

5.6 The Patos-Mirim basins, lagoons and estuary, South Brazil: natural and human forcing factors

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Introduction

The warm-temperate coastal region of Brazil's extreme south (Seeliger *et al.* 1997) comprises enormous ecological resources that, despite man's early interference (von Ihering 1885), have satisfied social and economic interests without management for many years. The dominant features of the coastal plain are the Patos and Mirim lagoons. The lagoons receive freshwater runoff from five sub-basins that extend over 201,626 km² (Herz 1977; Castello and Möller 1977; Hubold 1980; Ciotti *et al.* 1995). The Patos Lagoon has a surface area of 10,227 km² and is the world's largest choked lagoon (Kjerfve 1986). The lagoon has an average depth of 5 m, a maximum width of 60 km, and the main axis extends over 180 km in a NE-SW direction (Figure 5.14). Shallow marginal bays, freshwater marshes, and sandy beaches dominate the shorelines.

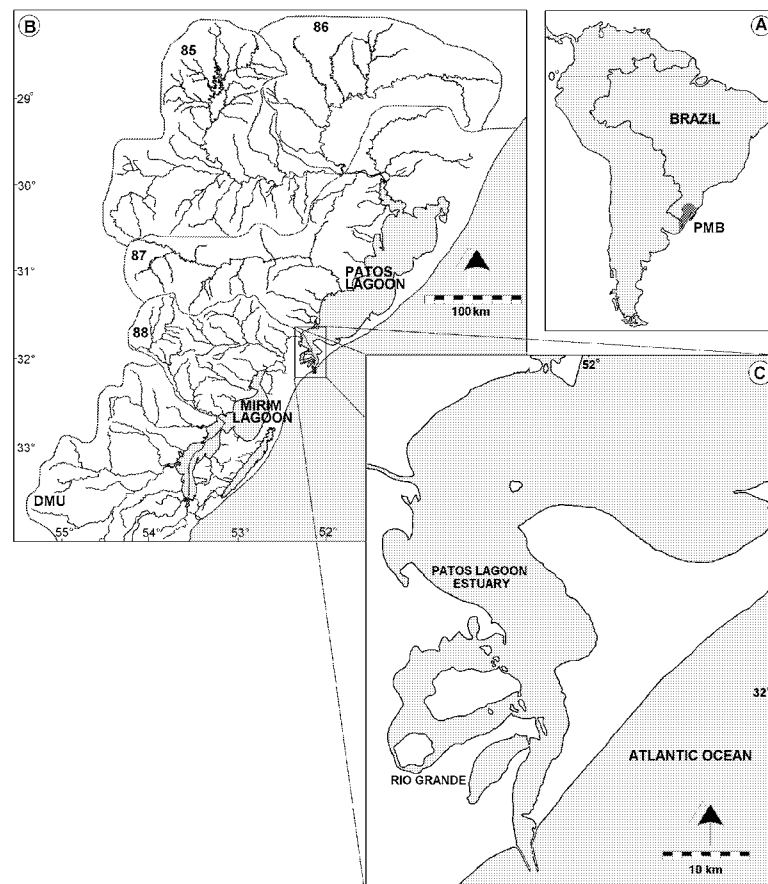


Figure 5.14. A - Geographic location of the Patos-Mirim Basin (PMB); B - Patos-Mirim Basin with sub-basins (85, 86, 87, 88, DMU); C - Patos Lagoon estuary.

About 85% of the runoff originates from the Guaíba River (basins 85, 86), the Camaquã River (basin 87), and from São Gonçalo Channel (basins 88, DMU) falling into the upper, central and lower Patos Lagoon, respectively (Figure 5.14). Freshwater runoff from the Guaíba basin may vary from 41 to 25,000 m³ s⁻¹ between summer/fall and winter/spring and runoff from the Camaquã basin from 6 to 5,300 m³ s⁻¹ (Herz 1977). Artificial locks in the São Gonçalo Channel, which impede saltwater penetration from the Patos

Lagoon estuary into the Mirim Lagoon, are only opened during periods of elevated freshwater accumulation, thus discharge into the upper estuary ($700\text{--}3,000\text{ m}^3\text{ s}^{-1}$) is usually higher in winter/spring. Average runoff values are greatly exceeded during years under the influence of El Niño, with direct consequences on biogeochemical processes in the coastal marine ecosystem in the South-west Atlantic (Ciotti *et al.* 1995; Seeliger *et al.* 1997). Approximately 971 km^2 of the southern lagoon reaches are estuary through which waters exchange with the Atlantic Ocean. The estuary is dominated (70%) by extensive and shallow ($<1.5\text{ m}$) shoals, though the inlet and other channels may reach a depth of 18 m (Calliari 1980, Toldo 1991) (Figure 5.14).

Natural forcing

More than any other parameter, the nature of the narrow (700 m) and deep inlet channel characterize the system as a choked coastal lagoon (Kjerfve 1986). The inlet acts as a set-down filter and largely confines tidal influence (0.47 m) to the channel, strongly attenuating amplitudes as the tidal wave advances into the estuary and lagoon. After prolonged periods of heavy rainfall, flushing current velocities in the inlet may reach $1.7\text{--}1.9\text{ m s}^{-1}$ (DNPVN 1941), whilst peak inflowing seawater current velocities approach 1.5 m s^{-1} (Hartmann 1996).

Rather than being tidal-driven, the Patos Lagoon is forced by winds. Since the predominant NE (22% of the year; mean velocity $3.6\text{--}5.1\text{ m s}^{-1}$) and SW (12% of the year; mean velocity $5.7\text{--}8.2\text{ m s}^{-1}$) winds are parallel to the main axis of the lagoon, they were early identified as the principal forcing factor (Bicalho 1883; Malaval 1922). They decisively control circulation, salinity distribution and water levels, although fluvial discharge may also generate seasonal pressure gradients with elevated water levels after the onset of the rainy period.

Wind direction influences both local and large-scale circulation patterns. Under NE winds a pressure gradient rises along the main lagoon axis. A pressure gradient between the inlet channel and retreating adjacent coastal waters favors flushing of the lagoon water (Motta 1969). In contrast, SE and SW winds cause inversion of flow in the main lagoon body and raise the water level at its northern limits. In the inlet channel, outflowing currents are forced along the western margin under the influence of NE winds, whilst SE and SW winds direct inflowing currents towards the shallower eastern bank (Gafrée 1927, Moller *et al.* 1991, Hartmann 1996).

The time-space variability of physico-chemical estuarine parameters and their component concentrations lack tidal variability but relate to regional temperature cycles and wind and precipitation patterns (Vilas Boas 1990). The temperature and salinity profiles delineate different estuarine conditions. Homogeneous conditions, ranging from freshwater to full-strength seawater, are associated with high fluvial discharge and NE quarter winds or minimal freshwater discharge and southerly winds, respectively. NE quarter winds together with high fluvial discharge significantly decrease estuarine salinities (Calliari 1980; Costa *et al.* 1988). During periods of low fluvial discharge (i.e. summer/fall), southerly onshore winds force seawater through the inlet into the lower estuary and occasionally as far as 150 km into the lagoon (Hartmann 1996). In contrast, wind-induced seawater penetration and fluvial discharge in excess of $3,000\text{ m}^3\text{ s}^{-1}$ cause pronounced salinity stratification in the inlet because freshwater advances over the salt wedge. Even higher runoff values transfers the estuarine mixing zone into coastal waters (Möller *et al.* 1991).

The estuary receives sediments from a variety of sources. Suspended matter loads in the water column strongly depend on precipitation in the Patos-Mirim basins. However, owing to a gradual decrease ($1\text{ m}/120\text{ km}$) in elevation towards the estuary and slow currents, much of the sediment load is deposited in the main lagoon body during transport (Martins 1963; Hartmann *et al.* 1980). Apart from fluvial input, the erosion of estuarine margins contributes significant amounts of sediments. In general, suspension loads tend to increase in the inlet due to re-suspension of bottom sediments by inflowing seawater (Niencheski and Windom 1994, Hartmann 1996). Seasonal mean suspended matter loads in the inlet channel ($50\text{--}350\text{ mg l}^{-1}$) may sporadically exceed $1,200\text{ mg l}^{-1}$ (Hartmann 1996). In years with average rainfall, hundreds of tons of silt and clay sediments ($>95\%$) reach coastal waters every second. Based on the erosion of estuary margins, the annual sediment removal to coastal nearshore waters may approach $2.5 \times 10^5\text{ m}^3$ (about $4 \times 10^5\text{ t}$; Calliari 1980). Even higher values of about $2.4 \times 10^6\text{ m}^3$ or $3.8 \times 10^6\text{ t}$ occurred during 143 days of flushing between May and October of 1984 (Hartmann 1996) (Figure

5.15). During the same period, 1.1×10^4 t of nitrogen and 1.2×10^5 t of carbon were exported, assuming mean total concentrations of 0.32% and 3.0%, respectively (Hartmann 1996).

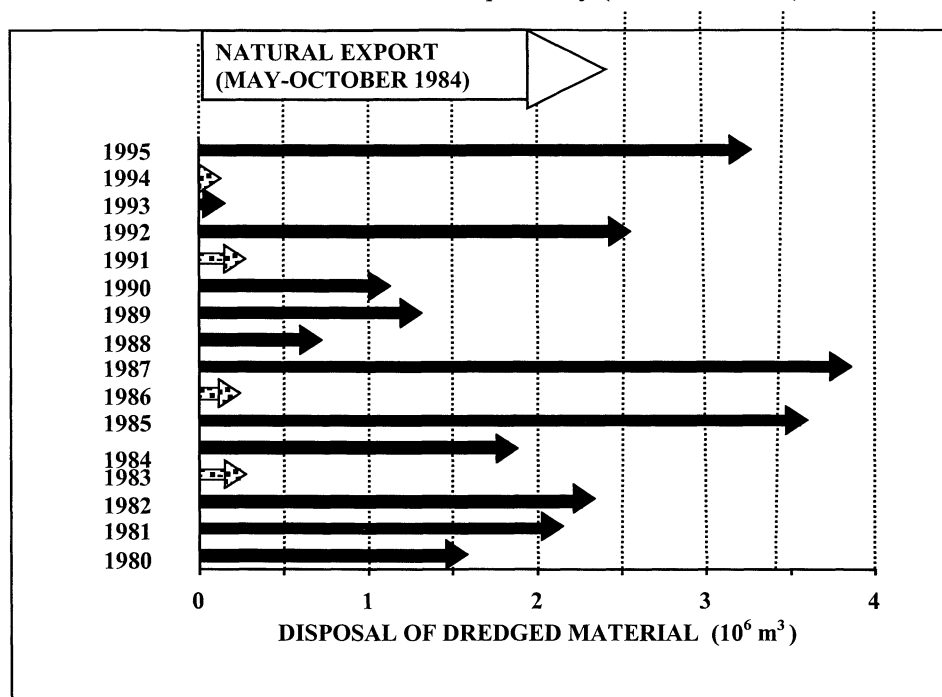


Figure 5.15. Estimate of natural sediment export from the Patos Lagoon estuary and disposal of dredged material in coastal waters (black arrows) and inside the estuary (dotted arrows) over a fifteen-year period (after Hartmann 1996, SUPRG 1996).

Despite high mean suspended matter loads in the channel and shallow shoals, dissolved oxygen in the water tends to be close to saturation or even at super-saturation levels (Niencheski and Windom 1994), especially in the inlet channel with pronounced hydrodynamic activity. The shallow depth (<1 m) of the larger part of the estuary favors water oxygen levels in equilibrium with the atmosphere.

Human forcing

Freshwater Flow

The water quality of the Patos Lagoon, estuary and coastal nearshore environments is ultimately related to natural freshwater runoff. Because of the assumption that runoff is available for expanding agricultural and industrial activities and domestic needs without any limitation, the importance of freshwater flow into the estuary has been overlooked. The annual estimated stream flow through the Patos Lagoon inlet averaged 109 km^3 between 1965 and 1975 (Castello and Möller 1978) but varied significantly within ($\text{CV}=80\%$) and between ($\text{CV}=29\%$) years. During the drought years 1968-1969 (IPAGRO 1977), the water demand for irrigated rice cultivation (EPAGRI 1992) and for the population of the watershed approximated 6% of the expected (75 km^3) annual runoff. Since then, the population and the area of irrigated rice cultivation have increased by more than 37% and 120%, respectively (IBGE 1993). Today, in drought periods as La Nina events (CPTEC/INPE 1998), more than 13% of the natural runoff may be diverted (Figure 5.16). Furthermore, retention of water for irrigation by the locks in the São Gonçalo Channel has considerably reduced freshwater flow into the estuary. The decreasing freshwater discharge into the estuary has modified seasonal variations in flow rates that are essential for flushing and maintaining the balance of salinity and nutrients in the estuary. Therefore, many of the commercially important fish and crustaceans in the south-western Atlantic, which visit the estuary periodically, may lose the benefit of low salinity waters, physical protection, and food sources for either growth or reproduction (Vicira and Castello 1997).

Nutrient Enrichment

Freshwater runoff not only influences estuarine salinity regimes but also affects the quality of surface waters through inputs of nutrients and toxic materials. Most urban centers around the Patos Lagoon (~3.5 million inhabitants) either lack or have inadequate sewage treatment facilities, which tend to overflow during heavy rains and discharge raw sewage directly into the lagoon or estuary. The major tributaries also add nutrients from large-scale agricultural activities; phosphate (2-3 μM) and nitrogen ($> 40 \mu\text{M}$) concentrations in particular tend to be seasonally elevated in the receiving waters of the Patos Lagoon (Vilas Boas 1990). Despite a substantial reduction during transport, estuarine nutrient levels are also occasionally elevated (Kantin 1983; Niencheski and Windom 1994), owing to remobilization of bottom sediments in the lower estuary (Abreu *et al.* 1992), local discharge of industrial and domestic effluents, and agricultural runoff through the São Gonçalo Channel. Excess nutrient loads in the estuary cause eutrophication, which favors blooms and changes in phytoplankton composition. Blooms of the potentially toxic blue-green alga *Microcystis aeruginosa* form in limnic regions of the lagoon and, during years with high spring tributary discharge, are transported into the estuary (Odebrecht *et al.* 1987; Bergesch 1990). During the summer, estuarine embayments with prolonged water residence time favor blooms of other species (Persich 1993) that contribute to the decline of the submerged macrophyte biomass in the estuary, owing to attenuation of light penetration and epiphytic algae loading on *Ruppia* leaves (Cafruni 1983; Costa and Seeliger 1989). Recently, red tide blooms associated with the dinoflagellates *Gyrodinium aureolum*, *Dinophysis acuminata* (Odebrecht *et al.* 1995) and *Alexandrium tamarense* (Persich 2001) have been reported for waters adjacent to the estuarine mouth.

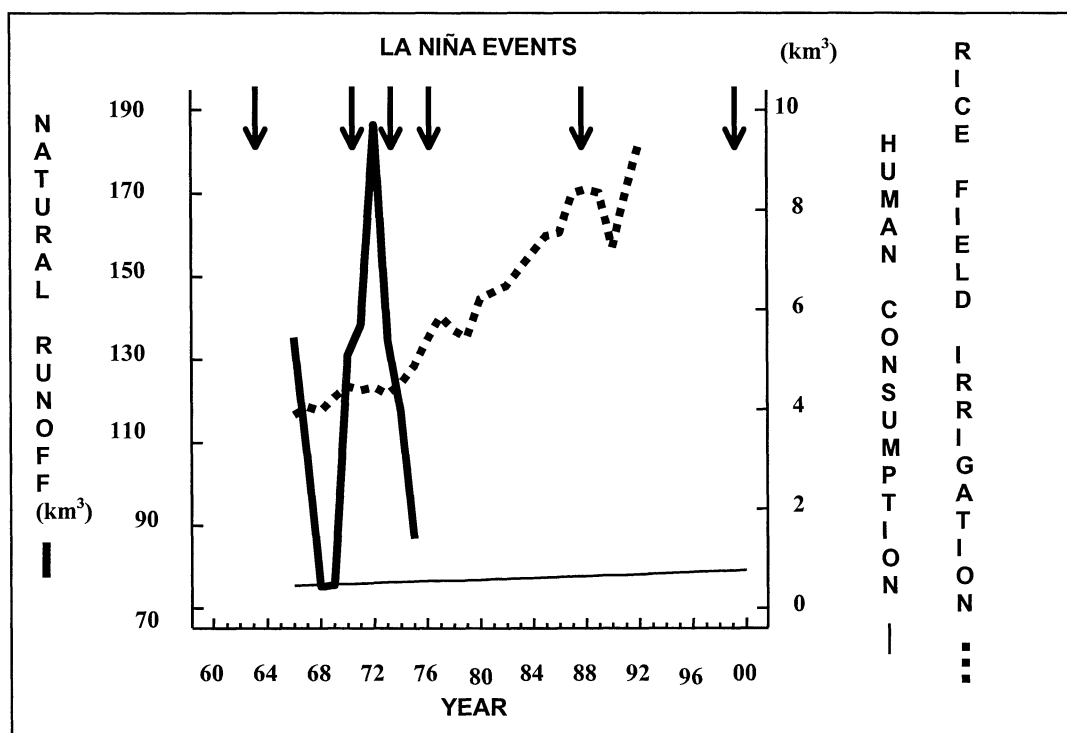


Figure 5.16. Estimated runoff from the Patos Lagoon estuary between 1965-1975 and projected water diversion for human use and rice field irrigation (after IPAGRO 1977, Castello and Moller 1978, EPAGRI 1992).

Hazardous Materials

Since large stretches of coastline north and south of the inlet are devoid of industrial discharge, trace metals are added to the estuary either through freshwater runoff from the Patos Lagoon or through local discharge of effluents (Seeliger *et al.* 1988). Average metal concentrations in estuarine waters with high suspension loads correspond to natural background levels (Seeliger and Knak 1982a; Niencheski *et al.* 1994) reported for estuarine systems elsewhere (Windom 1975), though dissolved copper concentrations are occasionally slightly higher (Seeliger and Knak 1982b). Sporadic increases of suspended copper and lead concentrations in the

estuary may reflect metal input from industrial effluents and mining activities to the upper limnic part of the Patos Lagoon (Baumgarten 1987; Vilas Boas 1990). In general, metal concentrations correlate significantly with suspended matter loads, and estuarine metal gradients are not well defined (Seeliger and Cordazzo 1982) because physico-chemical processes add particulate metals through re-suspension of estuarine bottom sediments by inflowing seawater, wind and waves (Niencheski *et al.* 1994).

The biological effects of trace metal pollution have not yet been documented for the Patos Lagoon estuary, probably because estuarine organisms tend to display elevated metal tolerance and the concentrations are close to background levels. However, in shoals with reduced circulation and prolonged residence time of domestic and industrial effluents, even low pollution levels appear to induce changes in the zooplankton community structure and anatomical anomalies (Montú and Gloeden 1982). The excessive application of pesticides over vast extensions of agricultural lands around the Patos Lagoon (e.g., 890,000 ha of rice plantations: EPAGRI 1992) is likely to contribute through runoff elevated concentrations to the estuary. Some intertidal estuarine species (e.g. *Chasmagnathus granulata*), which decisively influence energy transfer in submersed and emersed habitats (D'Incao *et al.* 1992), appear to be highly susceptible to pesticide concentrations in warmer waters during the summer (Monserat and Bianchini 1995). Surficial estuarine and coastal waters are especially prone to pollution by different fractions of hydrocarbons from urban discharge or washing of tanks of vessels and values of up to 30 mg l⁻¹ of oil and 30 µm l⁻¹ phenol have been measured in enclosed estuarine bays (Niencheski and Baumgarten 1997).

Sedimentation, Fill and Dredge

The introduction of large amounts of suspended sediments from the Patos Lagoon and the presence of extensive and shallow shoals occupied by *Ruppia* beds and fringing marshes provide an ideal setting for natural deposition processes in the estuary. Over the last two centuries the water area of the lower estuary has decreased by approximately 11%, which emphasizes the depositional character of this environment (Seeliger and Costa 1997). However, losses of lower estuarine water areas not only result from natural sedimentation but also from man-mediated processes. The expansion of Rio Grande port between 1909 and 1914 generated 8.8x10⁶ m³ of dredge material, which served for the establishment of islands and was deposited along lower estuary margins. The construction of jetties in 1917 has probably intensified natural sedimentation at the northern side of the inlet.

Furthermore, the natural sediment deposition in the lower estuary has interfered with navigation, thus dredging activities have concentrated in the navigation channel and inlet since 1833. Modern vessels with increasing draft require deeper waterways. Between 1980-1995, approximately 2.4x10⁶ m³ (3.8x10⁶ tons) of channel and berth material was removed every year from the shipping channels and most (about 77%) was disposed of in nearshore waters four miles off the coast (SUPRG 1996; Figure 5.15). Although dredging activities may have solved immediate problems, they also resulted in unexpected and long-term changes by modifying depth, circulation, and sediment deposition patterns (Calliari 1980). Since the accumulative effects of frequent dredging are comparable to natural geological processes (Figure 5.15), the export of fine sediments to the adjacent coast is likely to have increased (Villwock and Martins 1972; Hartmann *et al.* 1980; Borzone and Griep 1991; Calliari and Fachin 1993).

The filling of intertidal and shallow water flats in the lower estuary for port, residential, and more recently industrial development has decreased or destroyed vital seagrass and tidal marsh habitats. Filling along lower estuarine margins and over and around small islands has destroyed as much as 10% of the total salt marsh area (Seeliger and Costa 1997). Seagrasses are especially susceptible to filling, and burial by dredged sediments results in their immediate eradication. Only if plants are lightly covered and the root-rhizome systems are not damaged may re-growth occur through the sediments. Since dredged sediments are readily re-suspended, they represent a source of excess suspended matter for long periods of time. The gradually increasing water turbidity reduces seagrass production and depth distribution. Therefore, the extension of natural beds and their valuable functions as habitat and shelter decrease. Although the disposal of dredged material is clearly affecting estuarine resources, the State government only recently established a monitoring program for dredging activities in the main shipping channel and disposals in nearshore waters.

Conclusions

Over the last few decades, demographic and industrial growth in the Patos-Mirim basins and around the lagoons have altered natural processes and magnified environmental conflicts. Elevated runoff from tributaries adds ever-increasing sediment loads, nutrients, hazardous heavy metals (Baisch *et al.* 1989), and agro-toxins to the Patos Lagoon, while port activities and fertilizers, fish processing and petroleum refining plants have led to deterioration of the waters in the estuary (Almeida *et al.* 1993). Escalating conflicts between human impact and resource exploration call for an increasing commitment to solve current management problems of the Patos-Mirim coastal ecosystem (Asmus *et al.* 1984). Contrary to the historic situation in other parts of the world that suffered consequences of uncontrolled human impacts decades ago, the information now available may still prevent further deterioration of the coastal ecosystem in Brazil's extreme south.

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5.7 Some implications of inter-basin water transfers - Mercury emission to Sepetiba Bay from the Paraíba do Sul River basin, SE Brazil

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Introduction

Streams are considered an integral part of a watershed, mainly considering the water transport. But in some cases, principally for water supply, some forms of river basin manipulation can transfer water between different, adjacent basins, an event which under natural conditions does occur. Despite transformations of the landscape, the ecological implications of such schemes have been inadequately addressed.

