio Ambiente (CETESB) (Governo do Estado de São Paulo 2002). Among the social and other community impacts are the loss of recreational and aesthetic value of many coastal areas. Pollution and habitat modification are also thought to cause reduction of fish stocks, leading to loss of sustainable livelihoods in hundreds of fishing communities along the coast of this LME. Habitat and community modification have also resulted in increased costs for coastal areas maintenance due to higher vulnerability to erosion and lower coastline stability. This concern has also created generational inequity and loss of scientific and cultural heritage through the disappearance of aquatic species (UNEP 2004).

V. Governance

The Brazilian Government became involved in coastal preservation and management during the 1970s when habitat degradation increased due to industrialisation and urban growth (Lamardo *et al*. 2000). Coastal management is supported by the Federal Constitution in Brazil, which defined the coastal zone as national property (UNEP 2004). In 1988, the government implemented the National Coastal Management Plan. In 1995 the National Programme of Coastal Management (Programa Nacional de Gerenciamento Costeiro, GERCO) proposed decentralisation, with the objective of stimulating initiatives by the states and municipalities, according to the local conditions and demands. The main objective of GERCO is to realign public national policies, which affect the coastal zone, in order to integrate the activities of the states and municipalities and incorporate measures for sustainable development (UNEP 2004). In parallel with the Ecological-Economic Diagnosis, the Ministry of the Environment has coordinated the implementation of the National Programme for Coastal Management involving all 17 coastal states and their municipalities. The programme's main objective is the assessment and diagnosis of the coastal zone uses and conflicts for better planning and management of its living and non-living resources.

Some of the requirements for sustainable development in Brazil include the alleviation of poverty, innovative development strategies, technological improvements as well as sound conservation policies. The greatest constraints are the lack of harmonised legal instruments and financial mechanisms, as well as discrepancies in the capabilities of national and regional experts and managers. The Centre of Fisheries Research and Development of Northeast (CEPENE) is a regional department of the Brazilian Institute of Environment and Natural Renewable Resources and is responsible for the northeastern and eastern coast from Rio Parnaíba to north of Abrolhos Bank. CEPENE has played an important role in supporting research and technological development and promoting technical and social assistance to the local labour force.

The East Brazil Shelf LME, along with the South Brazil Shelf LME and the Patagonian Shelf LME, forms the Upper South-West Atlantic Regional Sea Area. In 1980 UNEP's Governing Council launched a programme for the marine and coastal environment of Argentina, Brazil and Uruguay. In 1998, in cooperation with the UNEP/GPA Coordination Office and the UNEP Regional Office for Latin America and the Caribbean (ROLAC), a Regional Programme of Action (POA) on Land-based Activities and a regional assessment for the Upper South-West Atlantic were prepared and endorsed by representatives of the three governments. The first steps in implementing the programme, which covers the coast from Cape São Tomé in Brazil to the Valdés Peninsula in Argentina, are under development. Under this regional POA, the Brazilian National Programme of Action for the Protection of the Marine Environment from Land-based Activities in the Brazilian Section of the Upper South-West Atlantic has been developed. This national POA covers the area from São Tomé Cape to Chuí, in Rio Grande do Sul state.

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VI-54 South Brazil Shelf LME

S. Heileman and M. Gasalla

According to the re-definition of the Brazilian LMEs (Ekau & Knoppers 2003), the South Brazil Shelf LME extends from 22°-34°S along the South American southeast coast and is bordered by the Brazilian states of Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul. This LME has a surface area of about 565,500 km^2, of which 1.47% is protected (Sea Around Us 2007), with a wide continental shelf that reaches 220 km in some areas. Another feature is its mixed climate and composite structure of environmental conditions that imprints a warm-temperate characteristic (Semenov & Berman, 1977). According to Gasalla (2007), the South Brazil LME would extend over 3 sub-areas: (a) the Southern shelf (28-34°S), influenced by estuarine outflows; (b) the Southeastern Bight (23-28°S), also termed the South Brazil Bight, characterized by seasonal upwellings and cool intrusions; and (c) a slope and oceanic system at its eastern fringe, with the occurrence of meso-scale eddies. The Brazilian continental shelf lies within the path of the South Equatorial Current, which gives rise to the North Brazil Current and the southward flowing Brazil Current (Ekau & Knoppers 2003). The latter influences the South Brazil Shelf LME which is also under regional effects of the Malvinas current and the La Plata River plume edging northwards along the coast (Piola *et al.* 2008). Thus, the Brazil-Malvinas confluence system in the southwestern corner of the subtropical gyre also shapes this LME characteristics. Major rivers and estuaries include Patos-Mirim and Cananeia-Paranaguá Lagoon systems, Ribeira de Iguape and Paraiba do Sul rivers, and the Santos/São Vicente estuarine complex. Book chapters, articles and reports pertaining to the South Brazil Shelf LME include Bakun (1993), Vasconcellos & Gasalla (2001), Ekau & Knoppers (2003),UNEP (2004) and MMA (2006).

I. Productivity

The South Brazil Shelf LME is subjected to relatively intense shelf edge and wind-driven coastal upwelling of the South Atlantic Central Water (SACW), pumped by alongshore winds and by cyclonic vortexes originated from the Brazil Current, particularly in summer and at Cape Santa Marta (28° S) (Bakun 1993; Vasconcellos & Gasalla 2001). It is the most productive coast of the Brazil Current region and considered a Class II ecosystem with moderately high productivity (150-300 $gCm^{-2}yr^{-1}$). Productivity is higher in summer when upwelling of the SACW is frequent, and decreases towards the north (Metzler et al. 1997; Ekau & Knoppers 2003). In addition to coastal, shelf-edge and offshore upwelling, production is also sustained by various terrigenous sources such as the Patos-Mirim Lagoon system and La Plata River plume (Seeliger *et al*. 1997; Piola *et al.* 2008). This LME sustains higher production and fisheries than the East Brazil LME to the north (Ekau & Knoppers 2003).

Oceanic fronts (Belkin et al. 2008) (Figure XVI-54.1): The Brazil Current Front forms the offshore boundary of this LME. This current transports equatorial waters from off Cabo de São Roque (5° 30'S) down to 25°S, where the thermal contrast with colder shelf waters is enhanced in winter-spring by an equatorward flow of cold, fresh Argentinean shelf water reaching as far north as 23°S (Campos *et al*. 1995, 1999, Ciotti *et al*. 1995, Lima & Castello 1995, Lima *et al*. 1996). Shelf-slope fronts in the South Brazil Bight and off Rio Grande do Sul are year-round, but best defined from April through September (Castro 1998; Belkin *et al*. 2008). The Subtropical Shelf Front off southern Brazil has been recently described by Piola *et al*. (2000), Belkin *et al*. (2008) and Campos *et al.* (2008).

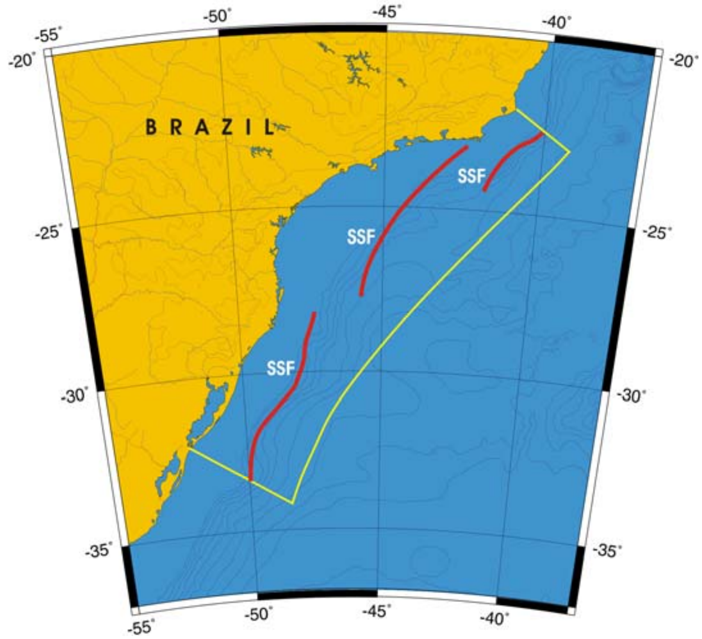

Figure XVI-54.1. Fronts of the South Brazil Shelf LME. Acronyms: SSF, Shelf Slope Front (most probable location). Yellow line, LME boundary. After Belkin *et al.* (2008).

South Brazil Shelf LME SST (Belkin 2008) (Figure XVI-54.2):
Linear SST trend since 1957: 1.12°C.
Linear SST trend since 1982: 0.53°C.

