XVI-54 South Brazil Shelf: LME #15

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According to the re-definition of the Brazilian LMEs, 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 (Ekau & Knoppers 2003). 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. 2009) (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*. 2009). The Subtropical Shelf Front off southern Brazil has been recently described by Piola *et al*. (2000), Belkin *et al*. (2009) and Campos *et al.* (2008).

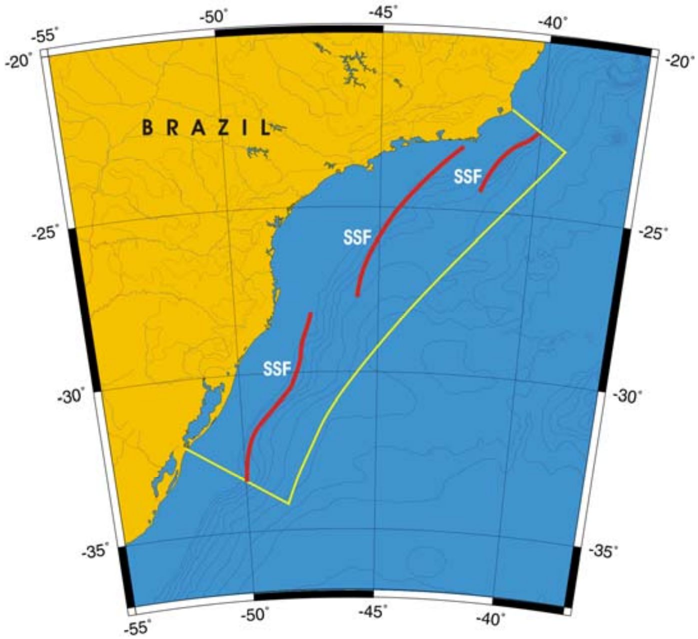


Figure XVI-54.1. Fronts of the South Brazil Shelf LME. Acronyms: SSF, Shelf Slope Front (most probable location). Yellow line, LME boundary. After Belkin *et al.* (2009).

South Brazil Shelf LME SST (Belkin 2009) (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. 2009).

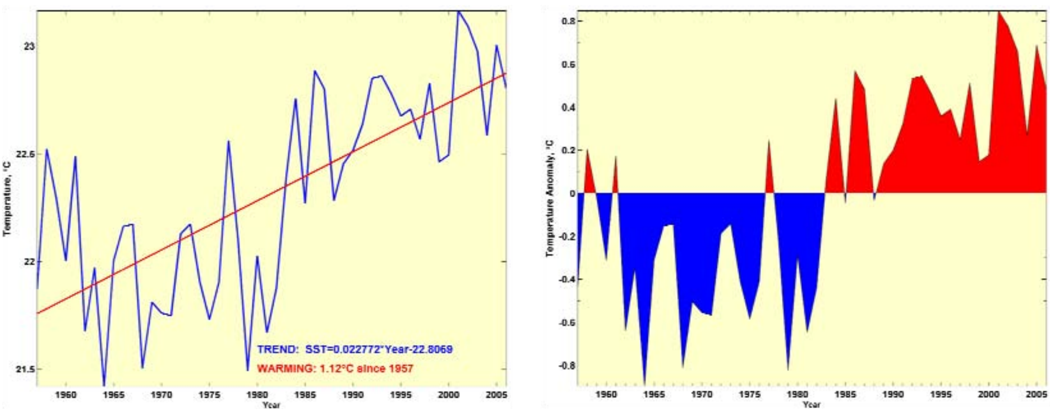


Figure XVI-54.2. South Brazil Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

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).