The interaction between the two different basins may change the environmental conditions of the water body that receives water from them and will lead to alterations in hydrology and sedimentology, such as water additions, water quality changes, contaminants input, alterations in physical properties of channels, temperature regimes and transfer and mixing of organisms (Snaddon *et al.* 1998).

These effects may spread through rivers that receive the transferred water, through impoundments constructed along the river channel to control the transfer fluxes between basins, and thence to coastal areas. In the case of trace metal contamination the impact that occurs in the continental location may be observed in areas away from the emission point. For example, mercury contamination in Sepetiba Bay, SE Brazil, originates from a variety of anthropogenic sources located along its basins. However, when emission *vs* fluvial output estimates are compared, the imbalance suggests that part of this emission may have originated from the adjacent Paraíba do Sul River basin, since over 80% of the water flux of this river is diverted to the Sepetiba Bay basin to supply the Rio de Janeiro metropolitan area (Marins *et al.* 1996; 1999). This is a typical case in which inter-basin water transfer may be contributing a pollutant load to a coastal environment that normally did not receive this load.

Study Area

The study area is located in Rio de Janeiro State, SE Brazil (Figure 5.17). The Paraíba do Sul River (PSR) discharges into the Atlantic Ocean about 400 km north of Sepetiba Bay, at Campos Municipality. It is a medium sized river, with a length of approximately 1,145 km and a watershed area of 55,400 km². Maximum river flow is observed during November and March (4,380 m³ s⁻¹) and the lowest discharges (180 m³ s⁻¹) occur between June and September (DNAEE 1983). The river drains the most industrialized states of Brazil - São Paulo, Rio de Janeiro and Minas Gerais - and is the most important river for Rio de Janeiro State because its water is widely used for agriculture, industry and human consumption (>20 million inhabitants). However, the river also receives effluents from all these activities, generally without treatment, compromising its water quality.

Sepetiba Bay and basin, SE Brazil (Figure 5.17) is a semi-enclosed water body, connected to the sea by a small, shallow inlet, with minimal water flux that crosses extensive mangrove forests. Mean water volume is 2.56x10⁹ m³, ranging from a maximum of 3.0x10⁹ m³ and a minimum of 2.38x10⁹ m³ (Rodrigues 1990). The average depth is about 6 m. Nine rivers draining the quaternary plain at the northeastern coast of the Bay, are responsible for almost all the freshwater input to the bay, with an annual flow of 7.6x10⁶ m³. Among them, the São Francisco Canal, with an annual flow of 6.5x10⁶ m³, accounts for 86% of the total fluvial inputs. This canal is artificial, and has an almost uniform flow rate throughout the year.

The two basins are not naturally connected, but in the late 1950's, to supply water and electrical energy for adjacent regions, engineering works pumped up water (with a constant discharge of around 160 m³/s) from the Paraíba do Sul River to form two successive reservoirs (Santana and Vigário) to supply water for generating electrical energy. The Paraíba do Sul waters flow to the Guandu River, to supply the Rio de Janeiro metropolitan area, and finally the excess volume is discharged into Sepetiba Bay through a large artificial channel, the São Francisco River, with a nearly constant flow volume of about 160-180 m³.s⁻¹. In

the Guandu River, there is the Guandu Water Treatment Plant that diverges waters from the Guandu River (originally Paraíba do Sul river waters) to supply the Rio de Janeiro City and other regions. The refuse of treatment processes is discharged into the Guandu Channel that also flows into Sepetiba Bay.

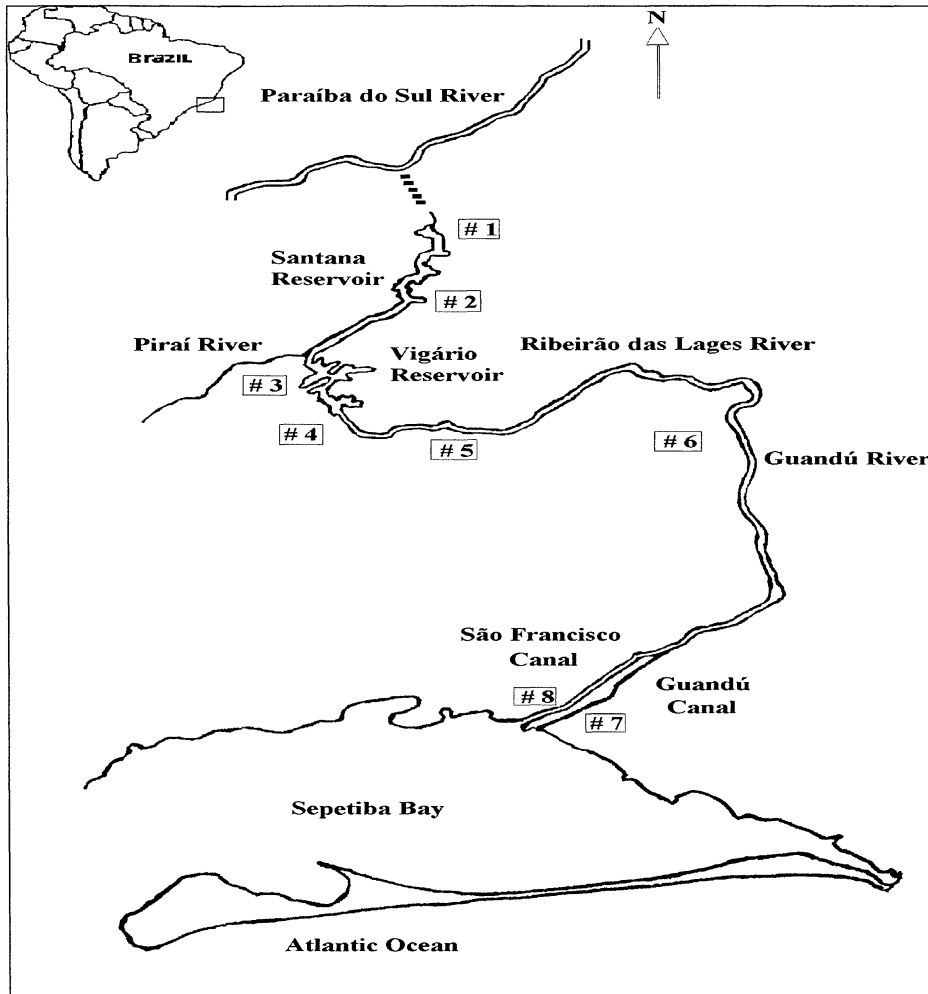


Figure 5.17. Sampling sites in Paraíba do Sul River - Sepetiba Bay system (scale 1:400,000).

Sepetiba Bay is an example of the environmental significance of basin-generated impacts on the coastal zone. The concentration of industries, urban centers and agriculture along the north-eastern portion of the Sepetiba Bay basin make this area of SE Brazil the most critical in terms of environmental contamination by trace metals. However, the bay itself is relatively free of direct inputs of most industrial contaminants, which reach the bay through rivers and atmospheric deposition (Lacerda *et al.* 1987).

Mercury emission from the Paraíba do Sul River

Method

Studies performed in the Paraíba do Sul River (PSR) indicated that trace metal contamination in the upper and middle basins originated mainly in industrial and domestic sewage (Pfeiffer *et al.* 1986; Malm 1988). The PSR portion before the water pump is considered the most mercury-impacted in the basin, due to the large industrial park in the river basin, which includes metallurgical, iron and steel production, paper, plastic, rubber and chemical factories, all of them producing mercury in their effluents. This is in addition to the inputs from a densely populated area, with wastes poorly treated before disposal into the river (Mello 1999). The mercury emitted by these activities may reach the river directly or after some time in the watershed, then transported by runoff to the river. Therefore, the Paraíba do Sul River water diversion can significantly contribute to mercury input into Sepetiba Bay. To verify this contribution the mercury

concentrations along the fluvial system from the Paraíba do Sul River proper to Sepetiba Bay were monitored.

Results and discussion

Samples were collected during the wet season (February 2001), when most of the transfer should occur, along the Paraíba do Sul River-São Francisco Canal waterway (Figure 5.17), showed similar concentrations of mercury in water and in suspended particulate matter from the Paraíba do Sul River end-member (site #1) and the São Francisco Canal end-member (site #8), near its delta in Sepetiba Bay (Table 5.9). Mercury concentrations in the Paraíba do Sul River site reached 0.102 ng l^{-1} in water and 400 ng g^{-1} in suspended particulate matter, while in the São Francisco Canal site the Hg contents in samples were 0.13 ng l^{-1} and 350 ng g^{-1} , respectively.

Mercury distribution among the sampling sites showed large variations, reaching 0.049 to 3.8 ng l^{-1} in water and 250 to $1,360 \text{ ng g}^{-1}$ in suspended particulate matter. These differences may be explained by point sources from activities introduced along the waterway, mostly due to water withdrawal for industrial uses and human consumption. For example, in reservoirs such as the Santana reservoir (sites #1 and #2, Figure 5.17), hydrological conditions promote the settling of suspended particles, scavenging mercury to bottom sediments and thus decreasing mercury concentrations downstream (Table 1). This mechanism, however, may be reversed since average water depth of the Santana reservoir is only about 1.5 m , and bottom sediment resuspension due to strong winds may remobilize settled particles into the water, allowing downstream transport.

Table 5.9. Mercury concentrations in sampling sites between Paraíba do Sul River and Sepetiba Bay. Average concentrations of duplicate values

Station (Figure 5.17)	Total Dissolved Hg (ng l^{-1})	Particulate Hg (ng g^{-1})
# 1	0.102	400
# 2	0.049	260
# 3	0.051	750
# 4	0.157	1,360
# 5	0.128	620
# 6	0.122	250
# 7	3.851	960
# 8	0.130	350

Other activities like industrial plants, located mainly in the Sepetiba Bay basin and a large landfill (Marins *et al.* 1999), contribute with direct mercury emissions to streams. The mercury concentration in the São Francisco Canal (site #8) also receives a significant contribution, through watershed runoff and atmospheric deposition, from the large industrial park located in the Sepetiba Bay basin, mainly metal manufacturing, iron and steel production, plastic and rubber production, and an oil-fired thermo-electric plant.

In the Guandu Canal (site #7), high mercury concentrations as dissolved and particulate forms may be explained by refuse discharge from a water treatment plant that collects water diverted from the Guandu River (Rodrigues 1990). The water cleaning processes use some techniques to settle particles and organic colloids in bottom sediments. But these contaminated sediments, rich in organic and inorganic substances, are eventually discharged into the Guandu Canal, at regular intervals.

Mercury concentration analyses are not sufficient to determine the actual contribution from the Paraíba do Sul River to Sepetiba Bay, so the use of mercury fluxes is an interesting tool to quantify this influence. Total mercury flux (particulate+dissolved) in the Paraíba do Sul River at site #1 reaches 107 kg yr^{-1} , while in the São Francisco Canal site #8, the total mercury flux reaches 372 kg yr^{-1} . Also, although the Guandu Canal (site #7) has a smaller water flux compared with São Francisco River, the mercury discharge, mainly as the dissolved forms, is very representative, being even larger than the dissolved flux from the Paraíba do Sul River or the São Francisco Canal (Table 5.10).

Table 5.10. Particulate and total dissolved mercury concentrations and fluxes (kg yr⁻¹).

River/Station (Figure 5.17)	Particulate Hg (ng g ⁻¹)	Total dissolved Hg (ng l ⁻¹)	Water flux (m ³ /s)	Particulate Hg flux	Total Dissolved Hg flux
Paraíba do Sul River (site #1)	400	0.102	160 ^a	106	0.50
Guandu Channel (site #7)	3,850	0.96	6.1 ^b	42	0.83
São Francisco River (site #8)	350	0.13	180 ^b	371	0.75

^a Light Electric Company (personal communication)

^b Rodrigues (1990)

The mass balance shows that the Paraíba do Sul waters contributed 25% of the mercury load exported to Sepetiba Bay. The other 75% may come from sources along the river's course, such as industrial plants in the Sepetiba Bay basin or domestic sewage input. The results showed that 90–99% of the mercury is transported as particulate forms, at least during periods with high suspended matter concentrations (around 100 mg l⁻¹), such as the rainy season sampled in this study.

The present study is in agreement with previous balances performed in the Sepetiba Bay basin based on emission factors (Marins *et al.* 1998a) and mercury measurements through rivers (Marins *et al.* 1999; Paraquetti 2001). Marins *et al.* (1998a, 1999) estimated that mercury emissions from the Paraíba do Sul basin could contribute up to 30–45% (about 200–300 kg yr⁻¹) of the total fluvial mercury input to Sepetiba Bay, roughly the same order of the magnitude as the present estimate based on the rainy season flux. It is important to note that freshwater inputs, and therefore associated transported substances, do not vary significantly between the dry and rainy seasons, since over 85% of it is artificially controlled by the water management station of the two basins, for water supply to the Rio de Janeiro metropolitan area. Therefore our single-period data are probably valid for other periods of the year.

The inter-basin water transfer is significantly contributing mercury fluxes to Sepetiba Bay, emitted from diffuse and point sources along the waterway. About 25% of the mercury transport is determined by water pumped from the Paraíba do Sul River. This suggests that any control measures and guidelines being applied to Sepetiba Bay basin will not necessarily abate the entire mercury pollution problem of the bay.

The mercury discharged into Sepetiba Bay may cause environmental problems, since dispersion through biologically complex coastal ecosystems will favor contamination of aquatic organisms through food chain transfer. Whereas fish consumption along the Paraíba do Sul River is of very minor importance to the local population, embayments such as Sepetiba Bay are significant sources of marine protein to a large proportion of the population, increasing the chances of mercury reaching humans through seafood consumption. In addition, the artificial reservoirs existing along the waterway and the estuarine area of Sepetiba Bay are important locations for biotic production and reproduction of aquatic life. Marins *et al.* (1998b), for example, showed correlations between mercury concentrations and fish size in Sepetiba Bay suggesting that methyl-mercury availability and accumulation through food webs may compromise fish consumption, while artificial reservoirs are believed to act as reactors producing methyl-mercury at very high rates (Lacerda and Salomons 1998). Therefore, a nearly insignificant environmental toxicological problem along the Paraíba do Sul River may become a serious environmental threat to the local population using aquatic resources in the Sepetiba Bay basin.

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5.8 Heavy metal transfers from Patagonia to the South Atlantic Ocean

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Introduction

Metals are introduced into the environment by different processes. Sources for trace metals are natural processes of weathering, erosion and volcanic activity. However, with the large-scale extraction of ore from the Earth's crust, pollution and other mechanisms have become increasingly important, almost obliterating natural rates in many regions of the world (Salomons and Förstner 1984; Nriagu 1990).

Important processes occur at the river/ocean interface and on the continental shelf, where accumulation of natural and anthropogenic trace metals take place. The arid/semiarid condition in the Atlantic seaboard of southern South America influences discharges to the South-West Atlantic Ocean through the supply of dissolved and particulate material transported from the continent via riverine and aeolian paths. Strong Patagonian westerly winds transfer sea-bound particles which may play a significant role in the input of trace elements to the ocean. Intense climatic anomalies may play a major role in transport of sediment load from continent to the ocean. The South Atlantic holds a wealth of biological resources, and the adjoining continental landmass may have a significant influence on the cycling of nutrients and heavy metals in the sea.

This paper reports the first results on the characteristics of heavy metals present in different Patagonian materials that are potential sources of such elements to the sea. Furthermore, the mass of heavy metals is estimated for the first time and the nature of these inputs to the Atlantic Ocean is discussed.

Study area

Continental Patagonia (38°- 52°S) has an area of about 700,000 km². The prevailing westerly winds supply all the moisture resulting in a strong west-to-east precipitation gradient. Only a small portion along the Andes (about 15 % of the total area) has a rainfall higher than 800 mm yr⁻¹.

The geology is dominated by volcanic rocks (basalts, rhyolites, andesites), and continental and, to a lesser extent, marine sediments. Also important are widespread Quaternary deposits dominated by alluvial, colluvial, lacustrine and glacial sediments. Metamorphic and plutonic rocks exist in relatively minor quantities.

Eight rivers drain this region and their drainage areas account for about 30% of the total Patagonian territories. The names, main features and localization of each basin can be seen in Table 5.11 and Figure 5.18. The set of river basins studied exhibits a spectrum of human impact. The main anthropogenic activity in the area is linked to oil production. Livestock breeding (mainly sheep) constitutes an important erosion agent that prevails from north to south within the area. Also environmentally important are the extensively farmed Negro, and to a lesser extent the Chubut and Colorado river valleys. Mining activities are of minor importance and are mostly restricted to coal mining in the headwaters of the Gallegos River.

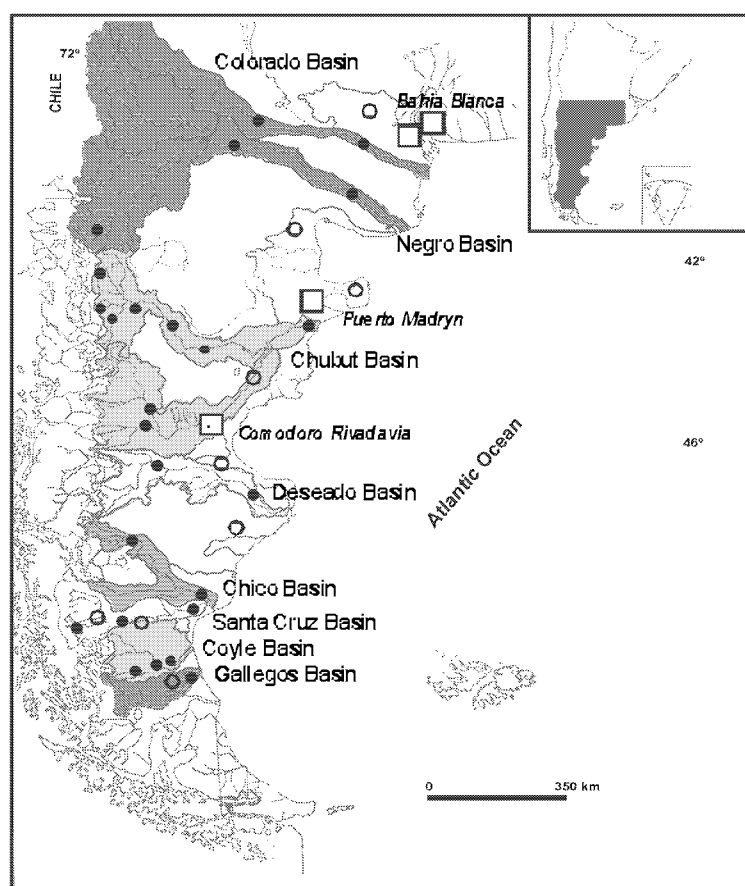


Figure 5.18. Patagonian river basins and sampling stations. The black dots represent water and bed sediment sampling points. The white dots indicate topsoil sampling stations. The white boxes indicate the location of the aeolian dust traps.

Table 5.11. Main features and average seasonal physico-chemical parameters measured along RN 3 in different Patagonian rivers.

River	Area (km ²)	Mean annual discharge (m ³ .s ⁻¹)	Population density (inhab.km ⁻²)	Conductivity (μS.cm ⁻¹)	pH	TSS (mg.l ⁻¹)	DOC (mg.l ⁻¹)	POC (% TSS)	SI _{calcite}
Colorado	22,300	134	1.0	942	8.1	62	1.2	2.6	0.3
Negro	95,000	930	7.1	157	7.7	16	1.2	4.4	-1.0
Chubut	29,400	49	7.5	295	7.7	62	2.1	2.5	-0.6
Deseado	14,450	5	0.4	3,730	8.8	355	7.6	1.7	0.7
Chico	16,800	30	1.5	141	7.7	356	2.1	1.1	-1.0
Santa Cruz	24,510	748	0.2	41	6.3	23	0.8	2.4	-3.2
Coyle	14,600	5	0.1	223	8.3	17	5.1	4.5	-0.2
Gallegos	5,100	17	1.3	112	7.1	32	6.7	7.8	-2.3

Materials and Methods

The sampling programs performed during the development of Project PARAT (EC-INCO/DC) involved trips at least 5,000 km long, stopping at the sampling stations to collect the samples and measure specific parameters in the field. Emphasis was placed on sampling the continent-sea interface along Patagonia's main road (RN 3). Some field trips included sampling along the Andean range (RN 40), to sample the headwaters of rivers crossing Patagonia from west to east (Figure 5.18).

Suspended matter was pre-concentrated by pressure filtration under 1.5 atm N₂ on 0.45 µm Millipore filter (Ø 142 mm). Submerged sediments were collected in duplicate from opposite riverbanks with plastic scoops. With the purpose of correcting the grain-size effect (Förstner and Wittmann 1981), sediments were sieved with a 63 µm stainless steel mesh. The <63 µm material thus retained was then subjected to acid leaching with HCl 0.5 N. This kind of extraction is a rapid technique, suited for measuring the authigenically-formed metal fractions in sediments since it extracts metals from sediments without attacking the aluminosilicate minerals (Ağemian and Chau 1976). Figure 5.18 also shows the sediment sampling points, generally coincident with water sampling stations. Atmospheric dust samples were and are being collected at Bahía Blanca (2 sites), Puerto Madryn, and Comodoro Rivadavia (Figure 5.18). A plastic inverted pyramid (50x50x40 cm depth) is employed in each site, following the methodology described by Orange *et al.* (1990) to collect fallout. For aeolian dust, a set of topsoil (upper 3 cm) samples were collected 300-400 km apart along the main route (RN 3). These samples were sieved with a 63 µm stainless steel mesh and then subjected to acid leaching with HCl 0.5 N.

Dissolved trace elements were analyzed by ICPMS (DL = 0.01 µg l⁻¹ and reproducibility <5%). Sediments, soils, and dust were chemically analyzed for major, minor and trace components with standard methodologies by inductively coupled plasma (ICPAES and ICPMS). Fine grain-size mineralogy (clays and silt) was determined by X-ray diffraction techniques. The relative abundance of carbonates and organic matter in the <63 µm size-fraction were respectively determined in riverbed sediment samples by means of a Scheibler-type calcimeter and the widely-used K₂Cr₂O₇ Walkley-Black method.

Total heavy metal in Patagonian sediments

In Table 5.11, the average heavy metal concentrations of different Patagonian sediment-types can be compared to those reported for other Argentinean rivers, as well as to basins in other world regions. The concentration of heavy metals in the Patagonian bed sediments (BS) are similar to those found in unpolluted Argentinean rivers (e.g. Manso River: Román Ross *et al.* 1995, Chicam-Toctina River: Gaiero unpublished data). In average topsoils (TS), heavy metal concentrations are very similar to both bed sediments located in remote areas and to those present in sampling stations close to the seaboard (Table 5.11). However, topsoil (TS) samples collected at Rio Colorado and San Antonio Oeste (Figure 5.18) exhibit the highest Cu concentrations (51.5±7.8 ppm) which explains the relatively high mean abundance of this element in TS as compared to other Patagonian sediments. Heavy metals present in the aeolian dust show high concentrations compared to those observed in topsoils (Table 5.11). Sample AD-1, (Ing. White) was collected in an area with a concentration of petrochemical industries. Hence, it shows a relatively high concentration of Pb, Ni, Cr, Zn and Cu.