The South Brazil Shelf remained relatively cold – or cooled down – until the relatively abrupt warming by 1°C between 1981 and 1984 that commenced the modern epoch of steady warming. The post-1982 warming of 0.53°C over 25 years is moderate compared to other LMEs. The warming event of 1981-1984 was concurrent with a similar warming in the East Brazil Shelf LME. In both LMEs, the maximum warming rate was observed between 1982 and 1983. This synchronism can be explained either by large-scale forcing spanning both LMEs or by ocean currents that connect these LMEs and transport SST anomalies along shelf and shelf-slope fronts (Belkin et al. 2008).

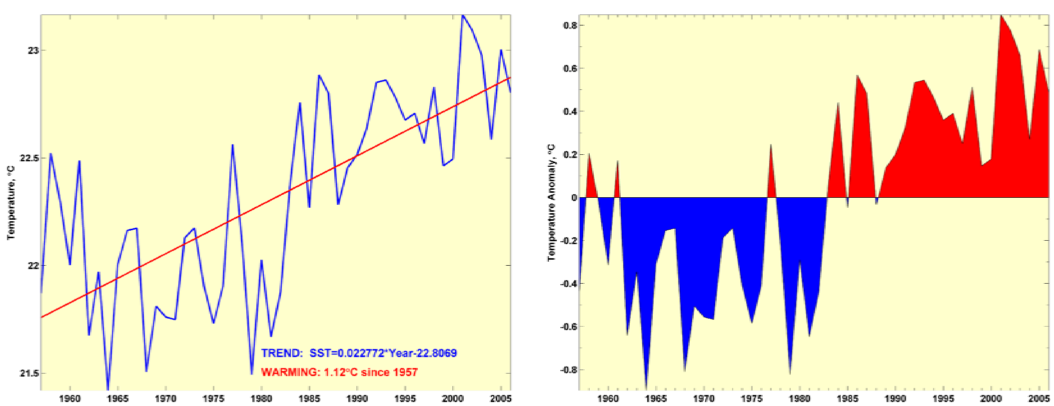

Figure XVI-54.2. South Brazil Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

South Brazil Shelf Chlorophyll and Primary Productivity

This LME is a Class II ecosystem with moderately high productivity (150-300 $gCm^{-2}yr^{-1}$) (Figure XVI-54.3).

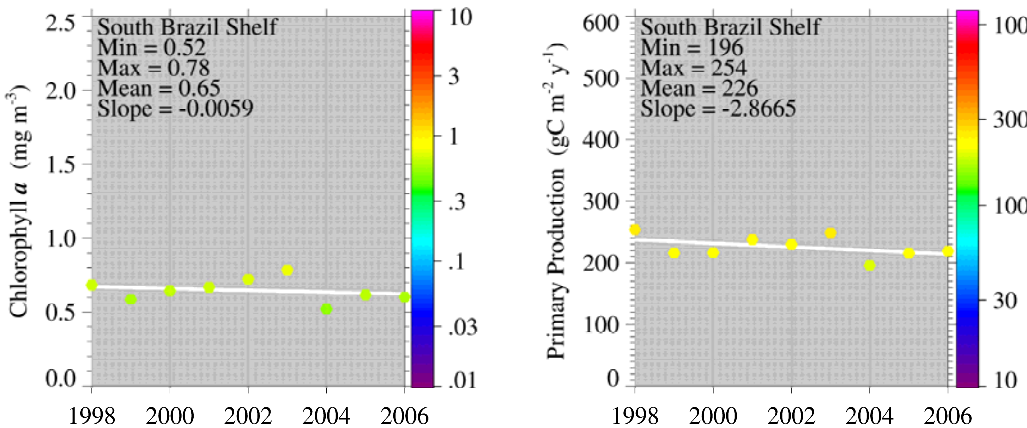

Figure XVI-54.3. South Brazil Shelf trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery; courtesy of J. O'Reilly and K. Hyde.

II. Fish and Fisheries

The South Brazil Shelf contributes about half of Brazil's commercial fisheries yield. In 2002, artisanal fisheries accounted for about 22 % of the total commercial catch in this LME (IBAMA 2002). Sardines represent the most important group in shelf catches (FAO 2003), while the important demersal species are the whitemouth croaker (*Micropogonias furnieri*), the argentine croaker (*Umbrina canosai)* and other sciaenids, the skipjack tuna *Katsuwonus pelamis*, and penaied shrimps (Paiva 1997; Valentini & Pezzuto, 2006). There is increasing expansion and importance of the oceanic fisheries in Brazil, particularly for tuna (FAO 2005a). In 2002, 23,128 tonnes of skipjack and 3,116 tonnes of yellowfin tuna were landed (IBAMA 2002). Deep fisheries initiated in the late 1990s including serranids, Aristaid shrimps, crabs and monkfish have shown unsustainable (MMA 2006).

Total reported landings showed an increase up to the early 1970s, when landings peaked at 356,000 tonnes, but have since declined to 160,000 tonnes in 2004 (Figure XVI-54.2). Historically, catches have been dominated by the Brazilian sardinella (*Sardinella brasiliensis*). Overexploitation as well as oceanographic anomalies are believed to have accounted for the fluctuations of the sardine and anchovy fisheries in this LME (Bakun & Parrish 1991, Paiva 1997, Matsuura 1998). Some recent changes in fishing strategies and their ecosystem effect has been investigated by Gasalla & Rossi-Wongtschowski (2004).The value of the reported landings reached nearly US$600 million (in 2000 US dollars) in 1986, with crustaceans accounting for a significant fraction (Figure XVI-54.3).

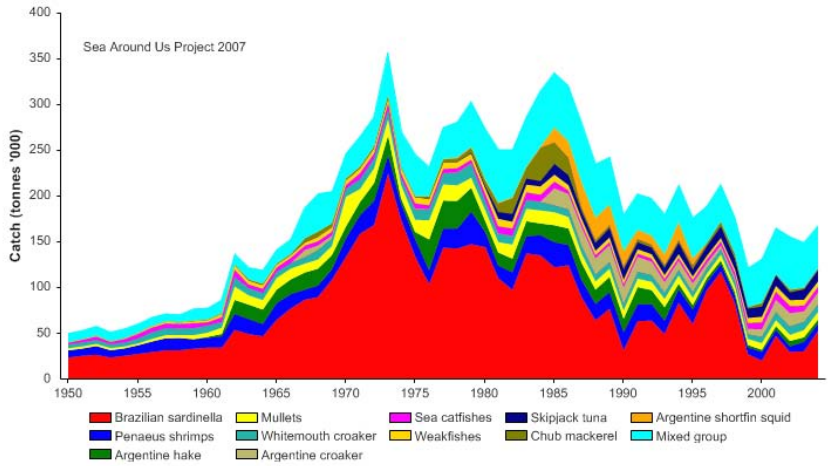

Figure XVI-54.4. Total reported landings in the South Brazil Shelf LME by species (Sea Around Us 2007). Note: Argentine shortfin squid and Whitemouth croaker trends are being reviewed.

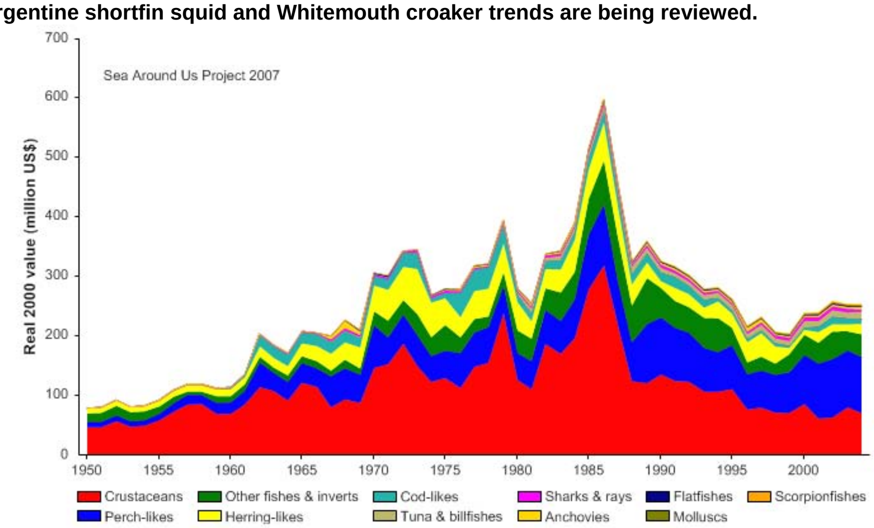

Figure XVI-54.5. Value of reported landings in the South Brazil Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME reached 8% of the observed primary production in the mid 1980s, and has fluctuated between 4 to 6% in recent years (Figure XVI-54.6). However, Vasconcellos and Gasalla (2001) estimated that fisheries utilize 27 and 53% of total primary production in the southern most shelf and in South Brazil Bight regions, respectively. Brazil seems to account for almost all of the ecological footprint on this LME, with very small fisheries by foreign fleets.