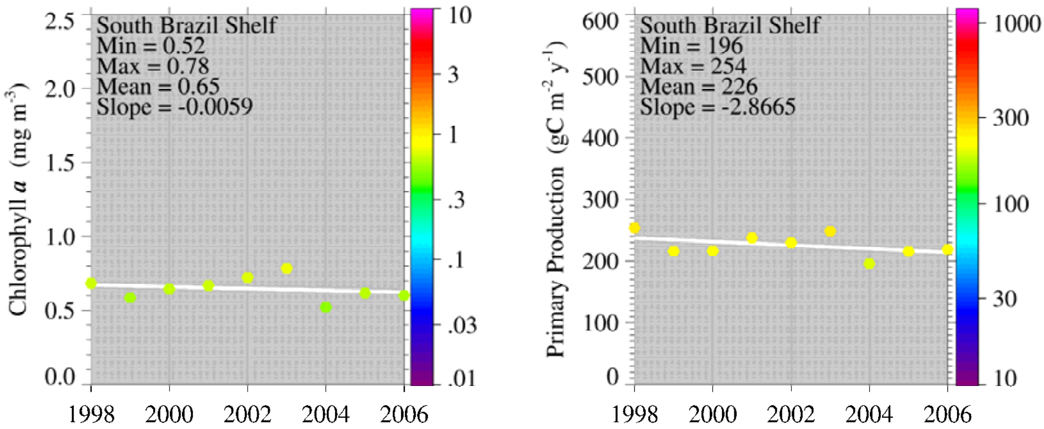


Figure XVI-54.3. South Brazil Shelf trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery; courtesy of J. O'Reilly and K. Hyde.

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 become unsustainable (MMA 2006).

Total reported landings showed an increase up to the early 1970s, when landings peaked at 356,000 tonnes, but 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).

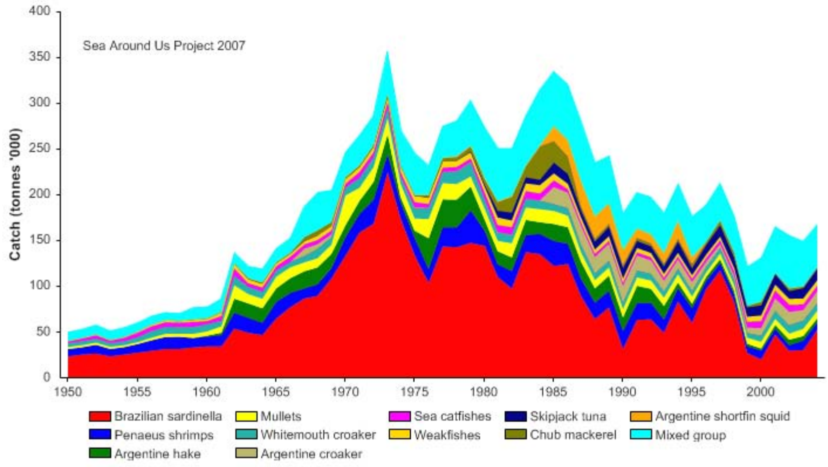


Figure XVI-54.4. Total reported landings in the South Brazil Shelf LME by species (Sea Around Us 2007). Note: Argentine shortfin squid and Whitemouth croaker trends are being reviewed.

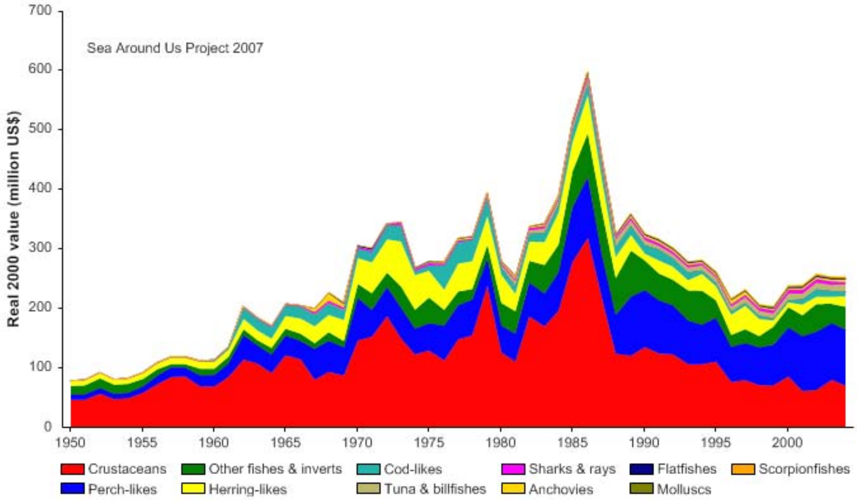


Figure XVI-54.5. Value of reported landings in the South Brazil Shelf LME by commercial groups (Sea Around Us 2007).

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.