In spite of the great affinity of trace elements with the finer sediment fractions, average concentrations of Mn, Pb, Ni, Co and Cr in the suspended matter (SM) are comparable to values found in riverbed sediment and topsoils of Patagonia (Table 5.11). In general, average heavy metal concentrations in Patagonian SM are lower than those found in non-polluted and polluted world rivers. Only Cu and Zn concentrations in SM show a clear enrichment compared to other Patagonian sediments and, in some cases, to world rivers suspended matter (Table 5.13). As a possible anthropogenic source, the Negro River had extremely high concentrations during December 1997 of both Cu and Zn (290 and 460 ppm, respectively). Also, the enrichment of Zn in the downstream sediments of this river are evident when compared to the concentration of this metal in the SM of the Manso River (Roman Ross *et al.* 1995) which can be considered as a natural background sample for this area. The Santa Cruz and Chico rivers also have high concentrations of Cu and Zn (248 and 179 ppm of Zn and 97 and 66 ppm of Cu), probably in response to a high natural lithological background of these metals in the area.

Non-residual heavy metals

Similar total average heavy metal concentrations are found in the finer grain-size fractions of Patagonian riverbed sediments from both the headwaters and the lower stretches (Table 5.12).

Table 5.12. Mean heavy metal concentration in different Patagonian sediment-types compared to other rivers. (BS) bed sediments, (TS) top soils, (AD) aeolian dust and (SM) suspended matter. All values are rounded to whole units.

Type	Site	Pb	Ni	Co	Cr	Zn	Cu	Reference
BS	Patagonia, headwaters (<63 μ)	18 \pm 6	21 \pm 6	19 \pm 2	62 \pm 13	86 \pm 12	23 \pm 9	This study
BS	Patagonia, lower stretches (<63 μ)	25 \pm 13	18 \pm 4	16 \pm 3	46 \pm 14	82 \pm 18	24 \pm 10	This study
BS	Manso River (<63 μ)	-	-	17 \pm 7	36 \pm 22	89 \pm 38	-	Román Ross <i>et al.</i> (1995)
BS	Ch-Toctina, upper stretches (<63 μ)	18 \pm 8	42 \pm 5	19 \pm 4	90 \pm 22	88 \pm 25	34 \pm 3	Gaiero (unpublished)
BS	Cordoba, Suquia downstream (<63 μ)	95 \pm 16	26 \pm 1	16 \pm 0	77 \pm 2	205 \pm 8	132 \pm 69	Gaiero (unpublished)
BS	Patagonia, lower stretches (total)	-	21 \pm 3	13 \pm 4	39 \pm 10	58 \pm 11	14 \pm 6	This study
BS	De La Plata River (total)	-	-	-	99	117	26	Bilos <i>et al.</i> (1998)
BS	Rhine River	369	175	31	493	1,240	286	Forstner and Wittman (1981)
TS	Patagonia (<63 μ)	15 \pm 5	16 \pm 5	20 \pm 3	51 \pm 17	83 \pm 21	30 \pm 13	This study
TS	Around Córdoba (<63 μ)	21 \pm 1	18 \pm 3	16 \pm 2	49 \pm 4	77 \pm 3	23 \pm 2	Gaiero (unpublished)
TS	Central Argentina (<63 μ)	17 \pm 1	20 \pm 11	21 \pm 9	54 \pm 27	97 \pm 36	34 \pm 3	Gaiero (unpublished)
AD-1	10 km north of Bahía Blanca	53	14	11	49	315	35	This study
AD-2	Ingeniero White	164	37	12	67	409	52	This study
SM	Patagonian rivers	32 \pm 18	26 \pm 8	16 \pm 5	52 \pm 22	176 \pm 120	61 \pm 72	This study
SM	Manso River	-	-	18 \pm 7	39 \pm 26	90 \pm 39	-	Román Ross <i>et al.</i> (1995)
SM	Upper Amazonas	-	65 \pm 57	18 \pm 15	-	189 \pm 167	34 \pm 25	Elbatz-Poulichet <i>et al.</i> (1999)
SM	Lower Paraíba do Sul River	-	-	-	81 \pm 42	297 \pm 178	75 \pm 41	Carvalho <i>et al.</i> (1998)
SM	De La Plata River	-	-	-	203 \pm 139	-	51 \pm 37	Bilos <i>et al.</i> (1998)
SM	Huanghe River	17 \pm 9	40 \pm 6	14 \pm 2	77 \pm 8	70 \pm 8	27 \pm 8	Huang <i>et al.</i> (1992)
SM	Rhine River	131	69	-	207	908	138	Paalman and van der Weijden (1992)
SM	World average	223 \pm 190	102 \pm 75	55 \pm 124	127 \pm 72	303 \pm 221	123 \pm 109	Martin and Maybeck (1979)

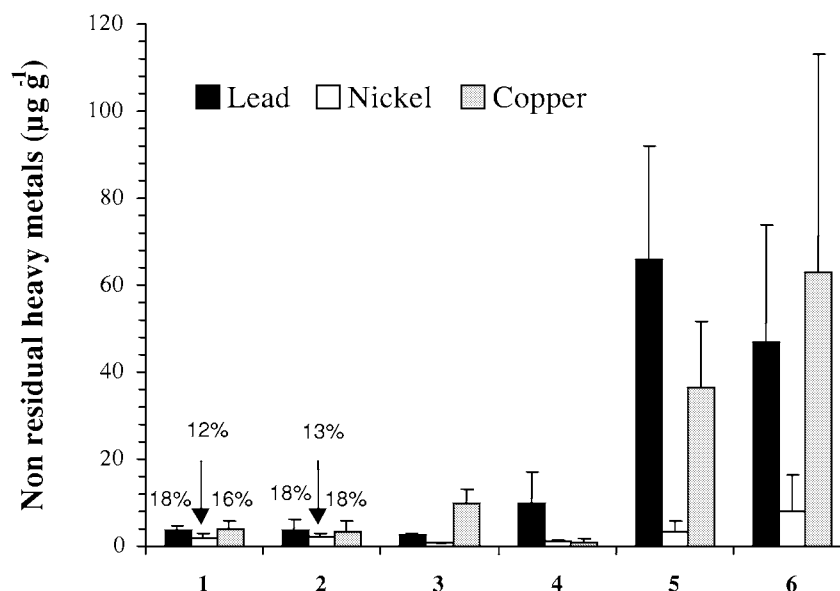


Figure 5.19. Mean concentrations of metals in the non-residual fraction of Patagonian bed sediments compared with other rivers. The horizontal axis corresponds to the average heavy metal concentration ($< 63\mu\text{m}$ size-fraction and extracted with 0.5 N HCl) for the following rivers: 1-Patagonian rivers at the headwaters, 2- Patagonian rivers at the lower stretches, 3- and 5- Suquia River headwaters and downstream Córdoba City (Gaiero *et al.* 1997), 4- Chicam Toctina Stream basin (Gaiero, unpublished) and, 6 - Jacarepaguá Lagoon tributary rivers (Fernández *et al.* 1994). The numbers above the bars represent the percentage extracted with 0.5 N HCl from the total metal concentration in the Patagonian samples.

The comparatively high average concentration of Pb in the downstream sediments is similar to the increase in concentration of this element in the Chico, Santa Cruz and Gallegos riverbed sediments. Only in the last could the relatively high concentration of lead be related to anthropogenic activity (coal-mining) in its headwaters. The highest discharges occur in September during snow melt, with the possible transport of wind-spread coal-mining by-products. In September 1995 and 1996 the Gallegos River showed dissolved Pb concentrations of $1.71 \pm 0.64 \mu\text{g l}^{-1}$, contrasting with the base flow measurements (May and December 1996: $0.40 \pm 0.02 \mu\text{g l}^{-1}$).

Extraction with 0.5N HCl can give enough information about the potential amount of available (or non-residual) heavy metals (NRHM) in sediments that could be transported to the ocean. Patagonian river-bottom sediments are 30% more concentrated in exchangeable heavy metals than the TS. Patagonian topsoil mineralogy shows significant heterogeneity, due to extremely variable contents of calcite minerals. Carbonate minerals seem to exert important NRHM dilution in topsoil samples, as indicated by the negative relationship between the amount of calcite (determined by means of X-ray) and NR-Ni, Co, Cu, Fe and Mn (average $r = -0.78$; $p < 0.01$). Figure 5.19 shows that Patagonian riverbed sediment samples from both the remote uninhabited areas and those close to the coastal ocean have NR-Pb, Ni and Cu concentration comparable with non polluted areas from central Argentina (e.g. Suquia River headwaters: Gaiero *et al.* 1997; Chicam-Toctina stream: Gaiero, in preparation). Leleyter (1998) and Leleyter and Probst (1999) found that Patagonian samples contain the lowest total and non-residual concentrations of Pb and Co.

The nearly pristine condition in the uppermost sectors of most of the Patagonian river headwaters enabled the use of the non-residual heavy metal concentrations as baseline values. Thus, the decreasing concentration trend of NRHM in the downstream direction shown by some Patagonian rivers (Figure 5.20) could indicate dilution by relative NR metal-free sediment from aeolian dust or bank erosion. However, increasing concentrations of Ni and Cu in the lower Negro River sediments could be associated to extended farm activity (use of fertilisers and pesticides) along its valley, while the scarcity of human activity within the boundary of the Santa Cruz River basin indicates that other natural processes could increase NRHM in the lower part of that river.

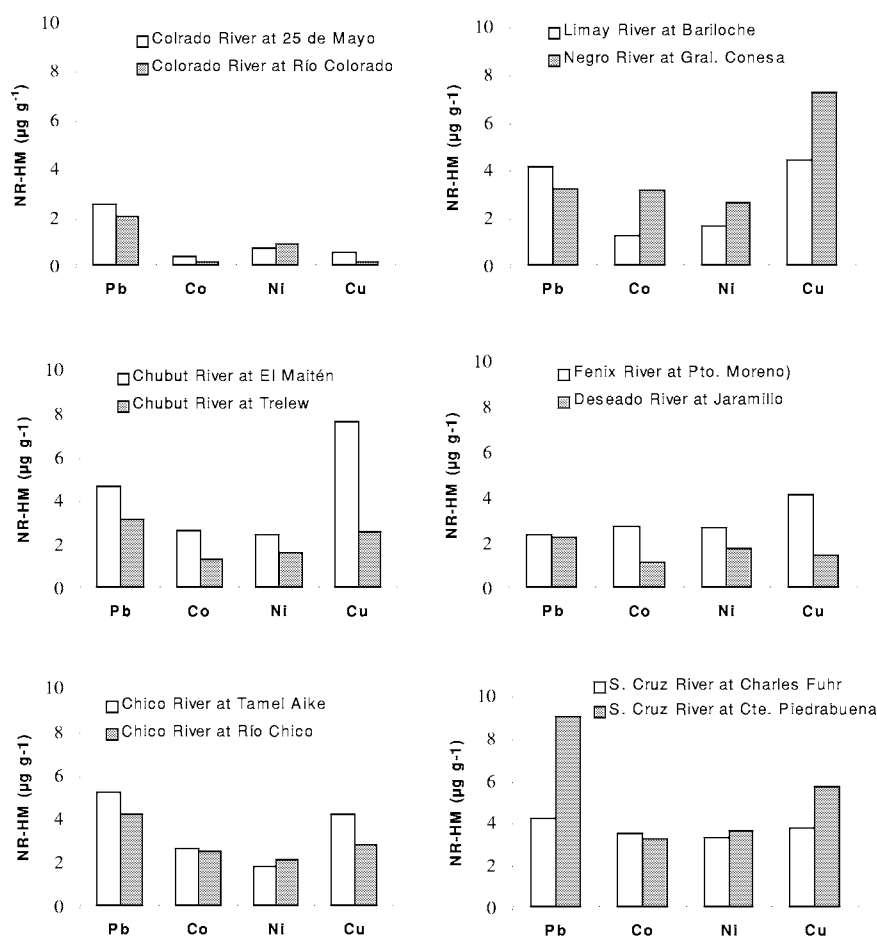


Figure 5.20. Comparison between non-residual heavy metals (NR-HM) concentration measured in bed sediments from headwaters and the lower stretches of some Patagonian rivers.

The non-residual heavy-metal fraction in the sediment is built up by means of different processes including adsorption onto clay, silt and organic matter, precipitation of secondary minerals, etc (e.g. Salomons and Förstner 1984). Patagonian bed sediments contain low concentrations of carbonate and organic matter, indicating that these phases could play a minor role in the control of heavy metal concentration. Apparently, iron oxides control non-residual heavy metals in Patagonian bed and suspended sediments. A significant correlation can be found between the concentration of NR-Fe and NR-Cu, Pb, Co and Ni (mean $r = 0.68 \pm 0.04$; $p < 0.05$) in the bed sediments. Leleyter (1998), using a sequential extraction procedure, found that the concentration of non-residual Fe, Mn, Pb and Co were mainly associated to iron oxide phases. To a lesser extent, Co and Pb were determined in the organic matter fraction. The Colorado and Deseado, which are the only Patagonian rivers with calcite supersaturation (Table 5.11), exhibit considerable amounts of NR-Mn and Pb in the carbonate fraction. Suspended sediment from the Chico and Colorado rivers studied by Leleyter (1998) indicate that in the Colorado River, significant proportions of Pb and Mn were linked to the carbonate fraction.

Table 5.13. Total heavy metals and corresponding percentages of non-residual fraction transported by the suspended matter of Patagonian rivers (t y⁻¹).

River/Metals	Pb	Cu	Zn	Ni	Cr
Patagonian rivers	67	104	335	47	85
Flux of NRHM	21 %	16 %	-	12 %	-
Rhine River ¹	278	358	2,466	256	458

1 -Paalman and Van der Weijden (1992).

Fluxes of heavy metals

Trace metals are transported from rivers to the marine environment mainly by suspended matter (Paalman and van der Weijden 1992). To estimate the particulate heavy metal fluxes, the amount of heavy metals present in the SM were considered as representative of the chemical composition of the suspended sediment concentration measured during the different PARAT sampling missions. Smaller particles (<63µm) seem sufficiently fine to be transported even in a very low flow conditions (e.g. Carvalho *et al.* 1998). Hence, we used the percentage of heavy metal extracted with 0.5 N HCl in the < 63µm size-fraction of bed sediment of each Patagonian rivers to estimate their concentration in the suspended sediments. Table 5.9 indicates that particulate (SM) Pb, Zn, Ni and Cr transported annually to the ocean represents on average 20% of that exported by the polluted Rhine River. As a likely response to anthropogenic contribution, the Negro River exports 60% of the total Cu transported by the Patagonian rivers. Their heavy metal productions are the highest in term of specific fluxes, indicative of a high natural background existing in the headwaters of the Chico and the Santa Cruz rivers.

The existence of dissolved Pb data allow us to make a more detailed budget of the characteristics of export of this metal to the ocean. An estimate of 10% of SM for the amount of transported sand is consistent with the literature (Milliman and Meade 1983; Pinet and Souriau 1988). Thus, Pb concentrations of total riverbed sediment samples and the percentage of heavy metal extracted with 0.5 N HCl in the < 63µm size-fraction of bed sediment were also considered in the budget. Figure 5.21 illustrates the total flux of Pb transported by Patagonian rivers. The Negro and Santa Cruz rivers produce about 70% of the total Pb transported to the ocean and the proportion of the available flux of this metal is very similar. Generally, Pb is transported in the particulate phase (65%) followed by the dissolved phase (30%) and to a lesser proportion by the bed load (5%) phase. Annually, the Coyle River transports almost 65% of Pb in the dissolved phase. The Colorado (with oil production in its headwaters) and Gallegos rivers transport more than 50% of total Pb as available form, mainly in the dissolved phase (more than 83%). The Chico River export 60% of the available Pb in the suspended sediment, while in the Negro, Chubut, and Santa Cruz rivers it is transported mainly in the dissolved phase (60 to 70%).

Conclusions

Most of the heavy metal concentrations found in the bed sediments and suspended matter from Patagonian rivers were comparable to those reported for non-polluted rivers. The presence of heavy metals in the non-residual fractions of the sediment represents an average of less than 20% of the total concentration and it is less significant in the topsoils. The studied Patagonian topsoils should be considered as a diluting agent in the riverine flux of sediments, as well as in its direct transfer by aeolian paths to the ocean. The heavy metals in the non-residual bed sediment fractions appear to be mainly bound to the iron oxides and they probably reach the ocean in this form. However, a more detailed study is needed, especially on the dissolved and suspended matter transported by Patagonian rivers.

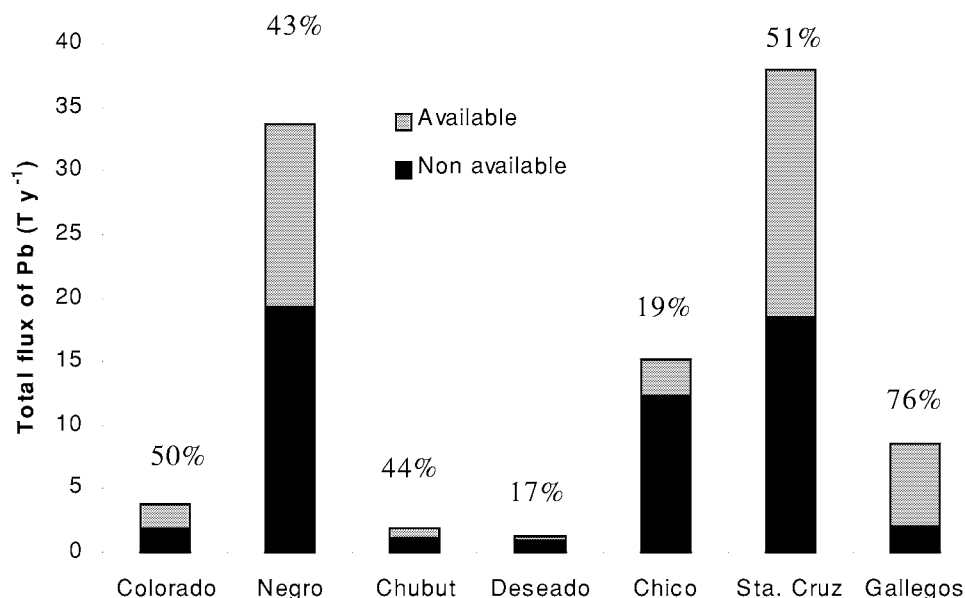


Figure 5.21. Total lead exported by Patagonian rivers. The numbers above the bars correspond to the percentage of Pb annually transported in the available form.

In agreement with the more intense human activity, higher Cu and Zn concentrations were found in the bed sediments and suspended matter of the Negro River as well as in the nearby topsoils. This river accounts for 60% of the total Cu transported by Patagonian rivers. The Colorado and Gallegos rivers have shown evidence of Pb contamination probably as a consequence of oil extraction and mining activity in their headwaters. In both rivers, more than 50% of Pb is transported in the available form, mostly in the dissolved phases (above 83%).

Acknowledgements –

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5.9 A summary of land based activities and environmental impacts on the coastal zone of the Pacific coast of South America

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1. Ecuador

The coastline of Ecuador extends through 2,859 km including 31 cities and 260 smaller towns, with commercially important ports such as Esmeraldas, Manta, Puerto Bolivar and Guayaquil. A further 845 towns have been built within 15 km of the sea. The coastal fringe houses most of the population of Ecuador and supports important commercial activities related to fisheries, aquaculture, tourism, recreation and distribution and exploitation of gas. Most of the foreign currency earnings of Ecuador are generated along the coast. During "El Niño" events severe losses affect the coastal area and impact heavily on the Ecuadorian economy. The most important river systems of Ecuador include the Guayas, Chone and Esmeraldas rivers.

1.1. Guayaquil Gulf

Guayaquil Gulf is the largest estuary on the Pacific coast of South America. The entrance of the Gulf stretches 200 km from north to south along the meridian 81°W, from Santa Elena's Peninsula (2° 12' S) in Ecuador to Máncora (4° 07' S) in Peru (Figure 5.22); toward the interior, the Gulf penetrates in the Ecuadorian coast, approximately 120 km. The southern limit of Ecuadorian waters is demarcated by the parallel 3° 23' 34'' S (CAAM 1996). (Figure 5.23).

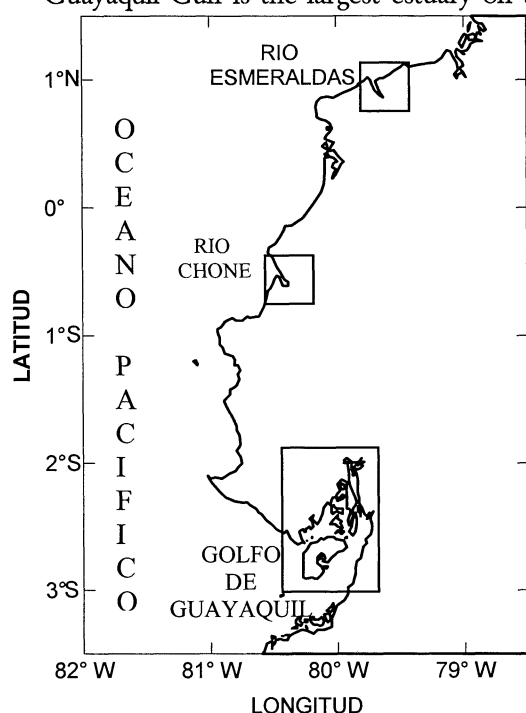


Figure 5.22 Profile of the Ecuadorian coast.

At the northern end of the gulf, the Guayas River and Salado tideland are connected artificially by a sluice built in the Cobina tideland for the traffic of small boats; while at the south end, just to the north of Puná Island, the Guayas River and Salado tideland are connected through the Channel of Cascajal, about 4 km wide and 8 m deep. Three channels, El Morro, Jambelí and Cascajal, have been formed by the presence of Puná Island, which is approximately 25 km wide. Almost 25 km south-west of Puná Island, aligned with the center of the entrance of Jambelí Channel (3°10'S) is Santa Clara Island, approximately 1.6 km long and 76 m high (INOCAR 1998).

Changes in the coastal ecosystem of the gulf due to different human activities impact on the same ecosystem and in consequence on the population. The most important economic activities along the coasts of Guayaquil Gulf and the impacts that each one can originate are summarized in Table 5.14 (PMRC 1993).

Table 5.14. Most important economic activities along the coast of Guayaquil Gulf and their major environmental impacts in the coastal zone (PMRC 1993). MB=Microbiology (fecal and total coliforms); PE=Pesticides (Cl, P); MP=Heavy metals (Cu, CR, Pb, Cd, Zn, Hg); A=Nutrients (NH₄⁺, NO₂⁻, NO₃⁻, PO₄³⁻, SiO₂); HC=Hydrocarbons; BOD=Biochemical Oxygen Demand; SO=Solids (total, suspended, dissolved); PH=Potential of hydrogen, DO=Dissolved Oxygen.