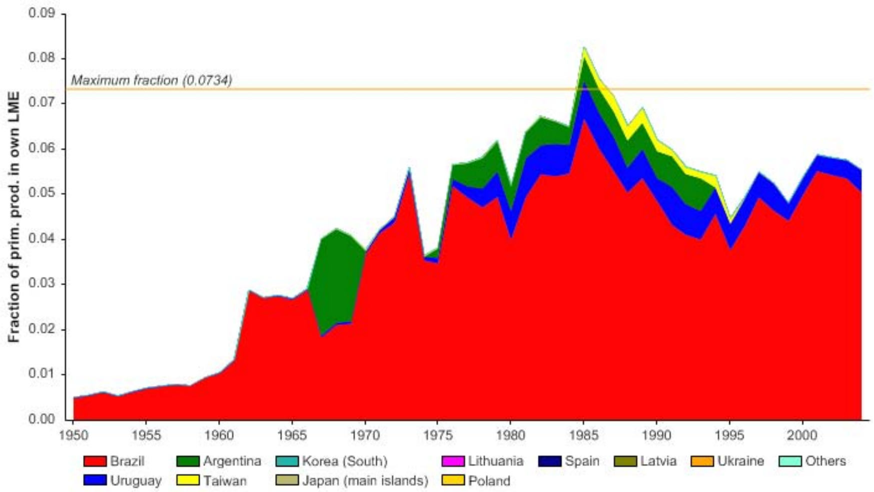

Figure XVI-54.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the South Brazil Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Both the mean tropic level of the reported landings (i.e., the MTI, Pauly & Watson 2005; Figure XVI-54.7 top) as well as the FiB index (Figure XVI-54.7 bottom) show an increase from the late 1950s, somehow consistent with what was previously found by Vasconcellos and Gasalla (2001). This pattern is indicative of the geographical expansion of the fisheries, the collapse of the sardine fishery and an increase of offshore fishing for higher trophic levels in the LME (Vasconcellos and Gasalla, 2001).

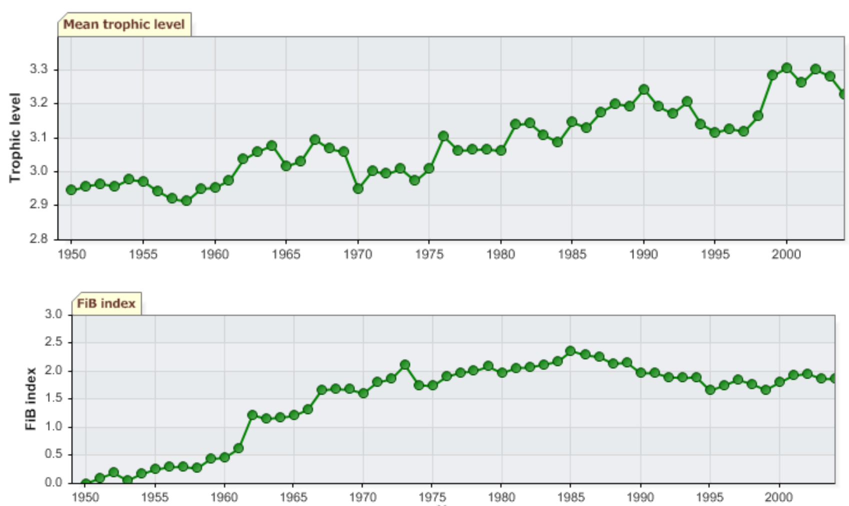

Figure XVI-54.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the South Brazil Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that about 80% of commercially exploited stocks in the LME are either overexploited or have collapsed (Figure XVI-54.8 top) with only 20% of the reported landings biomass supplied by fully exploited stocks (Figure XVI-54.8, bottom).

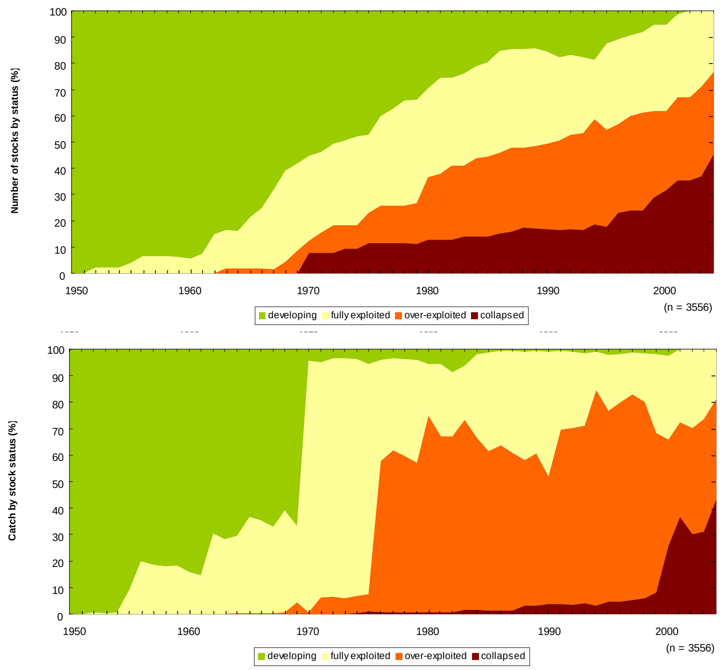

Figure XVI-54.6. Stock-Catch Status Plots for the South Brazil Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

Overexploitation of fisheries, excessive bycatch and discards and destructive fishing practices were found to be severe, particularly for the inshore fisheries (UNEP 2004). In some coastal areas, the stocks have been particularly overfished. For example, fish stocks in Sepetiba Bay have declined by 20% during the last decade (Lacerda *et al*. 2002). In the mangrove areas of Babitonga Bay, crab, shrimp and mollusc have also been overexploited (UNEP 2004). Recently, national evaluations showed that this LME is the Brazil's most impacted by overfishing, with 55% of fishery resources been overexploited and 29%, totally exploited (MMA, 2006). On the other hand, the oceanic fisheries for migratory species such as tuna are not yet very significant in Brazil's EEZ and could have some potential for further development (FAO 2005b). Bycatch and discards are currently one of the main problems being faced in the coastal areas. Trawlers fish illegally in shallow waters and apart from the capture of juvenile and adult fish during spawning periods, they discard enormous quantities of small and low-value fish (UNEP 2004). Also pelagic gillnets and driftnets are still allowed to operate in this LME, and finning have been contributing to the depletion of sharks stocks (MMA, 2006). Measures aimed at recovery and sustainability of the principal species may help to address overexploitation (FAO 2005b). However, improved fisheries statistics and stock assessments are still needed (Gasalla and Tomás, 1998), as well as fishery management programs, as in the other two Brazilian LMEs,.

III. Pollution and Ecosystem Health

Pollution: The pollution issues of great importance are usually associated with the process of coastal urbanisation observed in Latin America (Hinrichsen 1998), as well as industries, tourism and recreation centres, agriculture and shipping (UNEP 2004). Air and water pollution stem mainly from the presence of Brazil's two largest metropolitan areas that are situated in or close to the coastal area: São Paulo, the world's 7th largest city with a population of 10.9 million in 2007 (IBGE 2007) with a concentration of petrochemical and fertiliser industries, and Rio de Janeiro, with 6 million inhabitants. Megacities either affect the coastal waters or estuaries directly or contribute to coastal change through their location in catchments which carry the urban waste load. Overall, pollution was found to be severe in localised areas (UNEP 2004).

Sewage pollution is of concern downstream of densely populated metropolitan areas, with microbiological pollution and eutrophication being severe in some coastal hotspots. Several bays, estuaries and lagoons downstream of urban centres show different degrees of eutrophication due to the discharge of untreated domestic sewage and industrial effluents (Rorig *et al*. 1998, Knoppers *et al*. 1999, Braga *et al*. 2000). As a result, anoxia seriously affects some coastal embayments (Lacerda *et al*. 2002). Fish kills due to low concentration of dissolved oxygen associated with the proliferation of algae or algal toxins are not uncommon in some areas such as Conceição Lagoon (Sierra de Ledo & Soriano-Serra 1999) and Patos Lagoon estuary. Dredging and deforestation have resulted in increased soil erosion and siltation of coastal zones. Pollution by suspended solids is severe in many areas (Torres 2000).

