XVI-53 East Brazil Shelf: LME #16

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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.* 2009)(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 2009)(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.* (2009).

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.

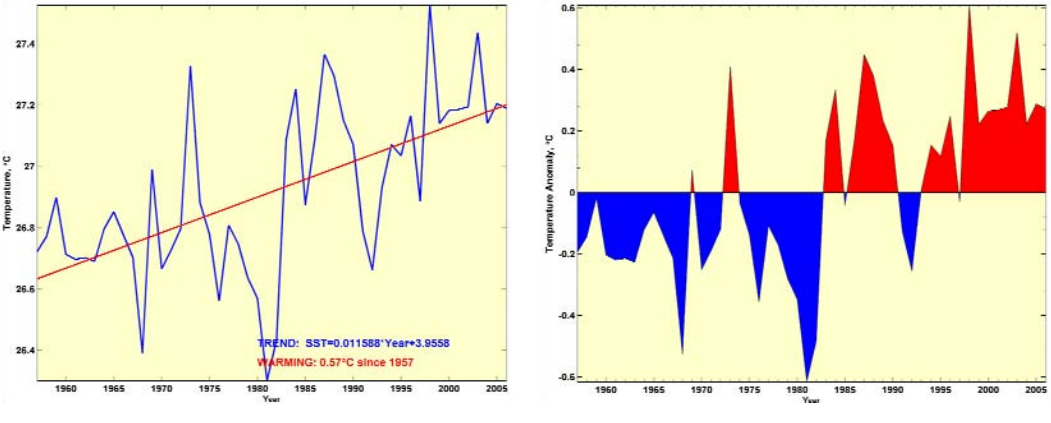

Figure XVI-53.2. East Brazil Shelf LME annual mean SST (left) and SST anomalies (right) , 1957-2006, based on Hadley climatology. After Belkin (2009).

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

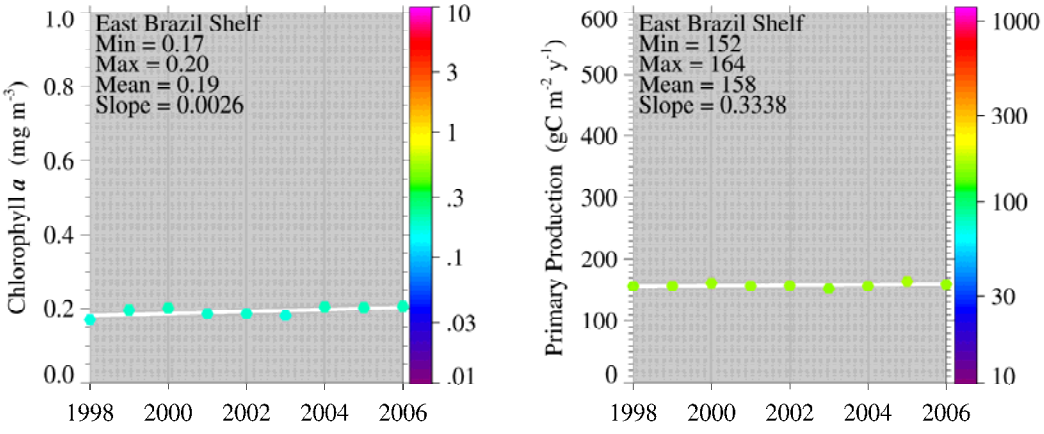

Figure XVI-53.3. East Brazil Shelf trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

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 declined 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).

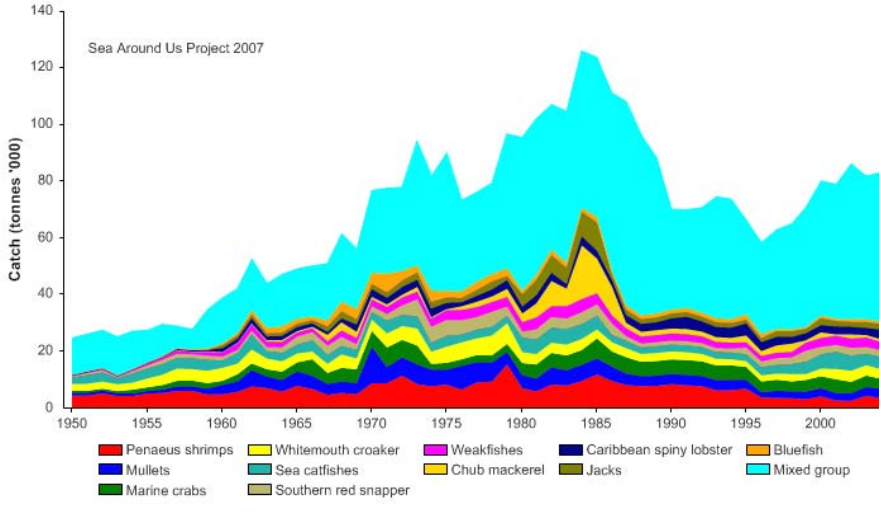

Figure XVI-53.4. Total reported landings in the East Brazil Shelf LME by species (Sea Around Us 2007).

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).