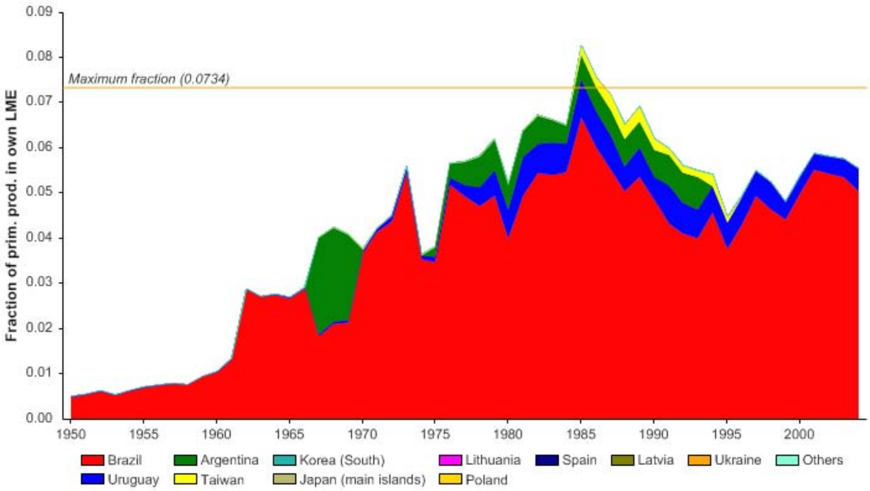


Figure XVI-54.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the South Brazil Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

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).

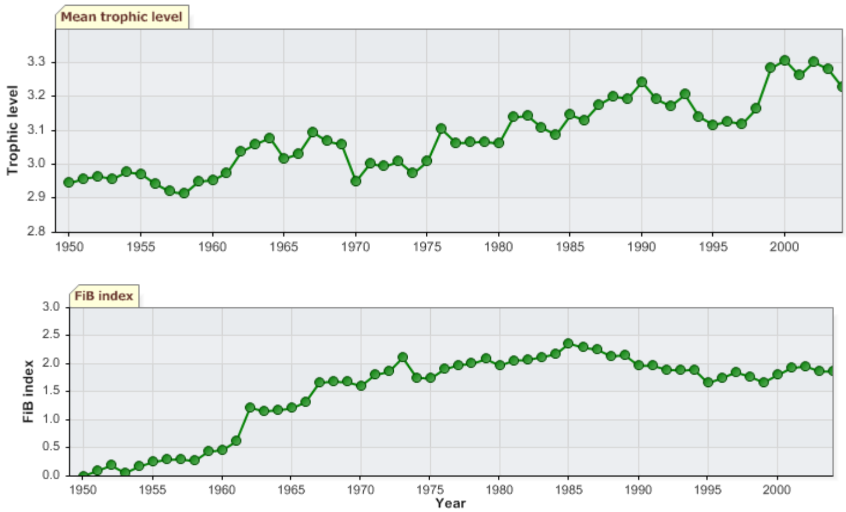
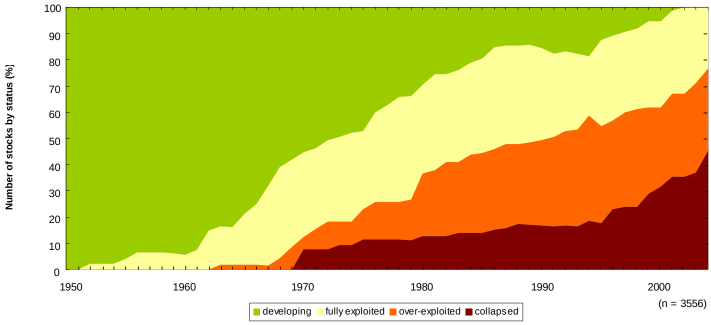


Figure XVI-54.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the South Brazil Shelf LME (Sea Around Us 2007).

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).



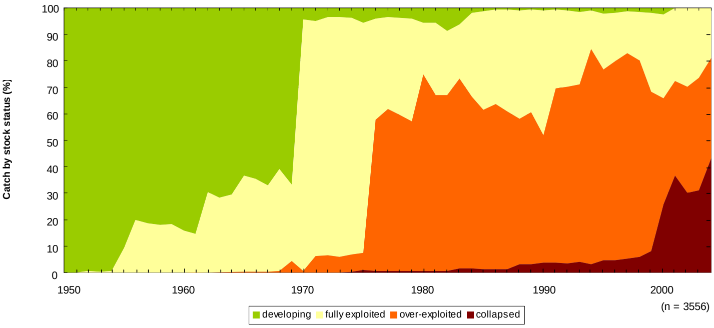


Figure XVI-54.6. Stock-Catch Status Plots for the South Brazil Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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 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 important 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 also has 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. The LME's major marine harbours annually move 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 estate 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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