Guanabara Bay represents one of the most severely polluted and eutrophic bays of Brazil (UNEP 2004). This and Sepetiba Bay are highly polluted as a result of discharge of domestic effluents, the petrochemical industry, trace elements, changes in sediment loading generated by river basin activities and port operation. There is no marine life in many parts of Guanabara Bay. Fishing has decreased by 90% during the last 20 years and several beaches are not recommended for swimming. The construction of Sepetiba Port and dredging of the shipping channel have caused re-suspension of heavy metals accumulated in the sediments. Cadmium, zinc, lead and chromium have been found in suspended material, sediments and in mussels, oyster and macroalgae of both Sepetiba and Guanabara Bays.

Coastal areas receive effluents with concentrations above threshold limits of heavy metals, such as zinc, mercury, chromium, copper and lead. High concentrations of heavy metals have been found in the water column, sediments and fish and shellfish tissues (Lamardo *et al*. 2000, UNEP 2000). Agricultural run-off is a significant cause of pollution in some areas such as the Patos Lagoon (Lacerda *et al*. 2002). Organochlorine compounds in tissue of molluscs were detected in Guanabara, Santos and Paranaguá Bays and Patos Lagoon. Association between water pollution and water-borne diseases such as microbiological and parasitic infections, poluted beaches, and microbiological infection were found, such as in the Paraiba do Sul river municipalities (UNEP 2004).

The country's main sea terminal, accounting for around 55% of all oil transported in Brazil, is situated on the São Paulo coast. A large number of accidents, including leaks and accidental oil spills, have been recorded during routine operations (Poffo *et al*. 1996) contributing to chronic pollution in nearby areas. Large spills have also occurred, with serious impacts on the region's coastal habitats (IBAMA 2002). From January 1980 to February 1990, 71 accidents involving spills of oil and its derivatives along the São Paulo coast occurred, causing serious damage to estuarine communities (CETESB 2001). Sea outfall monitoring showed also nutrient enrichment and increase of organic matter content in sediments of the São Paulo coast (CETESB 2003).

Recent global research on hypoxia in coastal zones showed the occurrence of dead zones in 4 regions of the South Brazil Shelf LME, as being the Patos Lagoon, Guanabara Bay, Rodrigo de Freitas and Conceição lagoons (Diaz & Rosenberg 2008). This suggests that this LME is the most impacted of Brazil.

Habitat and community modification: Urbanisation, petroleum exploitation, port operations, agriculture, tourism, fishing and aquaculture exert significant pressures on the coastal habitats, which has led to severe habitat degradation throughout this LME (UNEP 2004). Estuaries and bays have been particularly degraded. For example, drainage for rice culture, catching of shrimp and mullets, hunting as well as land speculation in beach areas have had negative impacts in the Patos Lagoon (Diegues 1999). Between 1956 and 1996, 10% of the marshland in this estuary was lost (Seeliger & Costa 1997, Seeliger *et al*. 1997). The filling of intertidal and shallow water flats in the lower Patos Lagoon estuary for port construction and residential and industrial development has destroyed or reduced seagrass beds (Seeliger *et al*. 1997). Estuaries and bays located around the cities in the states of Rio Grande do Sul, Santa Catarina have been impacted by river discharge of organic pollutants and increasing oxygen demand.

In Ilha Grande Bay in Rio de Janeiro, only 50% of the original mangrove remains (UNEP 2004). One of the largest natural fish breeding grounds, Sepetiba Bay, has been under severe impacts due to silting, pollution and mangrove destruction. Intensive soil excavation and transport for construction of the Rio-São Paulo highway, as well as increasing urbanisation have caused intense erosion and a significant increase in suspended solids in coastal waters and subsequent smothering of benthic species. The construction of decks, walls and land reclamation has destroyed rocky foreshores and modified beaches in this LME.

In Guanabara Bay, the mangrove system has been reduced by landfilling with solid waste, illegal exploitation of mangrove wood and occupation by low-income population. Changes in the sediment transport dynamics due to land-based activities on the coast are considered one of the most serious environmental issues in this region (IBAMA 2002). For example, the sediment transport and sedimentation rates in Sepetiba Bay have changed dramatically because of civil engineering works during the 1950s and water transfer from the Paraíba do Sul River for the purpose of supplying the Rio de Janeiro Metropolitan area (UNEP 2004). Coastal erosion is expected to become worse due to sea level rise, which may also eliminate mangrove habitats at an approximate rate of 1% per year (IPCC 2001).

The health of the South Brazil Shelf LME may come under greater threat in the future as a result of pollution and habitat and community modification becoming severe in the absence of any strong responses to address these concerns (UNEP 2004). These responses should include new and creative strategies to promote integrated environmental management and increasing investment in education and recovering.

IV. Socioeconomic Conditions

The population of the states bordering this LME is about 82 million, 20% of whom live in the coastal areas and are responsible for for more than 75% of the Brazilian GDP (IBGE 2007). In addition, the population of the megacity of São Paulo, about 80 km from the coast, is about 11 million people and Rio de Janeiro, the second, is about 6 million (IBGE, 2007). In most states, the increasing concentration of the population and economic activities in coastal cities is evident. Major LME's marine harbours movement an annual activity of about 214 million tons of goods (UNEP 2004). The region shows an extremely high social, cultural and economic diversity. Artisanal and commercial fishing, agriculture, tourism and shipping are important activities. The aquaculture sector (mainly for shrimp, oysters, mussels and clams) is developing rapidly, particularly the state of Santa Catarina with an annual production of more than 20,000 tonnes (Poli *et al*. 2000). This state is the largest mussel producer in Latin America, producing about 12,000 tonnes in 2000 (FAO 2005a).

Fisheries are of great social, cultural and economic importance and sustain a large number of traditional fishers who have lived for generations off fishing. Small-scale and artisanal fisheries are declining as a result of overexploitation in coastal areas and competition from large fishing fleets, but there are around 110,000 artisanal fishers registered (IBAMA 2003). Traditional fishing communities have almost disappeared in some coastal areas due to real state speculation, coastal degradation and urban-industrial expansion, and workers have moved to other activities (IBAMA 2007). Commercial fishing and the fish processing industry are important economic activities for export. Falling sardine production has led to the closure of many salting and canning companies and loss of employment. Social and community impacts in the region include reduced capacity of local populations in meeting basic human needs when fish stocks are reduced. The socioeconomic impacts of overexploitation are overall moderate in the LME (UNEP 2004) but they seem to be still underevaluated.

The economic impacts of pollution are severe in the LME (UNEP 2004). Coastal areas have already experienced economic losses, mostly in tourism and moderate to severe economic impacts in the fisheries sector because of pollution and habitat degradation. Impacts also include loss of property value, costs of remediation of polluted areas as well as penalties against companies responsible for accidents (e.g., major spills events). Health impacts due to water pollution include the incidence of water-borne microbiological and parasitic diseases. Increasing gastrointestinal symptoms related to exposure to polluted beaches have been reported (Governo do Estado de São Paulo 2002). Economic impacts of habitat and community modification are similar to those of pollution and also include increased costs for coastal area maintenance due to higher vulnerability to erosion and reduced coastline stability.

V. Governance

Brazil is party to several environmental conventions and agreements and has specific dated agreements with Uruguay relating to fisheries, the use of natural resources and environmental issues. Brazil, Uruguay, Argentina and Paraguay form the Common Market MERCOSUR. The Brazilian Government became involved in coastal preservation and management during the 1970s when degradation of ecosystems increased due to industrialisation and urban growth (Lamardo *et al*. 2000). Coastal management is supported by the Federal Constitution in Brazil (1998), which defines the coastal zone as national property. Brazil has expended great efforts to assess the state of the living and non-living resources within its EEZ. The greatest constraints include inadequate harmonised legal instruments and financial mechanisms and limited human resources. This country also has an ongoing coastal zone management programme, as well as a significant number of institutions such as universities, research institutes and foundations dedicated to fisheries research. The Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Sudeste e Sul (CEPSUL) is a regional department of the Instituto Brasileiro do Meio Ambiente (IBAMA) that is responsible for fisheries management of overexploited species in the area from Cape Frio to the Uruguayan border. Important protected areas include the Ecological Station of Taim and the National Park of Lagoa do Peixe-PARNA, as well as several APAs (Area de Proteção Ambiental) along the coast. Also, the so-called new “extractive reserves” have been created by fishers associations for fisheries conservation. By the other hand, since 2003, the Secretaria Especial de Aquicultura e Pesca (SEAP) with a Ministry status, have been responsible for the management of underexploited fishery resources, aquaculture and fishing development, including incentives and subsidies. There is a clear disconnection between agencies for fisheries, ICZM and conservation issues. See the North and East Brazil Shelf LMEs for additional information on governance.