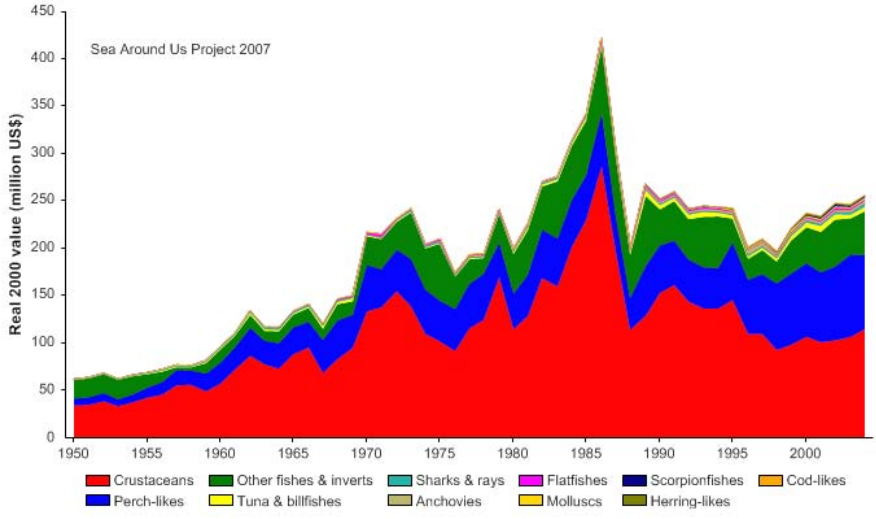

Figure XVI-53.5. Value of reported landings in the East Brazil Shelf LME by commercial groups (Sea Around Us 2007).

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 accounts for almost all of the ecological footprint in this LME, which has little foreign fishing (Figure XVI-53.6).

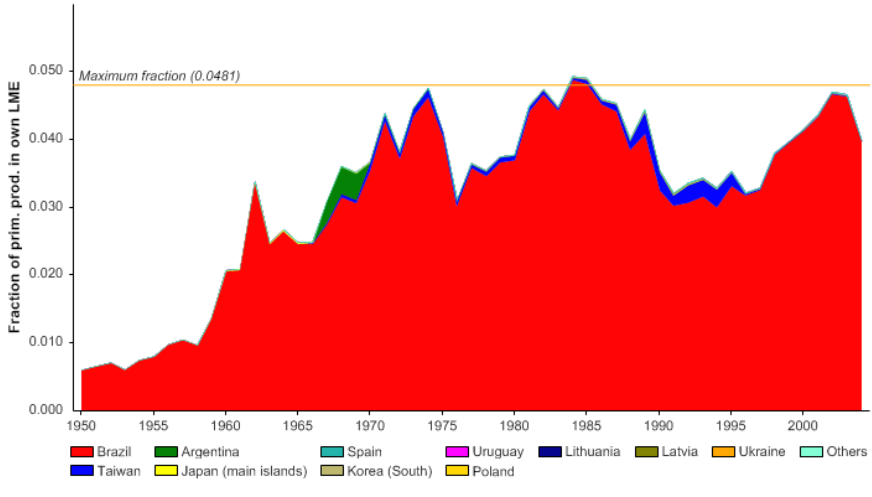

Figure XVI-53.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the East Brazil Shelf Sea LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

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).

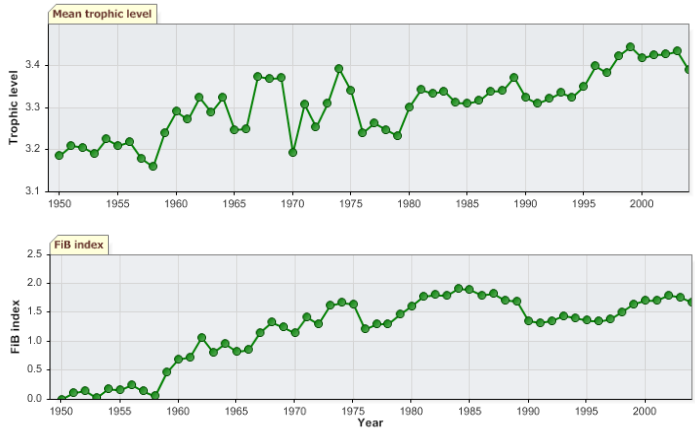

Figure XVI-53.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the East Brazil Shelf LME (Sea Around Us 2007).

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.

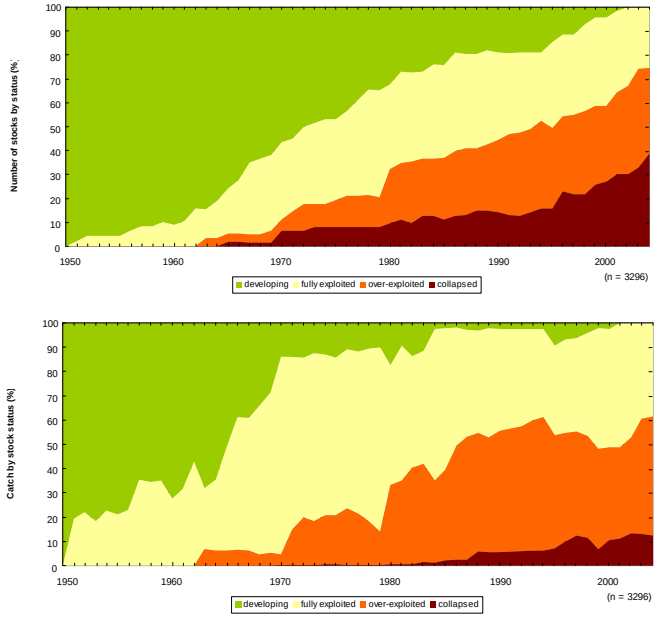

Figure XVI-53.8. Stock-Catch Status Plots for the East Brazil Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number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