ACTIVITIES	Indicators of Impacts								
	MB	PE	MP	NU	DO	HC	BOD	SO	PH
Urbanism	v	v	v	v	v	v	v	v	v
Tourism	v			v	v	v	v	v	v
Industry			v			v	v	v	v
Agriculture	v	v		v	v	v	v	v	v
Sailing						v			
Exploitation of petroleum					v	v	v	v	v
Aquaculture	v	v		v	v	v	v	v	v
Cattle raising	v	v		v	v		v	v	v
Mining			v					v	v
Fisheries	v			v	v		v		
Infrastructure works							v	v	v

One of the activities that increase the microbiological load in Guayaquil Gulf is tourism. During the wet season there is a big increment in the load of fecal coliforms in Posorja (from 23 to 14,000 NMP 100ml⁻¹), Beaches (from 24,000 to 240,000 NMP 100ml⁻¹), (NMP = Most Probable Number), due to the tourists (PMRC 1993).

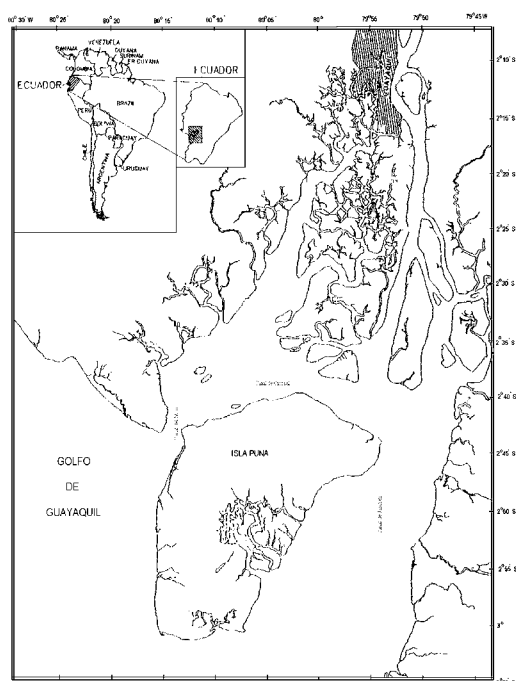


Figure 5.23. Location of Guayaquil Gulf.

Additionally, the unplanned growths of cities along the coastal areas of Ecuador have resulted in important losses of mangrove. It is now estimated that the original mangrove area has been reduced by about 23% of its original area (from 125,528 ha in 1969 to 105,039 ha in 1995) due to the increase of shrimp farms in coastal areas.

In general, during the wet season the microbiological quality of the water along beaches of the gulf exceeds the limit of fecal coliforms allowed for swimming. In the dry season the water quality in these places is considered to be within acceptable limits.

One of the factors that have contributed to the generation of negative environmental impacts in the urban areas has been the rapid urbanization of Ecuador since the 1950's.

The urban increase in the cities around the gulf has led to an appreciable increase in contamination of the waterways. Some studies found high levels of total coliforms in tidelands near Guayaquil.

Water contamination by organic and industrial effluents is due to the lack of appropriate water treatment plants in the major cities. A preliminary calculation carried out in 1996 indicates that industrial discharges into the Guayas River and Salado tideland amount to an average 25480 m³ day⁻¹ (INOCAR 1998).

Agricultural and cattle-raising activities require increasing levels of water usage and management (through damming for instance) which can have important consequences to the natural water tables of the rivers and waterways.

Damming of the Guayas River has resulted in an increased siltation process in the lower part of its basin. At the moment the average production of silts is about $15 \times 10^6 \text{ m}^3 \text{ yr}^{-1}$. This implies that the long and wide basin of the Guayas River is being eroded at an annual rate of 0.5 mm yr^{-1} .

1.2. The Chone River estuary

The estuary of the Chone River ($0^\circ 33' - 0^\circ 36.5'S$, $80^\circ 26.8' - 80^\circ 17.8'W$), formed by the convergence of Chone and Carrizal rivers, has a length of 25 km., with an average discharge of $31 \text{ m}^3 \text{ s}^{-1}$. The width of the estuary varies from about 3 km to about 15 m. The total area of the basin is about $2,696 \text{ km}^2$. This hydrographic system originates in the coastal cordillera with rivers of low flow, which increases during the wet season. The riverbanks of the exterior estuary are occupied by the cities of San Vicente and Bahía de Caráquez (PMRC 1998).

In the alluvial plain formed in the area of convergence of the Chone and Carrizal rivers there are important freshwater swamps covering a surface area of approximately $14,710 \text{ ha}$ - this varies annually according to the intensity of the rains. The most important lagoon is Segua Lagoon.

Several silt banks exist inside and outside the estuary. In the outer estuary, a sandbank which has formed in the center of the channel due to longshore sediment transport from the south obstructs shipping and highlights the continuous action of erosion and sedimentation.

The main impact in this basin is the deforestation, as the estuarine area has suffered critical levels of pruning of mangrove, which decreased in area from $3,980 \text{ ha}$ in 1969 to 392 ha in 1995. The conversion of 90% of the mangrove to shrimp farms happened in less than twenty years, changing drastically the natural ecological system of the estuary. The tropical forest has also decreased from 19.9% of the total surface area transformed into short cycle cultivation. (PMRC 1998).

There are indications that the water contribution of the Chone River to the estuary is diminishing. In the last few years water from the river is retained for the breeding of chame and tilapia fish. The daily water replacement between the estuary and shrimp ponds is very high (about 4×10^6 to $6 \times 10^6 \text{ m}^3 \text{ day}^{-1}$; PMRC 1998). Therefore the water quality in the estuary depends on its internal dynamics, which include the daily water replacement of pools. At the convergence of the Carrizal and Chone rivers, the water quality exceeds the standards for turbidity ($0.5 - 44 \text{ NTU}$) and nitrate ($0.12 - 12.1 \text{ } \mu\text{grat l}^{-1}$) (PMRC 1993).

During the wet season (December-April) the discharge of fresh water from the rivers cleans the inner estuary and improves the water quality, so that the dissolved oxygen registered in all the tracts is above values the acceptable minimum. (PMRC 1993)

1.3. The Esmeraldas River Estuary

Esmeraldas is smaller in population density ($16.3 \text{ inhabitants km}^{-2}$) than the other three counties. Important economic activity includes agriculture, cattle raising, hunting and fisheries. The Esmeraldas River is rich in resources like shrimps, lobsters shells, oysters, clams, crabs and other crustaceans, and also in small species of pelagic fish. The shark is an important marine species, while of the freshwater species the chame is dominant.

The Esmeraldas River system comprises 23 rivers which discharge about $1765 \text{ m}^3 \text{ s}^{-1}$, or about 48% of the national freshwater contribution to the Pacific Ocean (INERHI-CONADE-OEA). The Esmeraldas system constitutes the second largest hydrographic system of the Ecuadorian coast, with the Guayllabamba, the largest tributary, picking up water from the Andean slopes and transporting the urban and industrial discharges from Quito through the Machángara. The Cojimíes River system in the south has

a sand and mud riverbed. Many other smaller rivers flow directly to the sea across to the coastal front, the main one being the Muisne River, followed by the Verde, Tiaone, Atacames and Sua rivers (PMRC 1987).

CLIRSEN (1986) determined that until 1984 the Esmeraldas had 3,052 ha of mangrove, corresponding about 16.5% of the mangroves of the country. In 1969 the mangroves extended had covered 32,032 ha. As well as the tourist-attracting beaches, Esmeraldas also contains some areas of special landscape, ecological and scientific value, such as the San Lorenzo archipelago, Atacames, the forests of the cliffs between Galera and Quingue, and the Muisne and Cojimías estuaries.

The main pressures on the coastal resources come from the extraction and traditional gathering practices. This is the case in the swamps, which have been depleted by decades of exploitation for house piles, to extract shell or to make coal, endangering species like crab and shell, causing muddy beaches from silt washed down by rains and rivers from deforested lands. The new sources of problems are related to the domestic and industrial discharges that the Esmeraldas River transports towards tourist areas.

Water quality has deteriorated due to discharges from the oil refinery and domestic and industrial wastes carried from Quito by the Machángara and Guayllabamba rivers. The great urban growth and the fact that 40% of the city doesn't have a sewerage system both degrade the quality of the city air. The operation of the petroleum refinery can cause significant discharge of hydrocarbons into the waters of Teaone River due to spills. To this is added discharges from shrimp farms in the tourist areas of Súa and Atacames, and release of ballast waters by oil tankers in front of the coasts of Esmeraldas. Industrial wastes have caused the accumulation of heavy metals in the water, sediment and organisms. Results from studies carried out by the CPPS-PNUMA (Montaño 1993) are summarised in Tables 5.14 and 5.15.

Table 5.15. Dissolved heavy metal concentrations in river waters of the Ecuadorian coast.

Place	Cu ($\mu\text{g l}^{-1}$)	Cd ($\mu\text{g l}^{-1}$)	Zn($\mu\text{g l}^{-1}$)
Esmeraldas River	0.1-7.2	0.14-5.42	1.6-3.7
Taone River	0.6-1.7		1.9-4.2

Table 5.16. Heavy metals concentrations in silts from the Esmeraldas River (based on dry weight samples).

Place	Cu ($\mu\text{g l}^{-1}$)	Cd ($\mu\text{g l}^{-1}$)	Zn($\mu\text{g l}^{-1}$)	Pb($\mu\text{g l}^{-1}$)
Esmeraldas River	10.0-35.0	1.0-5.3	48.8-70.0	12.5-42.5

1.4. Management plan

The Program of Coastal Resources Management (PMRC), has as its general objective the creation of an integral program for the management of the coastal resources of Ecuador, with the following specific objectives:

- To obtain and analyze the scientific information and techniques needed to sustain the decisions that will enable the appropriate integral development of the coastal area.
- To develop procedures to evaluate environmental impacts due to development of coastal cities.
- To identify and to analyze the factors that affect the condition and use of coastal ecosystems.
- To train personnel for the planning and management of coastal development.
- To develop the institutional capacity to resolve the conflicts of coastal resources use.

For appropriate management of coastal resources, the following problems need to be addressed:

- Overfishing of several species especially blackish shell, mangrove oyster, lobster, and blue crab.

- Low level of technological development in shrimp cultivation.
- Lack of access roads to areas of interest to tourists.
- Deficit in basic services such as drinkable water and sewerage treatment.
- Contamination from untreated urban discharges.
- Contamination from oil refinery.
- Shrimp farms discharges.

2. Chile

In Chile, the hydrological system is conformed mainly by the rivers Loa, Aconcagua, Maipo, Itata, Bío Bío and Calle Calle. The flows and surpluses of these rivers are given in Table 5.17.

Table 5.17. Flows and surpluses of main Chilean rivers (CoNaMa 1995).

Basin	Qa (m ³ s ⁻¹)	Qs (m ³ s ⁻¹)	Qms (m ³ s ⁻¹)	Qs/Qa	Qms/Qa
Loa River	2.8	0.6	0.04	21.4	1.4
Aconcagua River	38	30	0	79	0
Maipo River	116	100	1.0	86	0.9
Maule River	257	569	58	221	22.6
Bio Bío River	639	1,000	120	156	18.8

Recent economic development has intensified the use of hydrological resources, where the biggest demands continue to be for drinkable water, irrigation and electricity generation (Table 5.18).

Table 5.18. General use of water in Chile. Source: CoNaMa (1995).

Water uses	Demand (m ³ s ⁻¹)	Use percentage consumption	Use percentage of total
Agricultural	620	89	-
Domestic	38	6	-
Mining-Industrial	37	5	-
Total consuming	695	100	32
Hydroelectric	1.500	-	68
Total	2.195	-	100

Human interference has caused water contamination (Table 5.19), which can end up affecting the health of people and the environment. The longest river in Chile is the Loa River, which has at the moment serious problems of contamination, a product of the mining activities of the region; 440 km from the highland to the ocean are polluted with arsenic and xantato; the arsenic rate allowed in Chile is of 0.05 mg l⁻¹ and the silt in Loa River registers a concentration of 4.64 mg l⁻¹.

Table 5.19. Pollutants (BOD, suspended solids and fecals coliforms) to the coastal zone of Chile (SISS 1993).

Zone	BOD (t month ⁻¹)	Suspended solids (t month ⁻¹)	Fecal coliforms (x10 ¹⁷ col l ⁻¹)
North zone	2.617	1.562	9.3
Center zone	10.211	5.391	29.0
South Zone	9.182	6.419	14.3
Total	22.009	13.372	52.6

The Aconcagua River, which rises in the Los Andes Cordillera, extends from 32° 14'S and 70° 00' - 71° 31' W, a distance of 214 km westward from the convergence of the Juncal and Blanco rivers to its mouth in Concon Bay. The flow regime is mixed, increasing during the wet and thaw seasons (spring and summer). The Putaendo River, with a basin of 1192 km² and a length of 82 km, joins the Aconcagua half way along its course. The Aconcagua River has a catchment area of 7,640 km².

The main uses of water in the basin of the Aconcagua River are for agriculture and drinking. With respect to the total basin surface, 45% is dedicated to agricultural use. Irrigation is a very important factor in the agricultural practices of this area, supplying 18,500 ha (28% of the surface of the basin) for wheat, beet and other cereals (barley and oats). Cattle raising occupies a large area of the basin over artificial, improved and natural prairies (approximately 50%).

As a consequence of the intense human activity (i.e., agricultural, forest, industrial, urban) in this ecosystem, one of the main problems for the hydrographic basin is the alteration of floor, surface and underground water quality. The Aconcagua River valley contains the most important agricultural activity in Chile, with intensive use of pesticides and fertilizers to protect and to increase productivity as the discharge of industrial and urban wastes, added to the lack of an environmental administration system puts in risk the environmental status of this hydrographic basin for agricultural use.

The Region of Bio Bío is located in the continental center of Chile. It has a surface of 36,929 km² and comprises four counties: Concepción (regional capital), Ñuble, Bio Bío and Arauco with fifty-two communities. It is the second region in importance in the country in population terms and in contribution to the PGB. It contains 13% of the national population with 1,734,305 inhabitants and it contributes 10% approximately to the national PGB.

3. Colombia

In Colombia water supply divides the country into areas that indicate the supply and demand of each one:

- a) Regions with large amounts of water because the rain exceeds 3000 mm yr⁻¹ or because there are forest areas with high humidity retention; this region covers about 44% of the country, including the Pacific coast, the Caquetá, Vichada, Vaupes and Inírida river basins and the highlands of the Arauca River.
- b) Regions with water almost all the year; this region covers 25% of the country, and includes the Nechi and Putumayo river basins, the plain and central part of Meta and Sierra Nevada de Santa Marta River;
- c) Deficit and normal water supply regions, representing 26% of the national area, including the Magdalena, Cauca, Tomo, Tuparro y Vichada river basins.
- d) Deficit water supply, 5% of the national total area suffers a strong water deficit during the whole year; this region includes the Baja Guajira, Córdoba and Sucre and Catatumbo river basins and the plain and central parts of the Chicamocha River.
- e) High water supply deficit, very dry zones, 1% of the country area, including Guajira and Tatacoa desert in Huila.

4. Peru

The surface water resources of Perú come from the Amazon, flowing along the border with Ecuador, including the Napo, Tigre, Pastaza, Santiago, Morona, Cenepa and Chinchipe rivers, which all supply water to Amazon River and the Atlantic: its calculated annually to supply about 125 km³ year⁻¹ (Table 5.20).

In the highlands there are lagoons between 4,000 and 6,000 m altitude, which are filled by rain, thaw and filtration from high basins.

On the other hand, the low rain level in the coast and the occidental side of the cordillera needs of rules to take advantage of the irregular river water supply. Most dams are for agricultural purposes although there are multipurpose dams (agricultural, energy and human supply); one of the biggest dams has a capacity about 2680 millions m³.

Table 5.20. Main hydrographic features of Perú.

Flowing	Drained surface (km ²)	Flow (km ³ yr ⁻¹)	Main rivers (in flow supply)
Pacific	279,689	36	Santa, Chira, Ocoña, Majes-Camaná, Tumbes
Atlantic	956,751	1,577	Amazon, Yurua, Madre de Dios, Marañón,
Titicaca	48,775	7	Shared Titicaca Lake
Total	215	1,616	

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6. Case studies

6.1 Changes in Mississippi River nutrient fluxes and consequences for the northern Gulf of Mexico coastal ecosystem

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Nutrient over-enrichment from anthropogenic sources is one of the major stresses impacting coastal ecosystems. There is increasing concern in many areas around the world that an oversupply of nutrients from multiple sources is having pervasive ecological effects on shallow coastal and estuarine areas (e.g. Nixon 1995, Diaz and Rosenberg 1995). These effects include reduced light penetration, loss of aquatic habitat, harmful algal blooms, a decrease in dissolved oxygen (= hypoxia) and impacts on living resources. The largest zone of oxygen-depleted coastal waters in the United States, and the entire western Atlantic Ocean, is found in the northern Gulf of Mexico on the Louisiana/Texas continental shelf influenced by the freshwater discharge and nutrient flux of the Mississippi River system (Figure 6.1), which drains much of the North American continent (Rabalais *et al.* 1991, 1996, 1998, 1999).

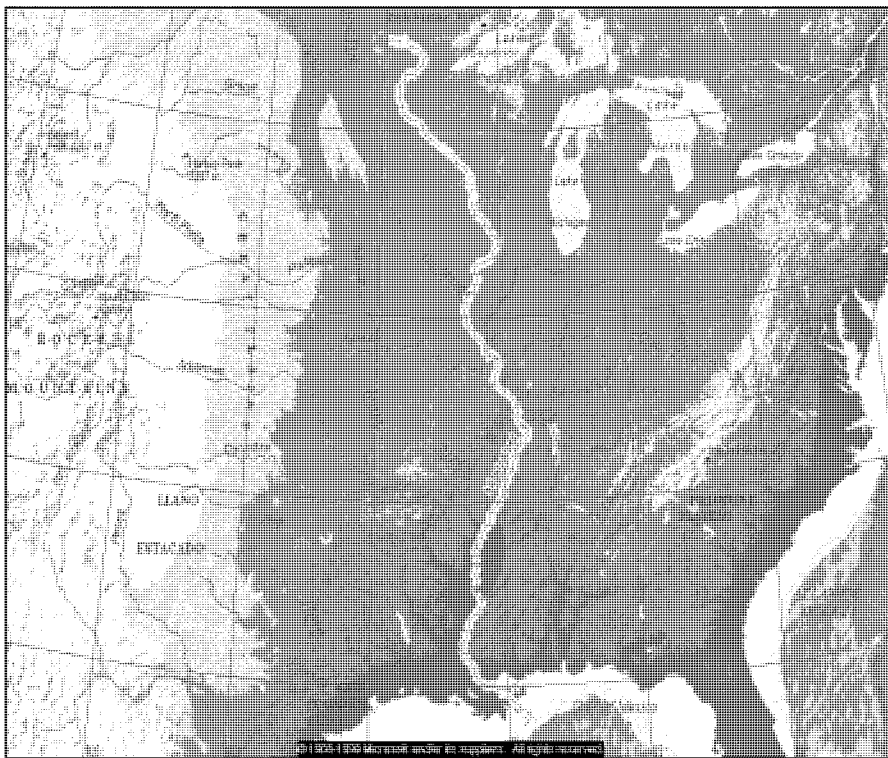


Figure 6.1. The Mississippi River.

General dimensions of hypoxia

The mid-summer bottom areal extent of hypoxic waters ($\leq 2\text{ mg l}^{-1} \text{ O}_2$, or 2 ppm) in 1985-1992 averaged 8,000 to 9,000 km² but increased to 16,000 to 20,000 km² in 1993-1999. The estimated extent was 12,500 km² in mid-summer of 1998. Hypoxic conditions exist over broad regions of the shelf for extended periods in mid-summer. A compilation of thirteen mid-summer shelfwide surveys (1985-1997) demonstrates that the frequency of occurrence of hypoxia is higher to the west of the discharges of the Mississippi and Atchafalaya Rivers in a down-current direction from their influence (Rabalais *et al.* 1999) (Figure 6.2). Hypoxic waters are most prevalent from late spring through late summer and hypoxia is more widespread and persistent in some years than in others. Hypoxic waters are distributed from shallow depths near shore (4 to 5 m) to 60 m water depth but exist more typically between 5 and 30 m depth. Hypoxia

occurs mostly in the lower water column but may encompass as much as the lower half to two-thirds of the water column.

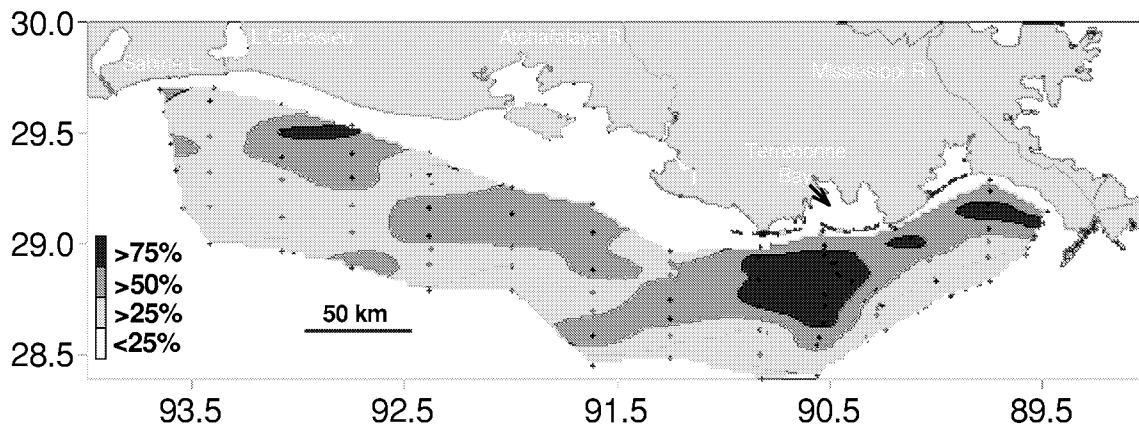


Figure 6.2. Distribution of frequency of occurrence of mid-summer hypoxia over the 60- to 80-station grid from 1985-1999 (modified from Rabalais *et al.* 1999).

River discharge and flux of materials

The Mississippi River catchment encompasses 41% of the conterminous United States and delivers an average of 580 km^3 of fresh water to the Gulf of Mexico yearly along with sediment yields of $210 \times 10^6 \text{ t yr}^{-1}$, $1.6 \times 10^6 \text{ t yr}^{-1}$ nitrate, $0.1 \times 10^6 \text{ t yr}^{-1}$ phosphorus and $2.1 \times 10^6 \text{ t yr}^{-1}$ silica (Turner and Rabalais 1991). The best current knowledge is that the outflows of the Mississippi and Atchafalaya Rivers dominate the nutrient loads to the continental shelf where hypoxia is likely to develop. The 1820-1992 average discharge rate (decadal time scale) for the Mississippi River at Vicksburg is remarkably stable near $14,000 \text{ m}^3 \text{ s}^{-1}$ despite significant interannual variability and some decadal trends. Since the 1700s humans have altered the morphology and flow of the Mississippi River so that now 30% is diverted to the Atchafalaya that also captures the flow of the Red River. The discharge of the Atchafalaya increased during the period 1900-1992, primarily as a result of the tendency for the Atchafalaya to capture more of the flow of the Mississippi (until stabilized at 30% in 1977) (Bratkovich *et al.* 1994). A slight increase in Mississippi River discharge for 1900-1992 is accounted for by an increased discharge in September through December, a period that is much less important in the coastal ocean than spring and summer in the timing of important biological processes that lead to the development of hypoxia or the physical processes important in its maintenance.