The South Brazil Shelf LME, along with the East Brazil Shelf LME and the Patagonian Shelf LME, forms the Upper South-West Atlantic Regional Sea Area. See the East Brazil Shelf LME for information on the POA on Land-based Activities and on the Brazilian National Programme of Action for the Protection of the Marine Environment from Land-based Activities in the Brazilian Section of the Upper South-West Atlantic.

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XVI-55 Patagonian Shelf LME

S. Heileman

The Patagonian Shelf LME extends along the southern Atlantic coast of South America from the Río de la Plata (La Plata River) to southern Patagonia and Tierra del Fuego, covering an area of about 1.2 million km^2, of which 0.18% is protected (Sea Around Us 2007). The continental shelf is one of the widest in the world, and encompasses the Falkland Islands/Malvinas some 760 km east of the mainland. Two major wind-driven currents influence the LME: the cold, northward flowing Falkland/Malvinas Current and the warm, southward flowing Brazil Current (Bakun 1993). The Falkland/Malvinas Current provides the LME with a distinctive ecological boundary to the east. This LME is also influenced by low salinity coastal waters (principally outflow of the Río de la Plata) and upwelling of cold Antarctic waters caused by the prevailing westerly winds. Major estuaries include the Rio de la Plata, Rio Colorado, Rio Negro and Chubut. LME chapters and reports pertaining to this LME include Bakun (1993), Bisbal (1995) and UNEP (2004).

I. Productivity

The Patagonian Shelf LME is one of the world's most productive and complex marine systems, and is considered a Class I, highly productive ecosystem (>300 $gCm^{-2}yr^{-1}$). Extensive mixing of the Falkland/Malvinas Current and the Brazil Current in the La Plata region results in a highly productive confluence zone. This mixing has biological, physical, and meteorological consequences that impact the entire LME. The outflow from the Río de la Plata, the second largest drainage basin (3.2 million km^2) in South America, also contributes to the high biological productivity on the continental shelf and slope. The waters of the sub-tropical Brazil Current show lower productivity. Phytoplankton species are dominated by dinoflagellates, coccolithophorids, and cyanophyceans, with few diatoms. The zooplankton community shows a high abundance of calanoid copepods, chaetognaths, salps and hydromedusa.

Biological diversity is rich, with species from warm, temperate and cold waters. Some endemic species such as the migratory Plata dolphin (*Pontoporia blainvillei*) are also found in this region. The coastal area has favourable reproductive habitats for small, pelagic-spawning clupeoids (Bakun & Parrish 1991). Some species (e.g., tuna and marine mammals) are migratory and are of outstanding global ecological, economic, and social importance. The LME supports significant seabird and marine mammal populations as well as fish and invertebrates (Bakun 1993, DRIyA 2001), and is particularly rich in fisheries resources.

Oceanic Fronts (Belkin et al. 2008) (Figure XVI-55.1): Three year-round fronts are distinguished over the Patagonian Shelf: Valdes Front (VF) at 42°S, San Jorge Front (SJF) at 46°S, and Bahia Grande Front (BGF) at 51°S. The origin of VF and SJF might be related to intense tidal mixing (Glorioso 1987, Glorioso and Flather 1995, 1997). Two seasonal fronts are the Bahia Blanca Front (39°S) and Magellan Front (MF), the latter consisting in fall (April-June) of two branches, the Patagonian-Magellan Front and Tierra del Fuego Front. The origin of MF and its branches is related to the influx of cold, fresh Pacific water via the Strait of Magellan. The offshore boundary of this LME coincides with the Falkland (Malvinas) Front/current that extends along the Patagonian shelf break and upper continental slope of the Argentinean Sea.

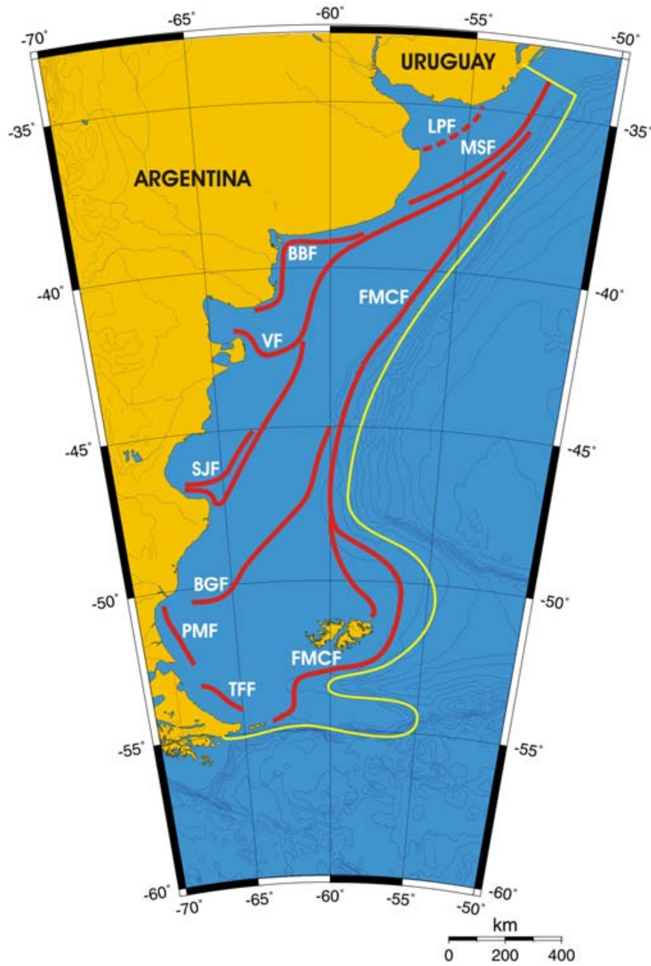

Figure XVI-55.1. Fronts of the Patagonian Shelf LME. BBF, Bahia Blanca Front; BGF, Bahia Grande Front; FMCF, Falkland/Malvinas Current Front; LPF, La Plata Front; MSF, Mid-Shelf Front; PMF, Patagonian-Magellan Front; SJF, San Jorge Front; TFF, Tierra del Fuego Front; VF, Valdes Front. After Belkin et al. (2008).

Patagonian Shelf LME SST (Belkin, 2008) (Figure XVI-55.2):
Linear SST trend since 1957: 0.15°C.
Linear SST trend since 1982: 0.08°C.

The Patagonian Shelf experienced a very gradual, steady warming over the last 50 years. The most dramatic event occurred in 1961-62, when SST rose from the all-time minimum of 10.3°C to the all-time maximum of >11.3°C. The most likely cause of the observed stability of the Patagonian Shelf is the constant influx of sub-Antarctic waters with the Falkland/Malvinas Current (see the Falkland/Malvinas Current Front, FMCF, associated with the namesake current. These waters in turn are stabilized by the Antarctic Circumpolar Current. Another possible cause of the Patagonian Shelf thermal stability is an extremely rich and well-defined frontal pattern; this pattern persists, albeit constantly evolving, year-round. Many fronts are tidal mixing fronts separating vertically mixed areas from vertically stratified areas. Naturally, SST in tidally mixed areas is more stable than elsewhere.

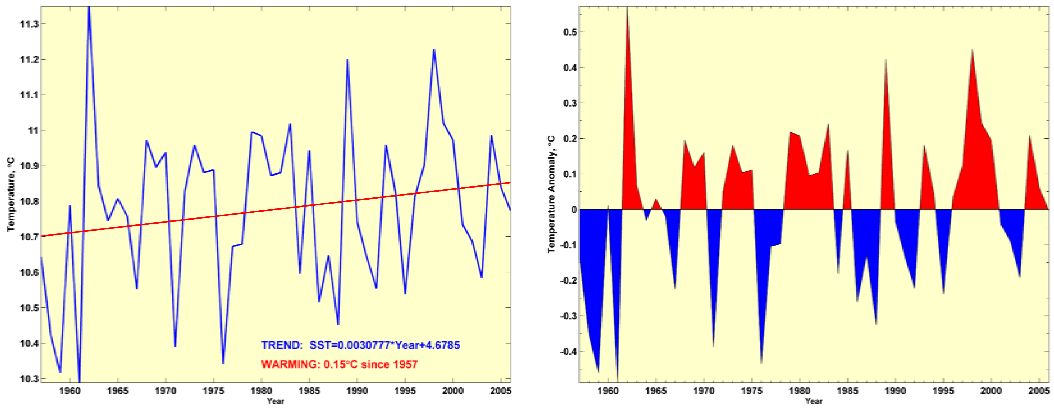

Figure XVI-55.2. Patagonian Shelf LME annual mean SST (left) and SST anomaly (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

Patagonian Shelf LME Chlorophyll and Primary Productivity

This LME is a Class I, highly productive ecosystem (>300 $gCm^{-2}yr^{-1}$) (Figure XVI-55.3).