Mississippi River nutrient concentrations and loading to the adjacent continental shelf have changed dramatically this century, with an acceleration of these changes in the last four decades depending on the constituent of concern. The mean annual concentration of nitrate was approximately the same in 1905-1906 and 1933-1934 as in the 1950s, but it has increased up to 3-fold from the 1950s to 1960s (Turner and Rabalais 1991). The increase in total nitrogen is almost entirely due to changes in nitrate concentration (Turner and Rabalais 1991, Goolsby *et al.* 1999).

There was no pronounced seasonal peak in nitrate concentration prior to 1960, whereas there was a spring peak from 1975 to 1985. Prior to the 1960s, nitrogen flux closely paralleled river discharge, a pattern that still holds but the load of nitrogen per volume discharge is greater now. There is no doubt that the concentration and unit flux of nitrogen (per unit volume discharge) has increased from the levels of the 1950s to 1960s, especially in the spring. The mean annual concentration of silicate was approximately the same in 1905-1906 as in the early 1950s, then it declined by 30 to 50%, depending on the type of statistical analysis used or the period of record. Concentrations of nitrate and silicate appear to have stabilized, but trends are masked by increased annual variability in the 1980s and 1990s data. There are no substantial records of total phosphorus concentrations in the lower Mississippi River before 1973 and subsequent values vary greatly among years. Application of a linear least-squares regression on the 1973-1987 data, however, indicates a two-fold increase in the total phosphorus concentration (Justic' *et al.* 1995a).

The proportions of dissolved Si, N and P in the lower Mississippi River have changed historically, and they now closely approximate the Redfield ratio (Si:N:P = 16:16:1) (Justic' *et al.* 1995a, b). Thus, any single nutrient is more likely to be limiting to phytoplankton production now than historically. Another reasonable hypothesis that follows a more balanced nutrient composition is that surface offshore primary productivity has increased. Fluctuations in the Si:N ratio within the riverine effluents and the offshore waters can affect diatom production and are believed to be major determinants in the coastal food web structure on a seasonal basis, with major implications to oxygen and carbon cycling (Turner *et al.* 1998).

Interaction of physics and biology

The physics of the system and the biological processes are linked and related to the freshwater discharge and nutrient flux of the Mississippi River system. The physics of the system defines where hypoxia can occur, and the biological processes of carbon production, flux and respiration lead to oxygen depletion. The high freshwater discharge, general circulation patterns on the Louisiana shelf and the presence of the Louisiana coastal current dictate a stratified system for much of the year, interrupted on occasion by wind-mixing events, notably tropical storms and winter cold fronts.

Nutrient-enhanced productivity

The evidence for nutrient enhanced primary production in the northern Gulf of Mexico and its linkage with oxygen depletion in the lower water column comes from information on a variety of scales - experiments for a parcel of water from a particular locale over a limited time to more integrative measures of ecosystem response (e.g., net production, carbon flux and respiration) and change over broader spatial and temporal scales. The concentrations, total loads and ratios of nutrients (nitrogen, phosphorus and silica) delivered to the coastal ocean influence the productivity of the phytoplankton community as well as the types of phytoplankton that are most likely to grow. The nutrient most relevant to overall phytoplankton production over the broad region fueling hypoxia is nitrogen, and nitrate-nitrogen makes up approximately two-thirds of the total nitrogen input from the Mississippi River. Silica and phosphorus may also be limiting at some times and places. There is clear evidence that primary production in shelf waters near the delta and to some distance from it is significantly correlated with nutrient inputs (nitrate+nitrite and orthophosphate) (Lohrenz *et al.* 1999). Similar relationships exist for net production (an indicator of the amount of carbon available for export to the lower water column and sediments) and nitrate flux (Justic' *et al.* 1997). There is also a strong relationship between the net production in surface waters, the amount of carbon exported, the accumulation rates of carbon, and the depletion of oxygen in bottom waters (Rabalais *et al.* 1999). Spatial and temporal variability in these components is closely related to the amplitude and phasing of Mississippi River discharge and nutrient fluxes. Thus, there are clear lines of evidence for nitrogen (particularly nitrate) driven phytoplankton production that leads to hypoxia. Although the Mississippi and Atchafalaya Rivers discharge organic matter to the shelf, the principal source of carbon reaching the bottom waters in the northern Gulf influenced by the river effluent and characterized by hypoxia is from in situ phytoplankton production (Turner and Rabalais 1994a, Eadie *et al.* 1994).

Long-term changes in the coastal ecosystem

It follows, and is supported with evidence from long-term data sets and the sedimentary record, that increases in riverine dissolved inorganic nitrogen concentration and loads are highly correlated with indicators of increased productivity in the overlying water column, i.e., eutrophication of the continental shelf waters, and subsequent worsening of oxygen stress in the bottom waters. Evidence from changes in diatom production, increased accumulation of diatom remains in the sediments, increased carbon accumulation in the sediments, decreased diversity of selected benthic fauna, and relative changes in selected benthic fauna indicate that oxygen concentrations are decreasing (Turner and Rabalais 1994a, b; Eadie *et al.* 1994; Nelsen *et al.* 1994; Rabalais *et al.* 1996; Sen Gupta *et al.* 1996). Human activities in the watershed undoubtedly changed the natural functioning of the Mississippi River system. Century-long patterns of freshwater discharge are not evident; thus, the long-term changes on the Louisiana shelf are linked to the quality of the discharge (nutrient loads and ratios of nutrients) and not the amount. While century-long changes are evident in some of the retrospective analyses, the most dramatic and accelerating changes have been since the 1950s, when nitrogen loads began to increase, primarily from nitrate inputs, and eventually tripled their earlier values. The fact that the most dramatic changes in the continental shelf

ecosystem have occurred since the 1950s and are coincident with an increase in nitrate load, points to that aspect of human ecology for future management scenarios.

Evidence associates increased coastal ocean productivity and increasing severity of oxygen depletion with changes in landscape use and nutrient management that resulted in nutrient enrichment of receiving waters. Nutrient flux to coastal systems, while essential to overall productivity, has increased over time due to anthropogenic activities and has led to broad-scale degradation of the marine environment.

Modelling results

The northern Gulf of Mexico adjacent to the discharge of the Mississippi River system is an example of a coastal ocean that has undergone eutrophication (increased rate of primary production) as a result of increasing nutrients and that has worsened hypoxic conditions on century-long and accelerating recent decadal time scales. Models that link Mississippi River discharge with Gulf of Mexico hypoxia demonstrate increasing severity of hypoxia in bottom waters with increased freshwater discharge and even more extreme hypoxia with additional nitrogen accompanying the increased discharge. Conversely, the models show that a reduction in oxygen demand in the lower water column will result from a reduction in nitrogen (and to a lesser degree the phosphorus) load to the surface waters. In other words, hypoxia in the northern Gulf of Mexico can be alleviated to some degree by a reduction in the nutrient loading.

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See also the full report available at http://state-of-coast.noaa.gov/bulletins/html/hyp_09/hyp.html

6.2 Estimation of the nutrient inputs into river basins – experiences from German rivers

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One of the main objectives of LOICZ is to determine the fluxes of nutrients to the coastal zone. Because most of the load to the coastal zone is caused by medium and large rivers, there is a need for tools to estimate the nutrient load from such river basins into the coastal zones depending on the uses of nutrients in the human sphere and on the inputs reach the river system by different point and diffuse pathways.

The model **MONERIS**² (**MO**delling **N**utrient **E**missions in **R**iver **S**ystems) was developed to estimate the nutrient inputs into river basins of Germany by point sources and various diffuse pathways. The model is based on data of river flow and water quality as well as on a geographical information system (GIS), including digital maps and extensive statistical information (Behrendt et al., 2000). Whereas point inputs from waste-water treatment plants and industrial plants are directly discharged into the rivers, diffuse inputs into surface waters are caused by the sum of different pathways, which are realised by separate flow components and different nutrient concentrations. Consequently seven pathways are considered:

- point sources
- atmospheric deposition
- erosion
- surface runoff
- groundwater
- tile drainage
- paved urban areas

Along the path from the source into the river, substances are governed by manifold processes of transformation, retention and loss. Knowledge of these processes is necessary to quantify nutrient inputs into the rivers. Since this knowledge of the processes and the database are at present limited, the description of the processes could not be done by detailed dynamic models. Therefore, MONERIS estimates the pathways with existing and new conceptual approaches. One specific topic of the model development was to validate the different submodels by using independent data sets. For example, the groundwater model was developed on the basis of the observed nitrogen concentrations in the groundwater and not of the observed nutrient loads in the rivers.

The use of GIS allows a regionally differentiated quantification of nutrient inputs into river systems. Therefore, estimations were not only carried out for large river basins. Altogether the MONERIS model was applied to 300 different river basins for two time periods, 1983-1987 and 1993-1997. The temporal changes of nutrient inputs were calculated considering the difference in hydrological conditions for both periods.

Nitrogen

Total nitrogen input into the river system of the Rhine River basin (Figure 6.3a) in the period 1993-1997 was 400 ktN y⁻¹. This represents a reduction of 169 ktN y⁻¹ or 28% since the mid-eighties. 46 % of the total nitrogen going into the Rhine basin are caused by groundwater. The second major source is discharges from municipal waste-water treatment plants. Whereas direct industrial discharges were the third dominant pathway in the mid-eighties, this source contributes now only 4.8 % to the total inputs.

For the Elbe River basin (Figure 6.3b), total nitrogen inputs into the river system of 233.8 ktN y⁻¹ are estimated for the period 1993 to 1997. This is a decrease of 95 ktN y⁻¹ or 29 % since the mid-eighties. In the Elbe River basin, the groundwater pathway is also the major source of N-inputs with 43.3 %. In contrast to the Rhine, the contribution of municipal waste-water treatment plants is lower, caused by a lower population density. Otherwise the proportion of tile drainage is much higher in the Elbe area,

² **MONERIS** was developed within a research project founded by the German Federal Environmental Agency

because more agricultural land was artificial drained by tiles. Direct industrial discharges show the largest reduction. The main reason for the decrease of the N-inputs into the river systems was the large reduction of N-discharges from point sources by 46 %. The estimated decrease of diffuse inputs was only about 10%.

In spite of the substantial decrease of the nitrogen surplus in agricultural areas, a slight reduction of the nitrogen inputs from the groundwater can only be estimated for the Rhine basin. In other river basins the nitrogen inputs along this pathway will still have increased during the nineties due to the long residence times of water in the unsaturated zone and in the aquifer. However, after the year 2000 the reduced nitrogen surplus will be followed by a slow reduction of the nitrogen inputs from groundwater. The consequence is that the nitrogen load from these rivers in the coastal zone will further decrease after the year 2000.

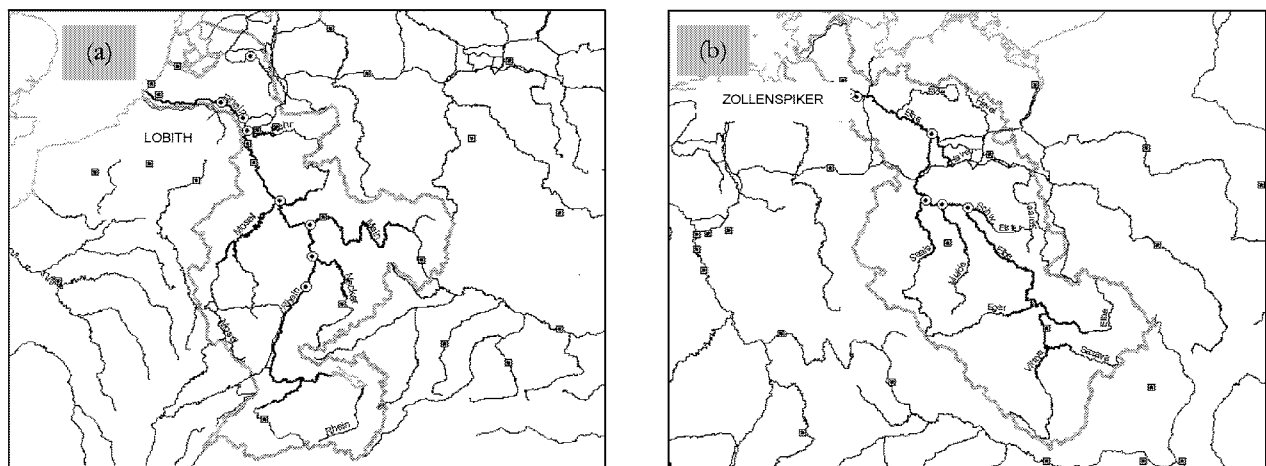


Figure 6.3. Catchment areas of the Rhine (a) and Elbe (b) rivers, Germany (from Behrendt *et al.* 2000).

Phosphorus

For the Rhine upstream of Lobith, a total P-input of 20,500 t P y⁻¹ is calculated for the period 1993-1997. In comparison to the mid-eighties this is a reduction of 30,600 t P y⁻¹ or 60 %. The enormous reduction in the discharges from municipal waste-water treatment plants could only partly change the dominance of this source. This pathway still accounts for 42.8 % of the P inputs. However, the sum of the diffuse inputs now represents more than half of the P-input to the Rhine basin. Among the diffuse pathways erosion is the major source followed by inputs of dissolved phosphorus via surface runoff and diffuse inputs from urban areas.

For the Elbe basin above Zollenspieker, a total P-input of 12,500 t P y⁻¹ is estimated for the 1993-1997 period. The reduction amounts about 52 % (13,300 t P y⁻¹) since the 1983-1987 period. In the Elbe River basin the point sources also represent the major source of phosphorus inputs but the sum of the total diffuse pathways is now more than 60 %. The dominant diffuse pathway is also erosion, followed by diffuse inputs from urban areas.

The decrease of phosphorus inputs is again mainly caused by an 80 % reduction of point discharges. The decrease of diffuse phosphorus emissions was larger than for nitrogen, which is results from a 56 % reduction of the emissions from urban areas.

Among the basins of the large rivers, the changes of nutrient inputs into the river systems as well as the contribution of the individual pathways to the total inputs vary widely.

The observed N- and P-loads in the Rhine and Elbe rivers are lower than the inputs, due to retention and loss processes (e.g. denitrification, sedimentation, adsorption) within the surface waters of the basins. The level of the retention within the river system of Elbe is much higher than in the Rhine, which can be explained by the different hydrological and morphological conditions in both basins. If the conceptual model approaches of Behrendt and Opitz (1999) are applied the load can be calculated from the inputs.

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6.3 A preliminary approach of the link between socio-economic and natural indicators into a driver-pressure-state-impact-response framework case study: Guanabara Bay basin, Rio de Janeiro, Brazil.

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1. Introduction

The Land Ocean Interactions in the Coastal Zone (LOICZ) Core Project of the International Geosphere Biosphere Project focuses on the role of the world's coastal zones in the functioning of the Earth system: the way in which global changes will influence that role; the way in which such changes will affect the use of coastal space and resources by humanity; and the consequences of such changes for human welfare (Turner *et al.* 1998).

Within Focus 1 of LOICZ, one of the main objectives is to determine the fluxes of nutrients to the coastal zone. Within Focus 4 the emphasis is on socio-economics issues. It is our goal to set up combined Focus 1 – Focus 4 project in Guanabara Bay, SE Brazil to:

1. Determine the fluxes of nutrients to the coastal zone (past, current and future);
2. identify the main socio-economic drivers, which have changed or will change the fluxes; and
3. identify indicators for the impact of land-based sources on the coastal zone and to derive from them a critical load (Salomons, 1999).

At a later stage these critical loads can be connected with the main socio-economic drivers on the continent and subsequently a cost-benefit analysis can be carried out those cases with negative impacts on the coastal zone and the need for remediation of land-based point and diffuses sources. To meet these objectives requires integration of natural, social and economic information into a broad analytical framework in which to set the more detailed analysis, and to provide the interdisciplinary working tool for a wide spectrum of users. The Driver-Pressure-State-Impact-Response (DPSIR) framework offers such a generalized context.

2. The Guanabara Bay basin: physical or primary environmental indicators

The study area, Guanabara Bay basin (Figure 6.4), located in Rio de Janeiro State (22°40' - 23°00' S and 43°00' - 43°20' W) is the most prominent coastal bay in Brazil. It was first occupied 4 centuries ago and but major industrial development only occurred in the early 1970's. Nowadays, there are 12 municipal districts, 7.8 million inhabitants and around 12,500 industries distributed unevenly over in the drainage basin area (4,000 km²). As a result of this occupation there are heavy metals, phenols and cyanides but also 350 t of BOD and 18 t of oil thrown in the bay on a daily basis. This explains the poor quality of water and sediments observed mainly in the western part of the bay. The renewal time of 50% of the bay water volume is 11 days. The depth ranges from 1 m to 30 m (Kjerfve *et al.* 1997).

The Guanabara Bay basin is backed by a high (1000 m to 1500 m) relief mountain range ("serras"). It has a large number of small catchments, usually <100 km². The river profiles have a very strong slope which change – over a few tens of kilometers - to a relief of hills before reaching the coastal plain. The ratio between slope:hill:coastal plain areas is variable and follows a general empirical rule: the magnitude of the hill and coastal plain areas increases with the size (i.e., total area) of the watersheds.

The predominant rock types are pre-Cambrian migmatites and gneisses with associated intrusive granites and diabase dykes. The material of the hills apparently originated from the weathering of the rocks at the base of the slopes. Alluvial Quaternary and Recent sediments compose the coastal plains. On the higher slopes, the predominant materials are essentially colluviums. Towards the lowlands the soils are thicker and generally of the latosol type. Hydromorphic soil types predominate in the lowlands.



Figure 6.4. Study area: Guanabara Bay basin

The climate of the study area is tropical humid. Temperature and atmospheric precipitation are very variable, from $>24^{\circ}\text{C}$ and $<1000\text{ mm}\cdot\text{year}^{-1}$ in the lowlands, to $<18^{\circ}\text{C}$ and $>2500\text{ mm}\cdot\text{year}^{-1}$ on the high slopes. The mean annual river discharges are small and vary from 10^{-2} to $10^{-1}\text{ m}^3\cdot\text{s}^{-1}$. In densely populated areas, the river discharge increases due to wastewater inputs *in natura*, i.e., without previous treatment. Because of their small areas, the watersheds have low hydraulic retention times. Consequently, during large rainfalls or storms ($\sim 80\text{ mm}$ or more), the effects upon river discharge are almost instantaneous reaching several $\text{m}^3\text{ s}^{-1}$. In urban areas these storm surges may have catastrophic effects.

Bidone *et al.* (1999) classified the watersheds of the Guanabara Bay region into three types:

- (i) the pristine type, without anthropogenic activities, which generally belong to legally protected areas, with Mata Atlântica (i.e., a tropical rain forest type) or/and similar abundant vegetation on the slopes and natural coastal vegetation in the lowlands (grasses, savannas, “restingas”);
- (ii) the weakly impacted type with well-preserved Mata Atlântica or/and other remnant vegetations on the slopes, and lowland sectors with human activities (small farming, tourist-urban activities); and
- (iii) the highly impacted watersheds, densely populated and/or industrialized.

3. Integrated system model for the Guanabara Bay basin

The system model proposed for the Guanabara Bay basin is based on the generic Driver-Pressure-State-Impact-Response (DPSIR) framework (Figure 6.5). From top to bottom the diagram presents the specific system elements (socio-economic and natural) considered up to the present time in this case study.

- (i) Socio-economic drivers: demographic growth and rise in land use/cover (principally residential land occupation) without sanitation improvement (above all domestic effluents treatment).
- (ii) Physical drivers: seasonal change in climate conditions (essentially rain intensity and distribution).
- (iii) River material fluxes: BOD, C, N, P, suspended solids and heavy metals.
- (iv) Guanabara Bay: DOC, heavy metals and chlorophyll *a* concentrations in water; TOC, N, P and heavy metals in sediments, and heavy metals in fishes (particularly Hg).
- (v) Socio-economic activities: fisheries and recreation in Guanabara Bay and small rivers draining into it.
- (vi) Policy response and management options: approach based, firstly, on the evaluation (Cost-Benefit analysis) of those public policies and management actions included in the ‘Guanabara Bay Recuperation Program’, conducted by Rio de Janeiro State Government and supported by the World Bank, Interamerican Development Bank and Japan Bank financing; and, second, on the correcting account (Gross Product of Rio de Janeiro State) for environmental costs and physical natural capital depreciation.

- (vii) Cost-Benefit analysis: this study proposes the use of extended Cost-Benefit analysis, in which standards of sustainability (reflecting estimated critical loads of selected substances/indicators) are fixed. The analysis attempts to highlight the cost of achieving them.

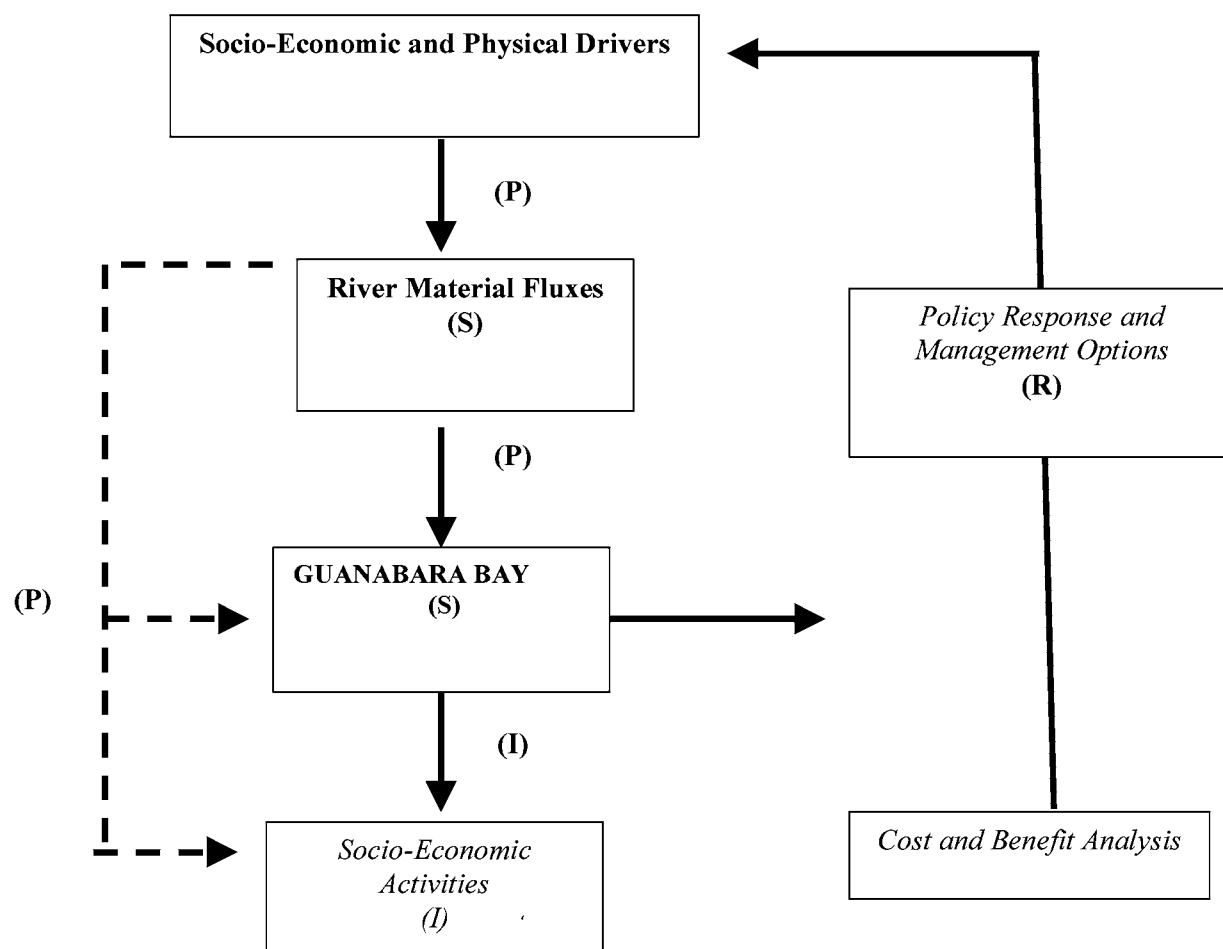


Figure 6.5. Integrated model used in Guanabara Bay case study, based on the Drivers-Pressure-State-Impact-Response framework. P = pressure indicators; S = state indicators; I = impact indicators; R = response indicators.

4. Integration of natural elements and indicators in the system model

The practical solution of each sub-system (specific system elements) of the proposed system model, and of the links between them (represented by arrows in Figure 6.5) shows different degrees of difficulty. Sub-systems involving natural elements and potential indicators of pressure, state change and environmental impact – i.e., rain distribution (physical driver), river material fluxes, Guanabara Bay water and sediment composition, and fish contamination - needs a standard, referenced scientific and technical approach. For example, to estimate river material fluxes and their links with rain distribution, several studies were carried out since the 1980's in the small coastal watersheds of Guanabara Bay basin, providing relevant data on the biogeochemistry of river waters. Essentially, the methodological approach used was to collect and rework the available data set in a compatible manner. It was demonstrated that the specific material fluxes of polluted and highly polluted rivers were one to two orders of magnitude higher than those estimated for unpolluted or weakly polluted rivers. It has been shown that the highly variable hydrology of the studied rivers directly controls the natural and anthropogenic river water concentration levels of biogeochemical materials, and their runoff loads. In pristine rivers during heavy rainfalls (80 mm or more), the increase in material fluxes was about one order of magnitude. In highly polluted watersheds measured on rainy days

(25 mm day⁻¹ rainfall) the material fluxes were twice those measured on non-rainy days (when the preceding period of non-rainy days was five days or more). Detailed approach, results and discussion can be found in Bidone *et al.* (1999).

Transfer of materials through the aquatic continuum - including the river system, estuaries, wetlands and the bay - involves passage through ecosystems which can act as very effective and selective “filters” for materials. The effectiveness and selectivity of the processes of transformation, elimination or immobilization of materials during their transfer through the aquatic continuum depends on their biogeochemical behavior and are also strongly influenced by hydrology and land use (Billen 1993).

These are relevant aspects in all basic biogeochemical studies and for surveys of river water quality control and the establishment of watershed management policies. However, to evaluate the effectiveness and selectivity of controlling processes of the biogeochemical behavior of materials in river waters is often difficult. In this study, using a mass balance approach between continual river segments, it was possible to identify portions of the Guanabara Bay basin with active transformation processes, including the elimination or immobilization of materials during their transfer through the aquatic continuum.

For example, P-PO₄ and N-NH₄ concentrations increase exponentially with pollution level, by about three orders of magnitude from unpolluted rivers (or river stations placed on the uncontaminated slope portions) to highly polluted rivers by domestic wastewater. The N-NO₃ natural concentrations are apparently little affected by industrial pollution. On the contrary they increase by about one order of magnitude when the river waters are polluted by domestic wastewater. However, a decreasing trend appears when river waters are highly polluted. A similar fate can be observed in DO concentrations when pollution levels increase considerably.

It is possible to establish the rates of transport of the biogeochemical materials by the river along the watersheds and toward its destination, i.e., the estimation of the material loads carried by rivers into the Guanabara Bay. For example, the estimated loads of BOD, TN and TP into Guanabara Bay were, respectively, 350t, 122t and 20t, on a daily basis.

The principal impacts of biogeochemical loads into the bay are eutrophication, pollution, excess sedimentation and trophic state change from its original trophic characteristics to eutrophy to hypertrophy (Chlorophyll *a* concentrations >100 µg l⁻¹). This results in a reduction of fish production and loss of biodiversity (for which real numbers can be estimated), interdiction of beaches to recreation and high levels of heavy metal pollution in sediments.

To assess the ecological and human health risks resulting from heavy metal and other contaminants (particularly APH's, toxins and DDT), we have adapted the Potential Ecological Risk Index (PERI) originally proposed by Håkanson (1980, 1988) as a contamination control for lakes and coastal systems of Scandinavia. The most important adaptation concerns the estimate of the trophic state system by using the bioproduction number (BPN). The N/organic matter ratio in sediments, originally used for the calculation of BPN, was substituted by the evaluation of chlorophyll *a* levels in the water column. Due to the high trophic state in Guanabara Bay, the PERI obtained was low (PERI = 36). Among heavy metals, Hg was identified as being the priority contamination to be detailed: PER: Hg = 25.4 > Cd = 5.7 > Cu = 2.8 > Pb = 1.2 > Cr = 0.3 > Zn = 0.2. A detailed approach can be found in Campos and Bidone (2000). Risk assessment for the organic contaminants is still to be calculated.

To make the link (transfer) between contaminants and biota (fishes in this case study), we have used an approach developed by Castilhos *et al.* (2001) firstly to Hg contamination. This approach suggests:

- a parameter to normalize Hg concentration in fishes based on the time of exposure needed to reach some percentage of their maximum length, in this case 50%;
- a graphical method to estimate Hg daily uptake rate by these fishes;
- an estimate of the time of exposure necessary to achieve 0.5 µg g⁻¹, the United States Food and Drug Administration (FDA) advisory level for concentration of mercury in fish; and
- calculation of the dose-response relationship for Hg accumulation.

The results of the existing studies suggest that it is possible to integrate the results obtained in the different sub-systems involving the natural elements of the proposed model (river material fluxes, internal bay system etc.) to identify potential indicators of pressure, state change and impact. The current major requirement is to integrate the natural and the socio-economic elements included in the proposed system model for the Guanabara Bay basin.

5. Integration of socio-economic elements and indicators in the system model

5.1. The 'socio-economic drivers' and 'socio-economic activities' elements

The "pure" socio-economic elements included in the system model are the 'socio-economic drivers' and the 'socio-economic activities'. In the proposed approach, the 'cost-benefit analysis' and 'policy response' may be classed as merged natural-socioeconomic elements. For this case study, recognition and characterization of 'socio-economic activities' is not complicated since the Guanabara Bay basin is a relatively well-documented region because of its cultural and historic importance to Brazil. From the large numbers of urbanization and development programs and the many scientific studies from local universities and State agencies, it was possible to identify fisheries and tourism-recreation as the major activities affected by eutrophication and pollution of Guanabara Bay. Within the river catchment, major activities affected are the use of water by the population and industry, which need relatively unpolluted water. In general, surface water use is substituted by the use of groundwater, or water supplied by the State, generally from diversion of other basins such as the Paraíba do Sul River (Molisani *et al.*, this report).

The principal 'socio-economic drivers' identified are urbanization (demographic growth and increase in land occupation for residential purpose) and industrialization. Urbanization and industrialization processes generate, respectively, diffuse and point sources of wastewaters and toxic effluents to the rivers, and from them to Guanabara Bay.

This paper is restricted to the discussion of the socio-economic indicators linkable to the socio-economic driver "urbanization", responsible for the increased fluxes of materials and for the extensive contamination of Guanabara Bay (JICA 1994).

5.2. Demographic indicators *versus* biogeochemical indicators in river waters

Primarily, indicators of the socio-economic drivers must be directly linked to demography and land occupation (in this case, for residential purposes) indicators, to provide an understanding of the external forcing effects of socio-economic changes such as population growth on fluxes of biogeochemical materials. Population growth (i.e., human occupation) within watersheds draining into Guanabara Bay is linear and without treatment of domestic sewage. Consequently concentrations and fluxes of materials also change linearly with the population density (JICA 1994; Bidone 2000). For example, DIP and DIN increase by about three orders of magnitude from unpolluted rivers to highly polluted rivers. N:P ratios clearly define the different intensities of basin occupation and reflect the levels of fluvial water contamination. These ratios show a decreasing trend inversely proportional to the degree of contamination of fluvial waters. Thus, river waters in areas with remnant tropical rainforest (on the slope parts of the watersheds) and with a population density of about 10^{-2} inhab. km⁻², has a N:P ratio of about 100; in non-polluted river waters draining areas with population density of about 10^{-1} inhab. km⁻², the N:P ratio varies from 10 to 100; low contamination waters with similar population density show N:P ratios varying from 1 to 10; polluted waters in areas of moderately high population density (10^2 inhab. km⁻²) show N:P ratios from 0.1 to 1.0; and heavily polluted waters in high population density areas (10^3 inhab. km⁻²) show N:P ratios from 0.01 to 0.1. This pattern is in accordance with the *quasi*-exponential increase of P with water contamination levels and the occurrence of denitrification in heavily polluted waters (Bidone 2000).

From material fluvial fluxes it is possible to derive loads of substances from domestic sewage. Fluxes to Guanabara Bay of BOD, TN and TP were estimated as 0.03 kgBOD inhab⁻¹ day⁻¹, 0.01 kgTN inhab⁻¹.day⁻¹ and 0.002 kgTP inhab⁻¹ day⁻¹ (Bidone 2000).

Other links between demographic and natural indicators must be established. However, the major objective of the present study is to highlight the importance of such an approach to question contained in the objectives of the **LOICZ Basins** project. These include:

- construction of future scenarios (forecasts) for pressures and state changes of fluvial waters and their inputs to coastal system;
- reconstruction of past scenarios of the historical occupation of watersheds;
- up-scaling of these indicators from the regional level towards a typology of the SE Brazilian coast and eventually to a sub-continental level;
- estimation of sustainability standards for fluvial waters and of defining critical loads (e.g. N:P ratios of about 16 for non-contaminated waters in this region); and eventually
- establishment of primary regulatory goals for river waters.

The sustainability standards should take into consideration a risk analysis at least for toxic substances (Bidone *et al.* 2000).

5.2 Other socio-economic driver indicators for basin ‘typology’ and ‘up scaling’

An important aspect to be considered in the studied area is the linearity observed between the demographic growth and the increase of pollution levels as reflected by the increase in fluxes of biogeochemical materials. This is also important for the ‘typology definition’ for ‘up-scaling’ (Turner *et al.* 1998). In the Guanabara Bay basin this linearity is due to the high rates of population growth and to unplanned occupation of watersheds, without the proper infrastructure to cope with their effluents. In this case, the question is whether the fluxes of materials would still reflect the indicators of demographic change if all basins, independent of their population density, had their sewage effluents treated.

The more realistic answer to this question is probably, yes! Theoretically a reduction of the forcing of anthropogenic activities upon the study areas would be achieved by introducing environmental protection rules for these activities. However, technical measure frequently do not solve the problem but only decrease its velocity, since the growth of a give activity in general surpasses the effect of the measure or due to delayed effects of the contamination. Even considering the long term, the ideal environmental control of such typology as that of Guanabara Bay is probable an utopian concept.

Mitigation measures are being implemented under the ‘Guanabara Bay Recuperation Programme’ conducted by Rio de Janeiro State Government. There is no possibility of returning to original, natural state because of increasing occupation pressure, prohibitive costs, the impossibility of implementing ideal control measurements, e.g., lack of areas to construct tertiary treatment systems, the low level of development of the local society and the inadequacy of public policies. To better characterize and eventually develop a ‘typology’ and promote up-scaling, it is necessary to develop other ‘socio-economic driver’ indicators, which can better characterize the socio-economic profile of the population.

A commonly utilized socio-economic indicator for the characterization of the economic activity (wealth) of a population is its Gross Internal Product *per capita* (GIP/inhab). In the study area the GIP/inhab is about US\$ 3,500. But in this case this indicator fails, since it doesn’t take into consideration the concentration of income and the wealth distribution within the population. The higher the income concentration, the higher the number of poor and the worse the quality of life of the population, including sanitary conditions.

Other frequently-used income distribution indicators are the Gini Coefficient and the Theil Index. These indicators take into consideration the average family income *per capita* of a given region. An index of coefficient 1.0 represents the largest uneven distribution of income among the population. In Brazil, the average index is 0.74, one of the highest in the world. In Rio de Janeiro city, between 1981 and 1985, this value was 0.57 and between 1995 and 1999 it was 0.60, suggesting a deterioration of social conditions. Today, the 50% poorer of the population has only 13.1% of the city’s income, whereas the 1% richest has 11.8%.

We have also been working on the application of the HDI (human Development Index) on the Guanabara Bay basin. This index allows the comparison of quality of life taking into consideration information on

income, health and education level of the inhabitants. The HDI ranges from 0 to 1.0, where the higher the value the better development is achieved by a give population ($HDI > 0.8$ = high, HDI between 0.5 and 0.8 = medium, and $HDI < 0.5$ = low). Our results show that high (> 0.8) development is associated with better sanitary conditions. Material fluxes through rivers are smaller, as are the impacts on the coastal zone. Sub-basins with high HDI also presented low population densities whereas low HDI occurs in areas of high population density. Thus considering two sub-basins of similar 'physical typology' (i.e., with similar primary environmental indicators) but with different values for the HDI, the sub-basin with the lower value will show the higher biogeochemical fluxes, and therefore pressure on fluvial waters and impacts on the coastal zone. We are presently ranking the sub-basins and relating HDI values to estimated biogeochemical fluxes. Independent of the result, these indexes showed fundamentally as a 'socio-economic driver' indicator essential to any desired 'typology definition' and/or 'up-scaling' procedure.

6. Supplementary socio-economic indicators based on sustainable development issues

In a wide sense, **LOICZ Basins** projects deal with sustainable coastal development, which can be described as 'the proper use and care of coastal environmental borrowed from future generations' (Turner *et al.* 1998). Sustainable development was defined by the Brundtland Report, 'Our Common Future' (WCED 1987) as that which 'meets the needs of the present without compromising the ability of future generations to meet their own needs', and it was suggested that economic development and environmental well-being are not mutually exclusive goals. In order to achieve critical sustainable development objectives for coastal environments and coastal development policies, it is important to have strategies such as conserving and enhancing the coastal environment, managing risk and coastal vulnerability, and merging coastal environmental considerations with economics in decision making. However, to be socially sustainable, the total capital of a given economy requires the inclusion of those considerations related to the biophysical environment

Sustainability from an economic perspective requires a non-declining capital stock over time to be consistent with the criterion of intergenerational equity. Sustainability therefore requires a development process that allows for an increase in the well-being of the current generation, with particular emphasis on the welfare of the poorest members of society, while simultaneously avoiding uncompensated and significant costs on future generations. The process would be based on a long-term perspective, incorporating equity as well as an efficiency criterion, and would also emphasise the need to maintain a healthy global ecological system (Turner *et al.* 1998).

The total capital of an economy may be described as the sum of man-made capital, natural capital, human capital and social/moral capital. Thus, beyond the need of holding the natural capital constant or rising over time, social sustainable development requires an improvement in the human capital and social/moral capital.

Socioeconomic indicators of human capital and social/moral capital could be considered as 'supplementary socio-economic indicators'. The practical aim of their utilization into the DPSIR framework, would be to support additionally the social evaluations and considerations obtained from the use of the proposed 'socio-economic driver indicators', as well as, to reinforce: a) the basin typology characterization and the up scaling purposes; b) the characterization of the socio-economical profile of the population living in the basins (in terms of its 'quality of live' characterization); c) the evaluation of the results of public policies.

At Guanabara Bay basin, no study to date has included an evaluation of supplementary socio-economic indicators of human and social/moral capitals such as infantile mortality, poverty, education, health and public safety indicators in face of their links with biophysical indicators of environmental change.

For example, the 'infantile mortality' is an index measuring the number of children that die before the end of the first year of life (number of dead children/1000 births). That index for the Guanabara Bay region varies from about 5 in basin occupied by high HDI (> 0.800) to about 45 in basins with population with low HDI (> 0.500 - < 0.800).

The 'poverty index' considers (as a percentage of inhabitants) the number of the poorest members of the population of a given area. A 'poor member' is defined as someone with monthly revenue of about US\$40 or less. The preliminary Guanabara Bay results show that areas with a high HDI value have a 'poverty index' of about 4% or less; while areas with low HDI values have a 'poverty index' higher than 20%. The 'education index', average number of years spent in school of the adult population, varies from, 11 years in areas with higher HDI values to about 7 years in areas with lower HDI values. The 'public safety index' used in this case study is the number of violent crimes per year. This varies from about 200 in higher HDI areas to 4,000 in lower HDI areas.

6. Merged socio-economic and natural indicators: cost-benefit analysis (CBA) and response indicators

6.1 CBA: strengths and limitations

LOICZ objectives and the DPSIR framework include the assessment of the human welfare impacts of flux changes due to changes in processes and functions in coastal resource systems. Such assessments of the social costs and benefits involved will provide essential coastal management intelligence based on social science and possible resource and value trade-offs.

CBA are economic techniques that produce information intended to improve the quality of public policies. In this context, 'quality' refers to a measure of the social wellbeing that the policy conveys to society. Policies that reduce wellbeing are *a priori* inferior to those that improve wellbeing. Conceptually, then, CBA could be used:

- a) to evaluate the results of a environmental public policy and/or a resource management action;
- b) to rank policies and/or resource management options; and, even
- c) to evaluate the results of the absence of a necessary environmental public policy and/or the absence of resource management action.

These evaluations and ranks are rated on the basis of their impacts on socio-economic wellbeing.

Because policy decisions are required for a range of spatial and temporal scales and different socio-economic and political levels, several broad assessment categories need to be distinguished (Barbier 1993). LOICZ proposes three assessment categories:

- a) the impact analysis in which a specific environmental impact is assessed via the valuation of the environmental state changes in the coastal resource(s) connected to the impact;
- b) the partial valuation analysis, which encompasses situations requiring the evaluation of alternative resource allocations or project options; and,
- c) the total valuation analysis, to evaluate protected areas schemes involving restricted or controlled resource use (Turner *et al.* 1998).

All these assessment categories require estimates of the environmental benefits and costs. For example, in an impact analysis, the total cost of the environmental impact in social welfare terms is the foregone net of environmental benefits. This and other strategies of CBA are apparently simple, but to evaluate natural resources, environmental goods and services, environmental benefits and associated costs to the environmental degradation in monetary terms is a very difficult task. This is mostly due to the non-quantifiable nature of the environment in the existing economic framework.

There are various methods and approaches to the economic valuation of environmental state changes: hedonic property method, travel cost, cost of illness, contingent valuation (Turner *et al.* 1998). There are conceptual, theoretical and empirical problems encountered in quantifying economic value for the environment (e.g., Pearce and Turner 1990; Costanza 1991).

CBA is a technique intended to improve the quality of public-policy decisions, a quality defined according to the change in social wellbeing that they bring about. CBA forces one to use a measurement of social wellbeing, which we refer to as social welfare. The measurement of social welfare in CBA and how it is affected by a policy depend on how the welfare of individuals is affected by the policy and how individuals' welfare levels are aggregated. Individual welfare is assumed to depend on the satisfaction of preferences

and on the theoretical construct of economic value derived from the axioms of preference satisfaction (Kopp *et al.* 1997).

Many of the critiques of CBA encountered in everyday policy debates are echoes of the more conceptual issues. They include the following:

- (i) the environment is a public good that is not exchanged in markets and therefore defies economic valuation. Thus, the use of CBA to evaluate environmental policies is inappropriate;
- (ii) environmental protection is often desirable for reasons that cannot be quantified (social, spiritual, and psychological values that defy valuation in simple economic terms);
- (iii) CBA does not take the “rights” of future generation into account.

Beyond these and other conceptual issues, criticism of CBA focusses on several overlapping points: the notion that preference satisfaction gives rise to individual well-being, the elements of the social-welfare index, the notion that economic value is a measure of preference satisfaction, the empirical and philosophic problems encountered in quantifying economic value, the presumption that the well-being of society can be defined as some aggregation of the well-being of individual members of that society, and the methods by which the aggregation is performed, (Kopp *et al.* 1997).

6.2 CBA in the DPSIR framework for the Guanabara Bay case study

In this case study, the ‘policy responses’ and their practical ‘management options’ are those included into the ‘Guanabara Bay Recuperation Programme’, conducted by the Rio de Janeiro State Government supported by the World Bank, Interamerican Development Bank and Japan Bank. That programme is a water pollution control plan intended to reduce the inflow of wastewaters into Guanabara Bay. It includes the construction of several treatment plants, stabilization ponds, ocean outfalls with primary treatment, and other actions and facilities aiming for the recuperation of the bay.

Based on conceptual and theoretical issues, and the practical difficulties in valuation of environmental goods and services for a proper CBA of ‘policy responses’ and ‘management options’ of the “Guanabara Bay Recuperation Programme”, we propose a strategy that does not require the valuation of the environment in monetary terms. Conceptually, this strategy is in agreement with the necessary environmental conservation paradigm implicit in sustainable development. Even with the best possible data and scientific understanding, the sense in which economists can value nature’s services is limited. Valuing these services is much less important than providing incentives for their conservation, and valuation and providing incentives for conservation are quite different. Valuation is neither necessary nor sufficient for conservation, whereas providing the right incentives is (Heal 2000).

The theoretical and practical basis of the proposed strategy is partially based on Huetting (1991) with suggestions and modifications more suitable to the present situation. The first need is to assign a value which society attributes to the raw materials and products of a project or policy. This involves a theoretical concept directly related to the dichotomy between individual and collective (i.e. society’s) preferences *vis-à-vis* the change in quality and quantity of natural resources. Thus: what standards (of environmental quality and quantity) are to be set? An answer to that question could be found in the notion of sustainable development: politicians, organizations and countries (more than 100 countries, including Brazil, which had already included the concept of sustainable development in its new constitution of 1988) declared in favor of sustainable development during and after the United Nations Environmental Summit in Rio de Janeiro in 1992. This can be conceived as a preference voiced by society, which opens up the possibility of basing a calculation on standards for a sustainable use of environmental functions, instead of (unknown) individual preferences.

The second need is the assignment of monetary values to the external benefits and costs to the environment which arise from the project or policy, so that these may be incorporated, together with market values of other project attributes, in the CBA. This is not a straightforward task, owing to the intangibility in monetary terms of most environmental goods and services. Huetting (1991) proposed the following procedure:

- a) define physical standards for environmental functions, based on their sustainable use;
- b) formulate the measures necessary to meet these standards;

- c) estimate the amounts of money involved in putting the measures into practice.

In technical terms, this means that in the familiar diagram of the supply and demand curve for environmental functions we have to determine a point on the abscissa which represents the standard for sustainability. A perpendicular on this point intersects the supply curve; the perpendicular replaces the (unknown) demand curve. The point of intersection indicates the volume of activities, measured in terms of money, involved in attaining sustainable use of the environmental functions. Thus a technical demand function is created, rather than a 'true' demand curve (which, theoretically, should be constructed from the aggregation of all individual preferences by environmental quality).