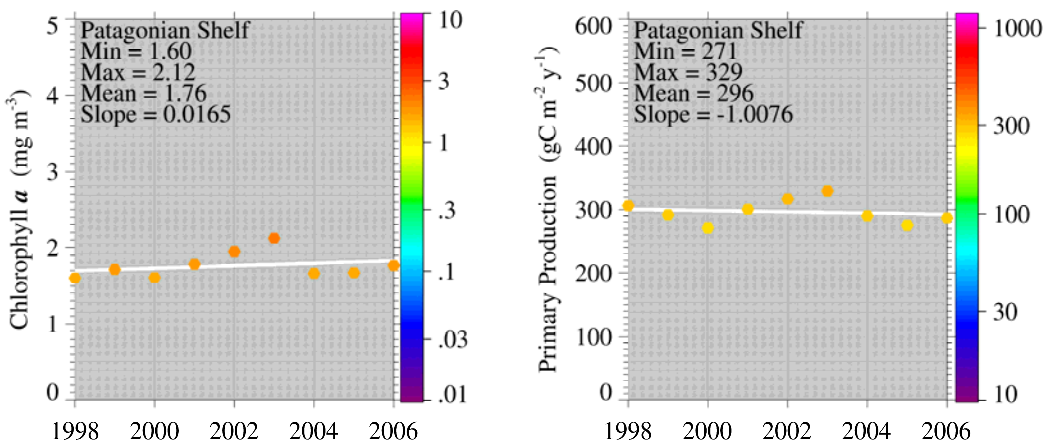

Figure XVI-55.3. Patagonian Shelf LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume

II. Fish and Fisheries

Fisheries in the Patagonian Shelf LME have undergone accelerated growth in the last decades involving mostly Argentine hake (*Merluccius hubbsi*), Argentine shortfin squid (*Illex argentinus*), southern blue whiting (*Micromesistius australis*), Patagonian grenadier (*Macruronus magellanicus*), and prawns (*Pleoticus muelleri*). Total reported landings have increased over the past three decades, recording 1.5 million tonnes in 1997 with Argentine hake and shortfin squid accounting for the majority share (Figure XVI-55.4). The landings have since declined to 970,000 tonnes in 2004 (Figure XVI-55.2). The value of the reported landings has been over US$1 billion (in 2000 real US dollars) since the mid-1980s with a peak of US$1.6 billion recorded in 1987 (Figure XVI-55.5). However, the value has been declining in recent years.

The Secretariat of Agriculture, Livestock, Fisheries, and Food (SAGP&A) reports landings of hake by the Argentinian fleet for the 2008 January through 4 September 2008 at 180,051.1 tonnes of common hake landed in Argentine ports, down 6% from the same period the previous year. (SAGP&A). The Joint Technical Commission for the Argentine-Uruguay Maritime Front (CTMFM) has banned *Merlussius hubbsi* fishing in the Common Fishing Area from 6 October through 31 December, 2008, to protect juvenile hake concentrations and "encourage rational exploitation of the resource" (www.fis.com/fis/worldnews, Tuesday, 7 October 2008).

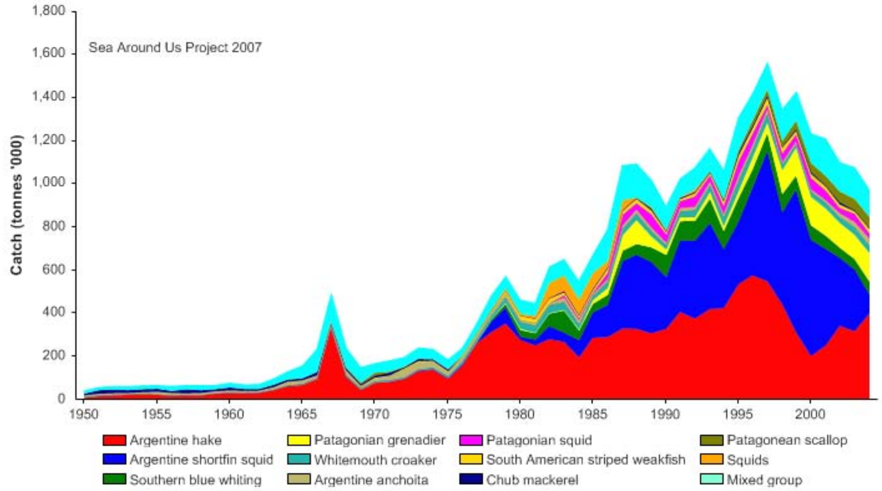

Figure XVI-55.4. Total reported landings in the Patagonian Shelf LME by species (Sea Around Us 2007).

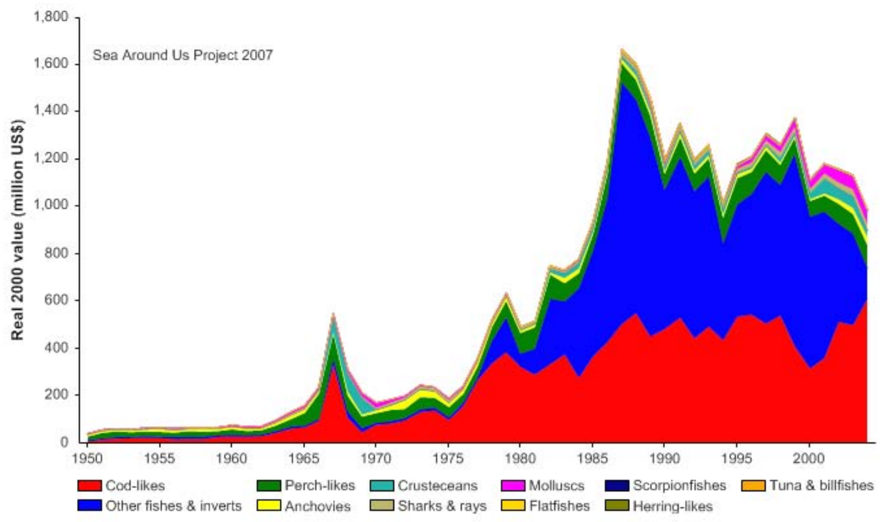

Figure XVI-55.5. Value of reported landings in the Patagonian Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME reached 25% of the observed primary production in the mid-1990s, but has declined to 20% in recent years (Figure XVI-55.6). Argentina accounts for the largest share of the ecological footprint in this LME (Figure XVI-55.6).

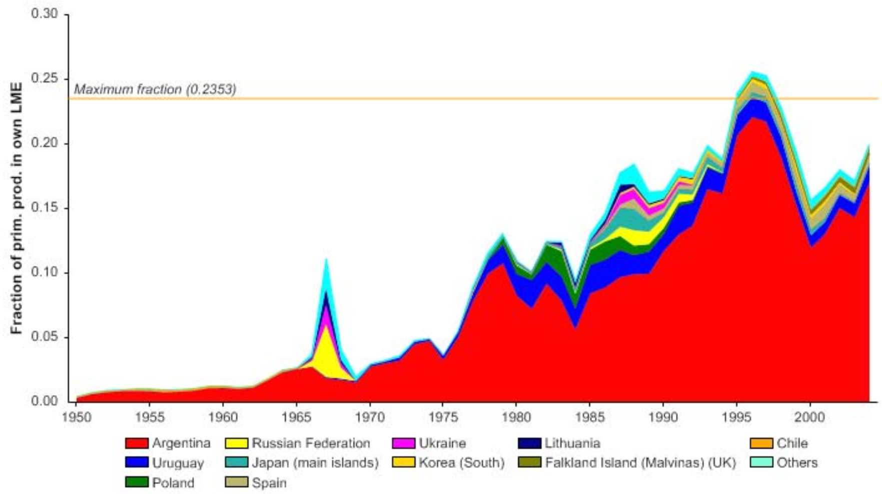

Figure XVI-55.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Patagonian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) shows a decline since the late 1970s (Figure XVI-55.7, top), an indication of a 'fishing down' of the food web in the LME (Pauly *et al*. 1998). Over the same period, the FiB index have remained flat (Figure XVI-55.7, bottom), implying that the increasing reported landings in Figure XVI-55.4 were due not only to ecological compensation, but also to a geographic expansion of the fishery. These compensatory mechanisms worked until the mid-1990s, at which points the number of overexploited and collapsed stocks increased (see Figures XVI-55.8, top and XVI-55.8, bottom).

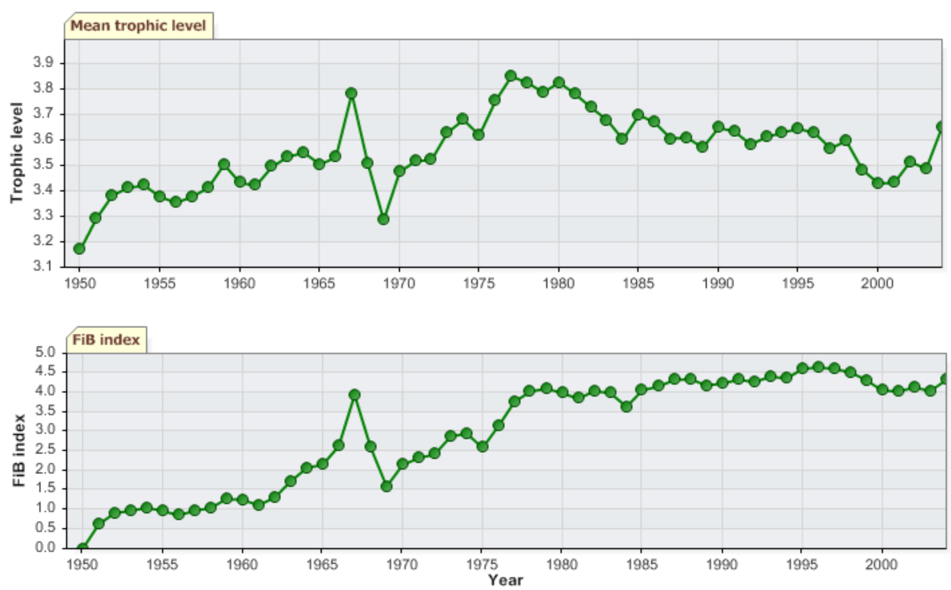

Figure XVI-55.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Patagonian Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots shows that over 70% of commercially exploited stocks in the LME are either overexploited or have collapsed (Figure XVI-55.8, top), with 70% of the reported landings supplied by overexploited stocks (Figure XVI-55.8, top). However, the transition from fully exploited to overexploited stocks in the early 2000s was rather abrupt.

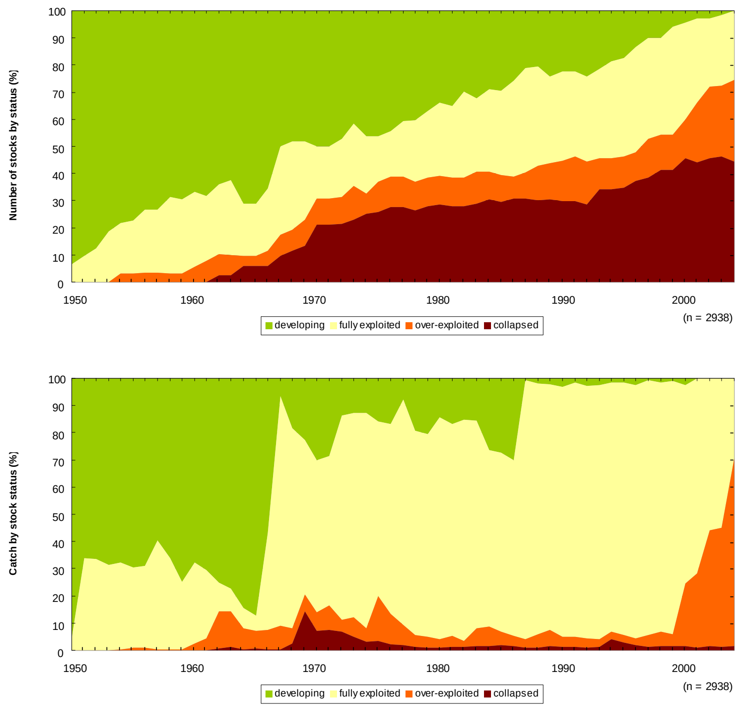

Figure XVI-55.8. Stock-Catch Status Plots for the Patagonian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

Despite the low exploitation levels of some species (e.g., Atlantic anchovy and southern blue whiting), intensive exploitation of other species by Argentina and Uruguay has resulted in moderate to severe overexploitation in the LME (UNEP 2004). This is particularly serious in the Buenos Aires coastal system and Common Argentine-Uruguayan Fishing Zone. Overexploitation of hake in the Mar del Plata area became evident in 1997, with increased fishing effort (Bertolotti *et al*. 2001) and catching of large quantities of juvenile and spawning fish (DRIyA 2001). Between 1988 and 1999, the proportion of hake in the total landings fell from 62 to 31% (DRIyA 2001). Subsequently, catch limits and other controls were implemented to allow recovery of the stocks. In 2000, the hake reproductive stock south of 41ºS was the lowest since 1986 (Pérez 2001). Total biomass of the northern and southern hake stocks decreased, reproductive biomass was lower than the biologically acceptable level, and the fishery was sustained by a few year classes (Aubone 2000, Pérez 2000). This led to the collapse of the hake stocks, which may have caused important changes in productivity and community structure as shown by a decrease in trophic levels of the catch and an increase in anchoita stocks between 1993 and 1996 (DRIyA 2001).

A number of other fish and invertebrate species are also overfished. The squid fishery was established in the 1980s, with catches by both Argentina and Uruguay off the Río de la Plata. In 1987, there were indications that squid stocks were being maximally exploited and probably overfished (Csirke 1987). However, this fishery has been highly variable in subsequent years and this has probably been driven by environmental variability. Most species of bony fish targeted in the multi-species coastal fishery show a decreasing trend in biomass. The estimated population of the southern blue whiting (*Micromesistius australis*) was found to be about 77% lower than previous levels, and its exploitation rate relatively high (Wöhler *et al*. 2001). Biomass of mackerel (*Scomber japonicus*), corvina (*Micropogonias furnieri*) and shore ray species have decreased since 1996. The cod (*Genypterus blacodes*) stock is near its maximum sustainable limit of exploitation (Cordo 2001, Perrota & Garciarena 2001).

The use of non-selective fishing gear results in the capture of large quantities of bycatch and discards (DRIyA 2001). Bycatch rates of the freezer and factory fleet vary between 9.9-24.3%, and 2.3-7.2% respectively (Cañete *et al*. 1999). The high seas fleet discards about 25%-30% of its catch, while the coastal fleet discards about 25% (Caille & González 1998). From 1990-1996, between 20 and 75 thousand tonnes per year of young hake (under two years old) that represented between 80 and 300 thousand tonnes of adult fish were caught as bycatch. The cod fishery has been declining since 1999 because of high levels of bycatch of this species in the hake fishery (Cordo 2001). Trawl fishing also affects mammals such as sea lions and dolphins, as well as penguins, albatross, petrels, and seagulls. Incidental capture of macrobenthic organisms is also a common occurrence in the San Jorge Gulf and Chubut coastal areas (Roux 2000). Some species historically discarded in Argentina, such as *Myliobatis* spp., are possibly 'keystone species' (Power *et al*. 1996).

III. Pollution and Ecosystem Health

Pollution**:** The coastal areas of the Patagonian Shelf LME face accelerating development pressures. Although pollution is generally slight, its occurrence in several localised areas is cause for concern (UNEP 2004). The effects of pollutants from land-based sources are exacerbated in large river basins such as the La Plata, which contains important urban centres as well as agricultural and industrial activities. The Rio De La Plata and coastal areas are sinks for substantial urban, agricultural and industrial wastes. Pollution of the water and sediments of the Rio De La Plata and its maritime front from land-based and aquatic activities is a key transboundary issue. Some pollution problems arise from the coastal cities of Buenos Aires and Montevideo, which are densely populated and have a high concentration of economic and industrial activities.

Raw sewage is commonly discharged into coastal areas mainly in the vicinity of cities due to the general lack of sewage treatment facilities. This has led to serious microbial pollution in some localised areas. Pathogens, which in some cases have exceeded international recommended levels for recreational water, have been detected in coastal areas (Fundación Patagonia Natural 1999). Toxic red tides are becoming more frequent and of longer duration in the outer La Plata River and maritime front.