We have focused on the economic-environmental evaluation of the results on fluvial water quality and the measurements adopted by the Guanabara Bay Recuperation Programme. The effects of these measurements on the water quality of the bay are also being evaluated. Table 1 shows a synthesis of the elements included in the proposed CBA. This procedure is being applied for each watershed draining into Guanabara Bay. Thus general considerations and total values to the elements listed in Table 1 can be obtained for the entire Guanabara Bay basin from the individual value for each sub-basin.

Table 6.1. Elements included in the CBA of the sanitation measures planned by the Guanabara Bay Recuperation Programme. Emphasis is on the riverwater quality state change.

ELEMENTS TO CBA	
Population density	Inhab/km ²
Human Development Index (HDI)	HDI >0.80 (high); HDI 0.500 - 0.800 (medium) and HDI <0.500 (low)
Biogeochemical fluxes	BOD, TN, TP, etc. (t km ⁻² day ⁻¹)
Current pollution level	Pristine, low, high and extreme
Planned sanitation measures	Ocean outfalls, stabilization ponds etc.
Costs of the planned sanitation measures	US\$
Cost <i>per capita</i>	US\$/inhab
Cost <i>per capita</i> / revenue <i>per capita</i>	Ratio (non-dimensional)
Forecast of state change	Modeling of the remaining biogeochemical load effects on the riverwater quality
Standard of sustainability	Natural indicators (e.g., biogeochemical fluxes) for 'drinking water' use after conventional treatment
Natural background level	Original state of the riverwater
Physical natural capital depreciation (PNCD)	Estimation of the environmental costs for the remaining biogeochemical loads
Pressures on other environmental resources	Pressures on the wetlands and on Guanabara Bay
Benefits	Qualitative approach

Although most of the elements listed in Table 6.1 have been already discussed or are self-explanatory, some considerations are still necessary:

a) Physical natural capital depreciation (PNCD)

The capital of an economy is its stock of actual goods with the potential to produce in the future more goods and services. The capital of an economy should include the natural resources of a given region, once they have the potential to generate more goods and services in the future, both as source of raw materials and as receptors of effluents and wastes generated by human activities. Therefore the impoverishment of natural resources must be viewed as an uninvestment and should be discounted from the incomes generated by production as a "depreciation of the natural capital" (El Serafy 1991).

One reason that depreciation exists is because of a reduction over time in the physical ability of capital to generate consumable services. This loss in physical ability – physical depreciation – may also lead to a loss in the value of the capital stock – value depreciation. That is, value depreciation may be caused by physical depreciation. However, value depreciation can also arise for other reasons. For example, the value of capital can fall due to a change in tastes for those consumption items produced by the capital or simply

because of a change in interest rates. Thus, the value of total depreciation could be considered as Value depreciation = physical depreciation – capital gain or + capital loss (Peskin 1989, 1991). We will only consider the physical depreciation (PNCD), hence capital (in financial terms) gains and/or losses are already included in conventional accounts.

In this study we propose to estimate PNCD through the estimation of the environmental costs associated to the remaining biogeochemical loads in the river waters. This is done by estimating the costs of the necessary measurements to reach the natural background concentrations of local fluvial waters, i.e., to attain the original state of the river water quality. The estimated values of NCD shall be included into the “satellite accounts” to correct the Gross Internal Product (GIP) of the Rio de Janeiro state for the environmental costs and benefits: ‘Satellite Accounts’ = GIP - Σ Costs of sanitation measures - Σ NCD.

b) Pressures on other environmental resources

The priority in the study is to consider the pressures on the wetlands and on Guanabara Bay proper. Pressures on wetlands are mostly due to the implementation of flood-control measures along the lower part of river basins (e.g., ponds, dredging, canals). In general, these measures are planned to work together with water treatment systems. But no policy specifically for protection and/or management of wetlands exists for the area, neither is any consideration given on the impact of external factors (e.g., sea level change) and other ongoing projects on development and management. These pressure are also due to the input of substances directly through rivers and residual from the outfall inputs due to sea currents and other dilution agents. The quantification of these pressures is underway but analysis of such pressures are still preliminary and its inclusion in the present model is only qualitative, indicating either its presence as significant or not, for each studied catchment.

c) Benefits

Forecasted benefits are related to the use of the Guanabara Bay water system. Improving the quality of incoming fluvial waters is a key step to the improvement of the water quality of Guanabara Bay. For many small communities better quality of fluvial waters for domestic supply would be highly beneficial. The potential for other uses such as aquaculture and recreation is not considered. Even for Guanabara Bay, the impact of improving water quality in fisheries and recreation is considered only under qualitative terms.

A basic principle of CBA is that all benefit types should have standing, whether they are quantifiable or not. The key issue is how to treat non-quantifiable elements. There are several options. One that has found favor among economists is a value-of-information approach. This involves estimating the net benefits for the quantifiable elements and asking how large the non-quantifiable elements would have to be to reverse the conclusion of the analysis. If the non-quantifiable elements were all on the benefits side and the net benefits were positive, information on the non-quantifiable benefits would have no value for the decision. If the net benefits were negative, the non-quantifiable elements would have to be at least as large to reverse the outcome of the analysis. The analyst or decision-maker could make a judgment about whether the non-quantifiable elements were likely to be greater than this amount (an easier judgment than one about the possible size of the non-quantifiable benefits: Kopp *et al.* 1997).

For instance, with respect to health benefits in the Guanabara Bay sanitation programme, the effects of water and soil contamination by bacteria, viruses etc. on human health is well known. Statistical data show that the population health is improved after the implementation of sanitation measures. That is, the costs with illness treat are reduced over time. How much? To answer to this question good statistical data on these costs are necessary. But, it is not so evident. For that reason, to estimate the approximated rates of illness reduction observed over time in areas with sanitation controls may be a sufficient approach to the benefits of sanitation programmes.

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6.5 Integrated management of the Uruguayan coastal zone of the Río de la Plata

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The ECOPLATA Program is an inter-institutional agreement for joint execution of activities in support of IMCZ with the participation of the Ministry of Housing, Territorial Planning and Environment (MVOTMA); the National Institute of Fisheries (INAPE, MGAP); the Oceanographical, Hydrological and Meteorological Service of the Navy (SOHMA, Ministry of Defense); the College of Sciences; and the College of Social Sciences of the University of the Republic.

The main objective is to contribute to the integrated management of the Uruguayan coastal zone of the Río de la Plata, through activities in pilot areas. It includes design and execution of management policies on the basis of a preliminary diagnosis. Planned actions should promote the conservation and sustainable use of coastal resources, with participation of the various governmental institutions that are responsible for management of the natural resources and their conservation, and other relevant organizations.

The proposed actions should resolve conflicts on the use of coastal resources, both in the terrestrial fringe and the aquatic section of the project's area. The identified conflicts of use result from activities that compete among themselves such as fishing, tourism, housing, industry and agriculture. These activities contribute to resource degradation as a consequence of overfishing, water-course pollution, solid residues accumulation, erosion and loss of agricultural lands' nutrients. Planned actions include some to protect areas that are presently relatively pristine, and corrective actions in areas where resource degradation and habitats alteration are occurring.

The involvement of several governmental institutions with national and local level responsibilities, the University of the Republic, non-governmental institutions and others that are directly involved in the use of coastal resources constitutes an innovative aspect of the project in the Uruguayan conditions.

Concentrated action in pilot areas is intended to demonstrate the contribution of technical and scientific information to integrated coastal zone management. The concentration of inter-institutional and multidisciplinary efforts in a restricted area and the selection of the pilot zones with most potential will provide results in a short period and will enable the replication of similar efforts in other parts of the project's area.

The open character of the project, which can be observed by the population, is complemented with training activities, public participation in resources management, education and information dissemination. This hopefully will ensure an improved attitude in relation to resources management and the environment.

Area of the Study

The study area includes 452 km on the Río de la Plata coast (Figure 6.6).

- **Terrestrial** – a 10 km corridor between the coast and National Routes No. 21, 22, 8 and 9, with its eastern political boundary set in Punta del Este, Maldonado Department and its physical boundary at Maldonado Creek.
- **Aquatic** – The exclusive jurisdictional zone is stated in “The Boundary Treaty of the Río de la Plata and its Maritime Front”: 2 miles wide from Km 0 of the Río de la Plata to Colonia del Sacramento City, Colonia Department, and from there seven miles stretching as far as Punta del Este, Maldonado Department.

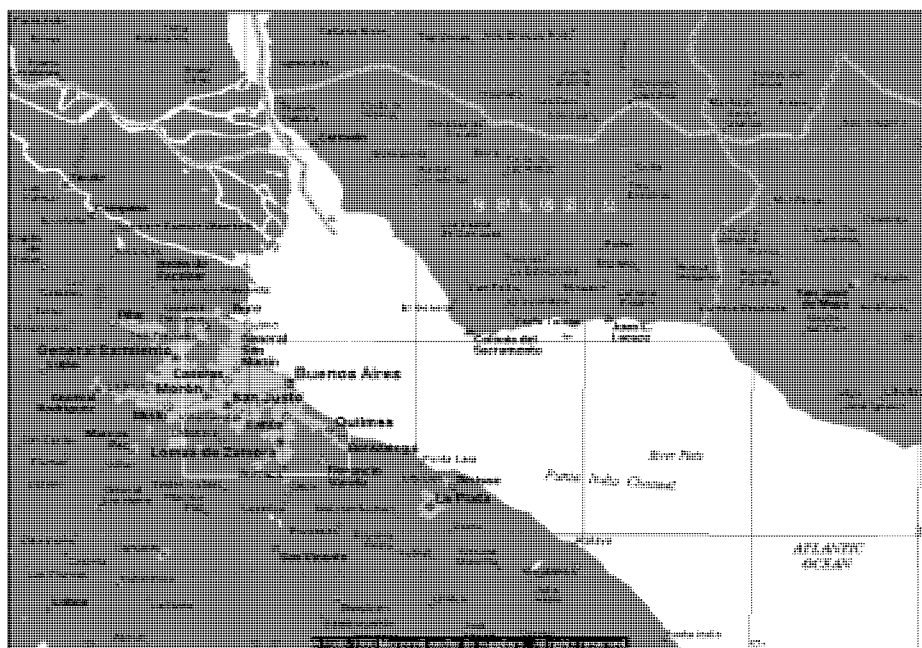


Figure 6.6. The Río de la Plata estuary, including the study area.

The terrestrial area is characterized by a great diversity of coastal environments. Sandy beaches are dominant with bars and coastal dunes, slopes and ravines developed over diverse geological structures.

A preliminary environmental diagnosis identified processes that affect the sustainability of the coastal resources:

- Beach erosion
- Ravine erosion
- Interference to the natural processes of morphological evolution and sediments transport
- Unlawful extraction of sand and other materials for construction

Zoning and degree of environmental impact

For the purpose of zoning and ranking of environmental impact in the areas, “pressure indicators” were applied, that show the presence of activities that can generate certain level of environment impact and “state indicators”, that show five *categories of environmental impact*:

- **Low:** minimal impacts or reduced damage to the environment
- **Moderate:** moderate impacts mostly related to discrete activities or less intensive use
- **Medium:** impacts with certain degree of area significance and moderately intense activities
- **High:** significant impact across large area
- **Very high:** very significant impacts over large areas and little possibility of reversion

Applying these indicators, the Uruguayan coastal zone of the Río de la Plata presented the following level of environmental impact:

- | | |
|------------------------------------|-----------------|
| • Nueva Palmira - Punta San Carlos | Low |
| • Punta San Carlos - Juan Lacaze | Medium |
| • Juan Lacaze – Kiyú | Moderate |
| • Kiyú - Arroyo Mauricio | Medium |
| • Arroyo Mauricio – PuntaTigre | Low |
| • Punta Tigre - Punta Espinillo | High |

• Punta Espinillo - Punta Lobos	Moderate
• Punta Lobos - Punta Sarandí	Very high
• Punta Sarandí - Arroyo Carrasco	High
• Arroyo Carrasco - Arroyo Pando	High
• Arroyo Pando - Arroyo Solís Chico	Medium
• Arroyo Solís Chico - Arroyo Solís Grande	Moderate
• Arroyo Solís Grande - Arroyo Zanja Honda	Medium
• Arroyo Zanja Honda - Punta Fría	Very high
• Punta Fría - Arroyo Potrero	Low
• Arroyo Potrero - Punta Ballena	Moderate
• Punta Ballena - Punta del Este	Medium
• Punta del Este - Arroyo Maldonado	Medium

Zoning and ranking of separate sectors of the coast also identified:

I) Human intervention considered irreversible:

- Sand extraction from dune fields and coastal strings
- Rectification of mouths of rivers and streams
- Afforestation
- Urbanization
- Engineering structures

and

II) Sensitive coastal areas:

- *Micropogonias furnieri* nursery and feeding zones;
- “Espartillar” or crab community area
- *Mytilus edulis platensis* exploitation area (mussel artisanal fishery)
- Flooding areas of wetlands
- Protected native woodlands.

In the aquatic zone, the diagnosis identified the degree of contamination of streams, rivers and bays that flow into the Río de la Plata:

Montevideo Bay
Río Santa Lucía
Arroyo Carrasco;
Arroyo Pando.

The real pollutant charge of these bodies will be analyzed during the present phase of the project.

From the analysis of the physical and chemical characteristics of the Río de la Plata and its tributaries, it was concluded that there is a need to:

- Strengthen and broaden the network of coastal monitoring stations;
- Determine the sediments’ granulometry and pollutant loads (organic and inorganic);
- Establish the pollutant loads of tributary streams and rivers and link it to the industries in the basin or small catchment;
- Establish “Quality Standards”, according to the sub-systems of the Río de la Plata (river, estuary, ocean) to control the evolution of the quality of the system.
- Study the coastal zone of the Santa Lucía River.

The physical characteristics diagnosed generated diverse charts. These charts were cross-linked to get a unique “Environmental Impact” chart. This chart was cross-linked to the socio-demographic diagnosis to select three pilot areas:

- ◆ Saline Front
- ◆ Santa Lucía (Punta Espinillo – Playa Pascual)
- ◆ Arroyo Carrasco – Arroyo Pando

In the Santa Lucía and Arroyo Carrasco – Arroyo Pando pilot areas, three working groups were established with the participation of ECOPLATA scientists and technicians, stakeholders, technicians of the local government and the coastguards, who defined the themes: (i) environment quality; (ii) physical planning and (iii) artisanal fisheries, with participation of local stakeholders. These working groups are part of two ECOPLATA teams, one for each pilot area, formed by representatives of each Institution of ECOPLATA. The working groups are now implementing studies of the water quality of the three streams of the pilot areas: Santa Lucía River and the Carrasco and Pando streams, evaluating the solid wastes in the beaches and developing a proposal for the use of the coastal area.

In the Saline Front, information needed to support fishing activities was gathered:

- Primary productivity estimates in the saline front;
- Physical and chemical factors and their influence in the reproduction of the croaker (*Micropogonias furnieri*);
- Detection throughout the year of the saline front, where reproduction of the croaker takes place, to support the artisanal fishermen;
- Identification of croaker populations for management of the fishery;
- Development of pressure indicators on the croaker fishery;
- Characterization of the fishing settlements in Pajas Blancas and Santa Catalina and their impact on the environment.

Analysis of these elements will help to establish management measures that will support the artisanal fishermen.

7. Regional Assessment Tables
Regional Assessment Table 1: Ecuador coast, by R. Martinez Güingla.
Table RA1.1. Ecuador coast: major coastal impacts/issues and critical thresholds.
 Overview and qualitative ranking: Impact code and relative class of importance: 1 = minimum, 10 = maximum

Coastal impact/ issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Eutrophication	Esmeraldas, Chone rivers; Guayas River/ Gulf of Guayaquil	Oxygen level (DO >4.0 mg l ⁻¹). Nutrients at background levels. Organic pollution = zero	<ul style="list-style-type: none"> Esmeraldas: 1° N – 79°40'W: OD= 0.9 -6.7 mg l⁻¹, BOD, N=10.35 µgat l⁻¹ NO₃, 0.36 µgat l⁻¹ NO₂, 2.35 µgat/l PO₄ Coliformes Fecales (1980)= 210-240000 NMP 100ml⁻¹ Chone River estuary: OD= 1.6 – 7.5 mg l⁻¹ N=12.1 µgat l⁻¹ NO₃, 1.35 µgat l⁻¹ NO₂; 0.34 µgat l⁻¹ PO₄, Total coliforms = 930 NMP 100ml⁻¹ Gulf of Guayaquil: Estero Salado: OD= 3.4- 8 mg l⁻¹; N= 0.1-1.4 µg-at l⁻¹ NO₂; 10-33 µg-at l⁻¹ NO₃; 1.2- 4.4 µg-at l⁻¹ PO₄. Total coliforms = 0-240 NMP 100ml⁻¹. Total coliformes >2400 NMP 100 ml⁻¹. 	<ul style="list-style-type: none"> Esmeraldas River=7 Chone River = 8 Guayas River/ Gulf of Guayaquil = 6 	PMRC (1993a,b); INOCAR (1998a,b)
	Esmeraldas, Chone River and Guayas River/ Gulf of Guayaquil	<ul style="list-style-type: none"> Pesticides = 0 Heavy metals at background levels Industrial discharges to Guayas River and Estero Salado reached 25,480 m³ day⁻¹ (mean) in 1996. 	<ul style="list-style-type: none"> Esmeraldas: Cu = 0.1- 7.2 µg l⁻¹ Heptacoloro= 0.005 ppb; DDT = 0.017 ppb Heavy metals in sediments: 87.4 ppm Zn, 2.31 ppm Cd, 43.75 ppm Cu. Cu and Cd ingested in 250 g of oysters and mussels reach 6.5 mg l⁻¹ y⁻¹, 0.384 mg l⁻¹ respectively. Guayas River: coliforms= 93,000 NMP 100ml⁻¹ 	<ul style="list-style-type: none"> Esmeraldas=7 Chone R. = 8 Guayas River/ Guayaquil Gulf= 6 	PMRC (1993a,b); INOCAR (1998a,b)
	Esmeraldas, Chone rivers and Guayas River/ Gulf of Guayaquil	Lack of vegetation protecting the coastline. Between 1969 and 1996 mangrove area reduced by 23.6% in Gulf of Guayaquil In the Chone River estuary mangroves reduced by 80% from 1969 to 1991 (3973ha to 785 ha)	Esmeraldas River estuary: suspended solids up to 210 mg l ⁻¹ Chone River estuary: High sedimentation rates and bank erosion due to clear cutting of mangroves. Guayaquil Gulf: 0-3,039 mg l ⁻¹ (rainy season) and 0- 4,132 mg l ⁻¹ (dry season) of suspended solids.	Esmeraldas: Erosion = 7 Chone River: Erosión = 8 Sedimentación = 9 Gulf of Guayaquil: Erosión = 7 Sedimentation = 8	PMRC (1993a,b); INOCAR (1998a)
	Coastal fisheries a. Direct effects b. Indirect effects (sediment)	Decreasing fisheries due to illegal use of pro (net mesh of 1.5 cm.)		Esmeraldas = 7 Chone River = 7 Gulf of Guayaquil = 8	INOCAR (1998a)

Table RA1.2. Ecuador coast: DPSIR matrix characterising major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.

State change dimension: 3 = major; 2 = medium; 1 = minor; 0 = no impact; ? = insufficient information. Time scale: p = progressive; d = discrete (Area 1-3 refers to West Coast sub-regions - see chapters 1 and 2.3).

Driver	Pressures	State change (qualitative index)				Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins: active coast	Small basins: passive coast		
Agriculture	<ul style="list-style-type: none"> Increased surplus of inorganic nutrients Increase of organic pollutants Pesticides use Soil erosion Water extraction 	?	Area 1: 0	Area 1: 1		<ul style="list-style-type: none"> Local contamination Human Dimension: Health of communities. Sedimentation Human Impacts: Artisanal Fisheries 	p
	Area 1: Esmeraldas River		Area 2: 2	Area 2: 2			
	Area 2: Chone River		Area 3: 1	Area 3: 2			
	Area 3: Gulf of Guayaquil						
Forestry	<ul style="list-style-type: none"> Deforestation. (mangrove, tropical bosque) Change in soil quality Soil erosion Habitat loss Ecosystem alteration 	Area 3: 2	Area 1: 1	Area 1: 2		<ul style="list-style-type: none"> Increase sediment load Human Impacts: Artisanal Fisheries 	p
			Area 2: 3	Area 2: 3			
			Area 3: 3	Area 3: 3			
Navigation	<ul style="list-style-type: none"> Waste effluent Dredging 	?	Area 3: 1	Area 3: 2		<ul style="list-style-type: none"> Increase sediment load Hydrodynamic changes. Human impacts: artisanal fisheries. 	d
Urbanization	<ul style="list-style-type: none"> Domestic and industrial waste increase Increase surface run-off Deforestation 		Area 1: 1	Area 1: 2		<ul style="list-style-type: none"> Contamination Increase sediment loads. 	p
			Area 2: 2	Area 2: 2			
			Area 3: 2	Area 3: 2			

Table RA.1.2 Ecuador coast continued

Damming	<ul style="list-style-type: none"> Changes in hydrobiological cycle Decrease in sediment transport Loss of runoff 		Area 1: 0 Area 2: 0 Area 3: 1	Area 1: 0 Area 2: 1 Area 3: 2	<ul style="list-style-type: none"> Reduce in sediment transport Change in patterns of salinity Human impacts: artisanal fisheries Change in stratification Human impacts: loss of amenity values. 	d
Marine Aquaculture	<ul style="list-style-type: none"> Increase load of organic material and nutrients Water extraction Destruction of mangrove 		Area 1: 2 Area 2: 3 Area 3: 2	Area 1: 2 Area 2: 3 Area 3: 3	<ul style="list-style-type: none"> Contamination Increased sediment loads 	P
Fisheries	<ul style="list-style-type: none"> Increase load of organic material and nutrients. Harvesting 	?	Area 1: 2 Area 2: 3 Area 3: 2	Area 1: 2 Area 2: 3 Area 3: 3	<ul style="list-style-type: none"> Contamination Increase sediment loads Decreased catch 	P
Oil and gas exploitation	<ul style="list-style-type: none"> Domestic waste Perforation mud discharge Gases and oil emission 		Area 1: 2 Area 2: 1 Area 3: 2	Area 1: 3 Area 2: 1 Area 3: 3	<ul style="list-style-type: none"> Contamination Destruction of habitat Narcotization and inhibition of reproduction in microorganisms 	P
Industries	<ul style="list-style-type: none"> Increased load of heavy metals Increased sediment load Increased load of hydrocarbons Water extraction and generation of heat 	?	Area 1: 1 Area 2: 1 Area 3: 2	Area 1: 2 Area 2: 1 Area 3: 2	<ul style="list-style-type: none"> Increased contamination by heavy metals Increased sediment load Reduction of fisheries Threat to human health. Reduction of amenity value 	P

Table RA1.3. Ecuador coast: the link between coastal issues/impacts and land-based drivers.