The Patagonian coastal zone experiences slight to moderate toxic chemical pollution. For example, lead, zinc and copper concentrations in sediments were registered in San Antonio Bay and in San Matías Gulf. Cadmium was also found in these two localities, affecting local flora and fauna, and threatening migratory birds. High cadmium concentrations were detected in kidney and liver of Commerson's dolphin and dusky dolphin, and in kidneys of kelp gulls. Persistent organic pollutant (such as pp'-DDE) was detected in penguins and kelp gulls. Significant halogenated residues have been found in dead new-born cubs of sea lions, suggesting maternal transmission (Fundación Patagonia Natural 1999).

A sharp increase in turbidity has been observed in localised marine areas due to mining and alteration of the natural vegetation cover of extensive sedimentary areas in Southern Patagonia. About 30% of the Patagonia region is experiencing desertification, basically caused by overgrazing by sheep and cattle (SAyDS 2003). This has increased water runoff and soil losses and in many cases, has resulted in an increase in suspended solids, which cause moderate pollution in coastal areas. Pollution from solid wastes is concentrated mainly in urban areas near the coast where disposal of solid wastes in open dump sites is common.

The LME is subject to heavy shipping and oil tanker traffic. Chronic oil pollution is a problem in the vicinity of ports and oil terminals that have become pollution ‘hot spots’. Ecologically sensitive areas are potentially at risk when winds and marine currents transport these persistent pollutants beyond the port facilities. Beaches are often affected by the presence of tarballs and marine birds are frequently covered with oil. Occasional major oil spills occur in the Patagonian Shelf LME, with significant impact at local levels. Petrogenic hydrocarbons in sediments show the highest concentrations in oil shipping locations where oil and ballasts washing are discharged.

Habitat and community modification: The Patagonian Shelf LME coastal areas have been under pressure from population and industrial growth over the last 15 years, with attendant habitat degradation, fragmentation and loss (Gray 1997). Although this occurs in localised areas, some impacts, for example on migratory species, may be transboundary. Overall, habitat and community modification is moderate, but is expected to worsen in the future (UNEP 2004). Physical alteration and destruction of habitats in the coastal areas occur mainly through mining, dredging, port activities, urban and coastal development, tourism, and destructive fishing methods (DRIyA 2001). Urban and industrial pollution also contribute to this problem. The operation of harbours and oil shipping facilities in some areas along the shore results in localised pollution ‘hot spots’ that harm coastal habitats and associated communities.

Sediments from the continuous dredging of the La Plata River alter marine benthic communities and re-suspend sediments and pollutants. Human-induced erosion is another cause of habitat modification. Most beaches of Buenos Aires have suffered significant erosion and consequent altered coastline. For instance, in Mar Chiquita beach, the rate of the beach retreat reaches 5 m/year in some localities (Bonamy *et al*. 2002). Coastal erosion has also degraded sand dunes, salt marshes and coastal lagoons. In spite of the severe erosion problems that affect the coastline, sand extraction for construction purposes continues.

There is evidence of fragmentation of sandy foreshores, the littoral belt system, and coastal fringes, mainly in the province of Buenos Aires. The La Plata estuary is a highly impacted system because of land use practices in the drainage basin. Modification of the structure of coastal communities and mortality of fauna, mainly on the Buenos Aires coast, has been attributed to habitat degradation. Biodiversity is seriously endangered (Fundación Patagonia Natural 1999); this situation is aggravated by the accidental introduction of exotic species, such as brown alga (*Undaria pinnatifida*), Asian clam (*Corbicula fluminea*) and dog’s teeth (*Balanus glandula*), in some areas. The brown alga, introduced in ballast water, has quickly spread in the Nuevo Gulf area (Casas & Piriz 1996). The persistence of brown alga in this LME is thought to be a consequence of sewage, oil spills and wastes discharged from ships (Fundación Patagonia Natural 1999). Other species such as brown trout, rainbow trout (*O. mykiss*), pacific oyster (*Crassostrea* *gigas*), Chilean oyster (*Tiostrea chilensis*), Chinook salmon (*Onchorhynchus tshawystcha*) and beavers were intentionally introduced.

In the long-term, a slight improvement is expected due to governmental action, the influence of environmental NGOs, enhanced community awareness and commitment and increased self-regulation of industry. However, improvements in pollution control will require major investments by the private and public sectors.

IV. Socioeconomic Conditions

This LME includes the entire coastlines of Argentina and Uruguay. The combined population of the coastal cities of Montevideo and Buenos Aires is close to 16 million inhabitants. Both countries have a high urbanisation rate, with the urban population significantly exceeding the rural population. Fisheries contribute less than 1% to the GDP of these countries. Other marine-related economic activities include tourism and offshore oil exploration. The overall socioeconomic impact of unsustainable exploitation of fisheries in the Patagonian Shelf LME is moderate, and could become worse in the future if regulations are not implemented and enforced (UNEP 2004). In particular, overfishing of hake has resulted in severe social problems, loss of employment, and the closure of fishing enterprises. Since 1997, employment has decreased by about 22%, while more recently it decreased by about 13% in the Patagonian region (Bertolotti *et al*. 2001). Between 1999 and 2000, employment by the high seas fleet decreased by about 9%. Likewise, in the same period, employment by the freezer and factory fleets decreased by up to 14% (Bertolotti *et al*. 2001). Argentine fish exports decreased in 2002, mainly due to international and national market conditions, but also to reduced hake landings, which led to the closure of many fish plants (Bertolotti *et al*. 2001). Of the 38 established plants only 26 were operative in 2001. Since 1998 there has been an ongoing trend towards poorer working conditions and lower incomes. The likelihood of conflicts among different sectors also increases as a result of overfishing.

Toxic algal blooms have a negative economic impact on the private sector engaged in fisheries exploitation and seafood production, when harvests and sales are prohibited due to toxic algal blooms. Algal blooms and oil spills demand major economic investment in contingency measures. Toxic algal blooms together with shellfish toxicity have serious consequences for public health, and have caused some deaths in the Patagonian Shelf LME region. Habitat and community modification have significant economic and social impacts on coastal populations, particularly those related to fisheries exploitation. Generally, the impacts on local communities are quite harsh. Economic losses and elevated costs associated with this issue affect both the State and private sectors comprised mainly of small enterprises, cooperatives, and individuals, who are most vulnerable. Damage to urban infrastructure and disruption of coastal activities by coastal erosion has strongly affected tourism revenues and promoted conflicts among different users (tourism, aquaculture, and fishing). Many affected municipalities are now executing projects to address problems created by coastal degradation.

V. Governance

Argentina and Uruguay have national and local environmental authorities and have developed national policies and programmes aimed at the protection and management of the natural environment. The two countries are in the process of strengthening the regulatory capacity of their national environmental authorities with support from the Inter-American Development Bank. The environmental action plans of Argentina and Uruguay have set as goals the conservation and rehabilitation of the coastal habitats of the Rio de la Plata and Atlantic Ocean and strengthening the management of common resources and boundary areas.

An area held in common by both Argentina and Uruguay is the Rio de la Plata and its maritime front. The Treaty of the Río de la Plata and its Maritime Front, signed in 1973 by both countries, established the legal framework for the bi-national management of this area. This framework includes two bi-national governmental Commissions responsible for the preservation, conservation and rational use of living resources and the prevention and elimination of pollution. The Argentine-Uruguayan Technical Commission for the Rio de la Plata Maritime Front has jointly managed the shared hake stock since 1975.

The Patagonian Shelf LME, along with the East and South Brazil Shelf LMEs, forms the Upper South-West Atlantic Regional Sea Area. In 1998, in cooperation with the UNEP/GPA Coordination Office and the UNEP Regional Office for Latin America and the Caribbean, a Regional Programme of Action on Land-based Activities and a regional assessment for the Upper South-West Atlantic were prepared and endorsed by representatives of the three governments. The first steps in implementing the programme, which covers the coast from Cape São Tomé in Brazil to the Valdés Peninsula in Argentina, are under development. The Argentine Federal Fisheries Council (CFP) has requested that the National Fisheries Research and Development Institute (INIDEP) implement a mechanism that provides updated scientific information on the status of the resource [www.cfp.gov.ar/funciones_ing.htm].

Argentina and Uruguay have embarked on a joint project supported by GEF and implemented by UNDP: 'Environmental protection of the Rio de la Plata and its Maritime Front: Pollution Prevention and Control and Habitat Restoration'. The project will contribute to the mitigation of current and emergent transboundary threats to the water body by assisting Argentina and Uruguay to prepare a Strategic Action Plan (SAP) as a framework for addressing the most imminent transboundary issues. Preparation of the SAP would be preceded by finalisation of a TDA, building on assessments already completed by prioritising issues, filling data gaps, and performing an in-depth systems analysis of cause/effect variables, including socioeconomic and ecological factors.

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