Overview and qualitative ranking on local or catchment scale: Category: 1 = low, 10 = high

Coastal impact/ issues	Drivers	Local catchment (allowing within and between catchment comparison)	Category	Trend expectations	References/ data sources
Erosion and sedimentation	Damming (Daule Peripa)	<ul style="list-style-type: none"> • Gulf of Guayaquil: Area inundated 27,000 ha; storage volume $6 \times 10^9 \text{ m}^3$. Natural flux $860 \text{ m}^3/\text{s}$; proposed flux $100 \text{ m}^3 \text{ s}^{-1}$. 	8	Increasing	CAAM (1996)
	Deforestation	<ul style="list-style-type: none"> • Esmeraldas River • Chone River • Gulf of Guayaquil: Annual mangrove deforestation rate of 1.3% in 1995 in relation to the mangrove cover in 1969 	7 10 8	Increasing	INOCAR (1998a)
	Navigation	<ul style="list-style-type: none"> • Gulf of Guayaquil: Coastal erosion due to wastes from large ships 	7	increasing	INOCAR (1998a)
Contamination	Agriculture	<ul style="list-style-type: none"> • Gulf of Guayaquil: Increasing use of fungicides to 1994 (1196 t) 	7	Increasing	CAAM (1996)
	Mariculture	<ul style="list-style-type: none"> • Esmeraldas River • Chone River: Shrimp farms discharge of nutrients and organic matter estimated between 3.3 and $3.5 \times 10^6 \text{ m}^3/\text{day}^{-1}$ • Gulf of Guayaquil: 72,978 ha occupied by shrimp farms 	7 10 8	increasing	INOCAR (1998a); PMRC (1993b)
	Urbanization (Municipal waste)	<ul style="list-style-type: none"> • Esmeraldas River • Chone River • Gulf of Guayaquil: $30,160 \text{ t yr}^{-1}$ of BOD5 	9 9 8	increasing	PMRC (1993a)
	Industrial	<ul style="list-style-type: none"> • Esmeraldas River • Chone River • Gulf of Guayaquil 	2 4 8	increasing	PMRC (1993a)
	Petroleum activities	<ul style="list-style-type: none"> • Esmeraldas River • Chone River • Gulf of Guayaquil: 200,000 gallons oil yr^{-1} • Gulf of Guayaquil 	7 4 7	stable	CPPS (2000); PMRC (1993a)
	Minerals	<ul style="list-style-type: none"> • Gulf of Guayaquil 	7	stable	PMRC (1993a)
Decreasing fishery	Fisheries	<ul style="list-style-type: none"> • Gulf of Guayaquil: Overfishing; 460 industrial boats in 1997 	7	stable	INOCAR (1998a)

Table RA1.4. Ecuador coast: the link between coastal issues/impacts and land-based drivers.
Overview and qualitative ranking on local or sub regional or country scale: Category: 1 = low, 10 = high.

Coastal impacts/issues	Drivers	(i.e. by country or considering open versus enclosed seas)	Trend-expectation	References/ data sources
		ECUADOR		
Erosion and Sedimentation	Deforestation and impacts from El Niño	1,246 km of intense coastal erosion	increasing	CPPS (2000).
Contamination	Agriculture	Between 1994 and 1995 about 43,248 kg ha ⁻¹ of fertilizers were used per year and 1,495 t yr ⁻¹ of pesticides in coastal agriculture areas	stable	CPPS (2000)
	Aquaculture	147,427 t of shrimps produced in 1997	stable	INOCAR (1998a)
	Municipal Waste	128,400,000 m ³ yr ⁻¹ of domestic effluent: Organic load of 48,280 t yr ⁻¹	increasing	CPPS (2000)
	Industries	In 1994 total industrial effluent was 55.2x10 ⁶ m ³	increasing	CPPS (2000)
	Oil production	1,350 m ³ /year	stable	CPPS (2000)
Decreasing fishery	Fisheries	Sardine and shrimp fleets operate in the Gulf of Guayaquil and along the Manabí and Esmeraldas rivers, respectively. The combined effect is an intensive exploitation resulting in significant biomass decrease from 1988 to 1997.	increasing	

Table RA1.6. Ecuador coast: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale.

River catchment	RESPONSE catchment scale		RESPONSE Sub regional/ Country Scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Gulf of Guayaquil	Monitoring of quality of water in the estuary of the Gulf (INOCAR)	Marine-coastal Environmental Education Program (PEAMCO). Handling of Coastal Resources Program (PMRC).		Priority area for National Policy on Biodiversity Ministry of the Environment. Marine-coastal Environmental Education Program(PEAMCO).		Strategic Regional Program for the Protection of the Coastal - Marine and Freshwater associated to the activities developed in land. CPPS- Integrated Management of the Coastal Area of the Southeast Pacific.
Chone River		Marine-coastal Environmental Education Program (PEAMCO). Handling of Coastal Resources Program (PMRC)		Marine-coastal Environmental Education Program(PEAMCO).		Strategic Regional Program for the Protection of the Coastal - Marine and Freshwater, associated with the activities developed inland. CPPS - Integrated Management of the Coastal Area of the Southeast Pacific.
Rio Esmeraldas		Marine-coastal Environmental Education Program (PEAMCO). Handling of Coastal Resources Program (PMRC)		Priority region for the application of the National Strategy and Policy on Biodiversity by the Ecuador. Ministry of the Environment.. Marine-coastal Environmental Education Program(PEAMCO).		Strategic Regional Program -for the Protection of the Coastal - Marine and Freshwater associated to the activities developed in land. CPPS - Integrated Management of the Coastal Area (MIZC) of the South-east Pacific.

Note: The criteria used here only consider responses to problems in the river affecting the coastal zone.

Table RA1.7. Ecuador coast: hot spots of land-based coastal impact and gaps in understanding, and a preliminary overview of issues to be addressed in future research. (identifying the appropriate scale for the design of a new scientific effort).

River catchment	Hot spot catchment scale		Hot spot country scale		Hot spot regional scale	
	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach
Esmeraldas River	<ul style="list-style-type: none"> • Temporal and spatial variability of physico-chemical and biological properties. • Rates of erosion. • Promote biodiversity conservation. 	<ul style="list-style-type: none"> • Biogeochemical studies and of the trophic food chain • Permanent water quality monitoring program • Monitoring program of heavy metals and hydrocarbons in bivalves • Water circulation study and its interaction with ocean circulation • Sediment load analysis, soil composition, relief and precipitation • Creation of a taxonomic centre for the Gulf of Guayaquil species 		<ul style="list-style-type: none"> • Investigation and handling of the contamination in the Gulf of Guayaquil. 		
Chone River						
Gulf of Guayaquil						

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Regional Assessment Table 2: Magdalena River, Colombia, by J.D. Restrepo

Table RA.2.1. Magdalena River coastal zone, Colombia: Major coastal impacts/issues and critical thresholds in the— Overview and qualitative ranking. Impact code and relative class of importance: 1 = minimum, 10 = maximum

Coastal impact/issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Eutrophication and pollution	Magdalena River lagoon-delta complex/ Caribbean Coast of Colombia	Biological communities near the delta show signs of mortality. Declining yield trend in fish resources, with total catches from more than 63700 tons yr ⁻¹ in 1978 to 7850 tons yr ⁻¹ in 1998.	No distance – system functions already affected by excess nutrient supply; (Drainage basin management - regulation of discharges and effluents - needed)	9	INVEMAR (1997); Beltran <i>et al.</i> (2000); INVEMAR (2000)
Water discharge and sediment load diversion	Channelization of the lower Magdalena River and partial diversion of the river flow	Observed coral reef mortality (El Rosario Island-Caribbean Coast of Colombia)	Currently no distance but potential for mitigation; (diversion of river discharge will allow recovery of coral reef ecosystems)	10	Vermette (1985); Restrepo and Kjerfve (2000a)
Hyper-salinization of mangrove soils	Magdalena River/ lagoon-delta complex/ Ciénaga Grande de Santa Marta	Mortality of mangrove forest over 39-year period (272 km ²)	Distance down to zero but slightly growing; re-diversion of fresh water into the lagoon-delta complex has allowed partial recovery of mangrove	8	Cardona and Botero (1998)
Erosion (Coastal Sediment Budget)	Magdalena River delta	Observed coastal erosion of 17 m yr ⁻¹ due to the construction of jetties in the Magdalena mouth.	Apparently no distance to the critical need of sediment accretion for coastal stability	8	Correa (1996); Martínez (1993)

Table RA.2.2. Magdalena River, Colombia: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes having impact on the coastal zone versus catchment size class.

State change dimension: major; medium; minor; no impact;? = insufficient information
Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
		MAGDALENA CATCHMENT (medium size catchment)		
Agriculture	<ul style="list-style-type: none"> • Soil conservation. • Poor agricultural practices. 	medium	Lost of coastal ecosystems due to accelerating upland erosion rates and eutrophication.	p
De-forestation	Suspended sediment loads are now an order of magnitude greater than 60 years ago.	major	Increased suspended sediment loads on coastal ecosystems – water quality/turbidity.	p
Navigation and Diversion	• Channel construction and dredging in the lower Magdalena River.	major	• Discharge of suspended sediment load into coastal ecosystems.	p
	• Jetty construction in the Magdalena delta mouth.	?	• Imbalance in the coastal sediment budget.	p
Urbanization (point-source effluents)	<ul style="list-style-type: none"> • Toxic contaminants (chlorinated and phosphorylated organic compounds). • Higher levels of nutrients. • Inputs of untreated waters. • Active elements, metals, and pesticides are known to have increased several-fold since the 1970s. 	medium to major	Contamination and eutrophication; Fish, invertebrate and avian bio-diversity and biomass are much lower than 10 years ago.	p

Table RA.2.3. Magdalena River, Colombia: the link between coastal issues/impacts and land based drivers.

Overview and qualitative ranking on local or catchment scale: ↑ increasing, = stable

Coastal impacts/issues	Driver	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ Datasources
		River	Category (1 low – 10 high)		
Eutrophication and pollution	Agriculture	Magdalena River	8	↑↑	Colciencias-Fen (1989)
	Deforestation	Magdalena River	10	↑↑	Colciencias-Fen (1989)
	Urbanization (Point Source Effluents)	Magdalena River	10	↑↑	HIMAT-INGEOMINA (1991); Cardona and Botero (1998)
Water discharge and sediment load diversion	Diversión	Magdalena River	10	=	Vernette (1985); Restrepo and Kjerfve (2000a)
Erosion (coastal sediment budget)	Navigation	Magdalena River delta	8	↑↑	Correa (1991); Martínez (1993)
Hyper-salinization of mangrove soils	Diversión	Magdalena lagoon-delta complex	9	=	Cardona and Botero (1998)

Table RA.2.6. Magdalena River, Colombia: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale.

n.a. = not applicable

River catchment	RESPONSE catchment scale		RESPONSE Sub regional/ Country Scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Magdalena River	Water discharge data (1940-2000). Sediment load data (1972-2000) Source: IDEAM (Colombia) Heavy metals 1980-1990 Source: HIMAT-INGEOM 1999; Bustos (1999).	Quality criteria for waste water in the tributary basins. Source: Ministry of the environment, Colombia.	In general: Monitoring programs through hydrological and geological institutes. Source: IDEAM HIMAT-INGEOMIN		n.a.	n.a

Table RA.2.7. Magdalena River, Colombia: hot spots of land based coastal impact and gaps in understanding as well as a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort)
n.a. = not applicable

River catchment	Hot spot - catchment scale		Hot spot regional/ country scale		Hot spot regional scale	
	Key issue, trend and gaps	Scientific approach	Sub-regional/ country scale	Scientific approach	n.a.	n.a.
<u>Magdalena River and tributaries</u>	Temporal variability of physical water properties (nutrients and pollutants)	Statistical analysis of time series	Key issue, Trend and gaps <i>Magdalena Delta</i> Fluvial fluxes into the Caribbean Sea	Scientific approach <i>Magdalena Delta</i> Analysis of fluvial fluxes to the Caribbean Sea and their interannual variability		
	ENSO-related variability	Relationships between time series variability and the ENSO cycle				
	Geology and landforms	Collection, synthesis and analysis of the information	Coastal dynamics analysis and recent delta front evolution	Temporal analysis		
	Mechanical erosion rates	Analysis of physical properties in the basin (precipitation, soil composition, relief, tectonics, water and sediment discharges)	Temporal variability of physical water properties in the river mouth (nutrients and pollutants)	Statistical analysis of time series.		
	Land-use and land use change in the catchment	Available GIS data bases and satellite image processing	State of the coastal ecosystems adjacent to the Magdalena River mouth and its channel, El Dique			
	Population trend in the basins and socio economic developments	Demographic analysis on population data from the drainage basin for the past five decades (needs inclusion of human development indicators)				

Regional Assessment Table 1.3. North-eastern Brazil tectonically passive coast, by R. V. Marins, G.S.S. Freire, L.P. Maia and L.D. Lacerda

Table RA3.1. North-eastern Brazil coastal zone: major coastal impacts/issues and critical thresholds.
Overview and qualitative ranking. Impact code and relative class of importance: 1 = minimum, 10 = maximum

Coastal impact/issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Erosion (coastal geomorphology)	Jaguaribe River estuary at Fortins	For coastal stability a sustained delivery of 0.5-2.0x10 ⁶ t yr ⁻¹ of sediments is necessary	Present sediment delivery is from 10-50% of the critical load. Strong seasonal variation occurs.	10	Maia (1992); Valentini (1996); Morais and Pinheiro (1999)
Sediment depletion/sorting	Jaguaribe River delta flood plains, mangroves and mud flats; Pacoti River estuary	Supply of about 1mm.yr ⁻¹ of fine sediments to keep mangrove and mud-flat communities	Not known, needs measurements of sedimentation rates of local mangroves. However, erosion and siltation can be seen in many mangrove areas.	7	Patchineelan & Smoak (1999); Ellison (1994)
Nutrient depletion	Estuary and adjacent coastal zone of the Jaguaribe River mouth	Chlorophyll <i>a</i> concentrations ranges from 0.05 to 0.5 mg.m ⁻³ . Primary production of about 0.02 to 0.2 gC.m ⁻² d ⁻¹ , characterises a typical oligotrophic water mass. NO ₃ and PO ₄ concentrations at the surface are about 0.2 and 0.25 µM.	Regional oligotrophy may increase, but no site-specific historical trend study is available for the area.	7	Ekau and Knoppers (1999); Medeiros <i>et al.</i> (1999)
Altering food webs and trophic status	Estuaries of metropolitan rivers of Fortaleza, Cocó River and Ceará River	Existing ecological communities, presently very poorly known	Totally unknown but algal blooms occur typically during the rainy season.	6	Soares Filho and Alves (1996)
Increasing marine sand supply	Jaguaribe and Pacoti river estuaries	Benthic and mangrove community siltation. Critical threshold >100 t.yr ⁻¹	Unknown, indication of occurrence due to dying mangroves.	6	Freire (1989)
Eutrophication	Cocó and Ceará rivers and adjacent beaches	Pristine rivers in the region have dissolved oxygen levels of about 5.0 mg.l ⁻¹ , NO ₃ is in general <1 µg.l ⁻¹ , whereas dissolved organic nitrogen (DON) is <0.6 µg.l ⁻¹	Estuaries of affected rivers present dissolved oxygen ranging from 2.5 to 4.9 mg.l ⁻¹ . NO ₃ and DON concentrations may reach 60-80 µg.l ⁻¹ and 6 to 15 µg.l ⁻¹ .	6	Marins <i>et al.</i> (2001); Mavignier (1992); Almeida <i>et al.</i> (2000)

Table RA3.2. NE Brazil: DPSIR matrix characterizing major catchment-based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.

State change dimension: major; medium; minor; no impact; ? = insufficient information
Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index) Small size basins	State change (qualitative index) Medium size basins	Impact on the coastal system	Time scale
Damming	Sediment trapping Altering nutrient balance* Altering water balance Decrease of flow transport capacity	major	(major)	<ul style="list-style-type: none"> • Sediment depletion/sorting • Depletion of nutrients* • Stable water flux • Erosion • Increasing marine sand supply 	p
Agriculture	Decrease of water volume and flow transport capacity due to water withdraw for irrigation Facilitating soil erosion Pollutant emission Altering nutrient fluxes	medium	(medium)	<ul style="list-style-type: none"> • Sediment depletion • Enrichment of nutrients* • Stable water flux 	p
Sand mining	Sediment remobilization Sediment withdraw Altering river morphology (banks and bottom)	medium	(medium)	<ul style="list-style-type: none"> • Sediment depletion • Sediment sorting • Altering flow patterns • Altering ecological conditions 	p
Aquaculture	Changes in hydrochemistry Increasing nutrient load	medium	(minor)	<ul style="list-style-type: none"> • Altering food webs and trophic status 	d/p
Urbanization	Pollutant emission Altering nutrient fluxes	major	(no impact)	<ul style="list-style-type: none"> • Altering food webs and trophic status 	p
Deforestation	Facilitating soil erosion Altering sediment balance	medium	(minor)		p

* During the filling phase of reservoirs, flooding of marginal areas results in discrete (short-term, months to a few years) increase in nutrients (Rebouças *et al.* 1999)

Table RA3.3. NE Brazil: the link between coastal issues/impacts and land-based drivers.

Overview and qualitative ranking on local or catchment scale: ↑ - increasing, = stable

Coastal impact/ issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
		River	Category (1 low – 10 high)		
Erosion	Damming	Jaguaribe	10	↑	Morais and Pinheiro (1999); Maia (1992)
Sediment depletion and sorting	Damming	Jaguaribe	6	↑	Morais and Pinheiro (1999); Maia (1992)
	Sand mining	Jaguaribe Pacoti	4	⇒	Freire (1989)
Nutrient depletion	Damming	Jaguaribe	9	↑	Medeiros <i>et al.</i> (1999)
Altering food webs and trophic status	Damming	Jaguaribe	2	↑	Soares Filho and Alves (1996)
Eutrophication	Agriculture	Jaguaribe Acarau	3	↑	Marins <i>et al.</i> (2001)
	Urbanisation	Ceará Cocó	8 10	↑ ↑	Mavignier (1992); Ameida <i>et al.</i> (1999)
	Aquaculture	Jaguaribe			
	Industrialisation	Ceará	3	↑	Marins <i>et al.</i> (2001)
Sedimentation due to increasing marine sand supply	Agriculture	Jaguaribe Pacoti	6 3	↑ ⇒	Morais and Pinheiro (1999); Freire (1989)
	Damming	Jaguaribe	8	↑	Morais and Pinheiro (1999)

Table RA3.6. NE Brazil: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale.

River catchment	Response Catchment scale		Response Sub regional/ Country scale		Response Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Jaguaribe River	11 pluviometric stations along the basin with 80 years of monitoring plus 13 river discharge stations with 25 years of monitoring (ANEEL 2000). Monitoring of sediment flux, nutrients and marine born sediments (Marins <i>et al.</i> 2001) Water balance model developed but needs testing for robustness (SRH 1998). Survey of soil, geology and ground water resources (CPRM 1996).	ICZM at national (Brazil) level. Local catchment under-management plan associated with dam development, water diversion and agriculture. PRODETUR program.	Survey of major drivers and impacts at the coastal zone (MMA 1996a,b). Brazil- German Joint Oceanographic Programs on coastal productivity, trophic status, fisheries and sedimentology. REVIZEE Northeast Program. Survey of Economic Resources of the Exclusive Zone (Freire and Hazin (2000).	ICZM plan in function. PRODETUR-CE Tourism development program PROURB-CE Urban development plan.	n.a.	n.a.
Cocó River	Monitoring of water quality including trace metals and Hg (Almeida <i>et al.</i> (2000)).	Creation of an Ecological Park preserving the mangroves, by Fortaleza Municipality. Monitoring of water flow and quality by SEMACE. PROURB-CE Program.				
Ceará River	Monitoring of water quality including trace metals and Hg (Marins <i>et al.</i> 2001).	Maranguapinho Ecological Corridor, a joint preservation and reforestation program by the four municipalities of the basin. PROURB-CE Program.				
Pacoti River	Monitoring of water quality including trace metals and Hg (Lacerda <i>et al.</i> 2001). Monitoring of sediment flux, nutrients and marine born sediments (Freire (1989)).	Creation of an Environmental Protection Area, including the mangrove forests of the river PROURB-CE Program.				

Regional Assessment Table 4: South-eastern Brazilian coast (Rio de Janeiro) by E.D. Bidone

Table RA4.1. South-eastern Brazilian coast (Rio de Janeiro): major coastal impacts/issues and critical thresholds in Latin American Coastal Zones.
Overview and qualitative ranking: * Impact category: 0= none; 10 = maximum

Coastal impact/issue	Local site/region (contributing river basins)	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Eutrophication	Rivers of small watersheds (with slopes changing drastically within few kilometers from high relief – 1,000m to 1,500m – to coastal plains) along the south-eastern and southern Brazilian coast, draining into bays and lagoons	Occurrence of anoxia or low oxygen in the rivers in lowlands of watersheds, estuary zones, lagoons and bays. Nutrient concentration levels (in mg l ⁻¹ from n=197 samples) in rivers at the threshold: N-NO ₃ = 0.42 (0.11-0.76); N-NH ₄ = 2.52 (1.49-4.0); P-PO ₄ = 0.78 (0.34-1.30)	The nutrient concentration levels are at or higher than threshold	10	Bidone <i>et al.</i> (1999); Knoppers <i>et al.</i> (1999); Bidone (2000)
Erosion	Paraiíba do Sul River delta	Not known	Suspended load of less than 60,000 t yr ⁻¹	8	Salomão <i>et al.</i> (2001)
Contamination (nutrients N-P-C, microbiological, HPA's, heavy metals etc.)	Rio de Janeiro metropolitan area	<ul style="list-style-type: none"> Nutrients Microbiological: <500 colis NMP 100 ml⁻¹ Heavy metals. HPA's and others toxic contaminants: WHO, USEPA etc. standards. 	<ul style="list-style-type: none"> The nutrient concentration levels are at or higher than threshold Microbiological: at the or higher than threshold Toxics: at or higher than threshold 	10	Bidone <i>et al.</i> (1999); Knoppers <i>et al.</i> (1999)
Sedimentation (in lowland sectors of the watersheds and estuarine zones, lagoons and bays. Overall in urban areas)	Rio de Janeiro metropolitan area	<ul style="list-style-type: none"> Large rainfall or storms (~ 80mm or more). Suspended solids concentrations <100 mg l⁻¹. Sedimentation rate in lagoons ~0.1 cm yr⁻¹. 	<p>Potential events occurring in summer/rainy season (December-March). Catastrophic effects on slopes/ upper sectors of the watersheds in urban areas) (emphasis Rio de Janeiro city). In the rainy season concentration levels of SS can be higher than 1000 mg l⁻¹.</p>	9	Knoppers <i>et al.</i> (1999); Esteves and Lacerda (2000)

Table RA4.2. SE Brazil: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.

State change dimension: 3 = major; 2 = medium; 1 = minor; 0 = no impact; ? = insufficient information

Time scale: p = progressive; d = discrete

Driver	Pressures	State change (qualitative index)				Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins active coast	Small basins Passive coast		
Urbanization	Domestic waste		2		3	<ul style="list-style-type: none"> Eutrophication Contamination 	p
Industrialization	Industrial waste		3		3	<ul style="list-style-type: none"> Contamination 	p
Deforestation	Sediment budget alteration Soil exposition		3		3	<ul style="list-style-type: none"> Sedimentation/ sediment accretion Catastrophic slope erosion in urban areas 	p/d

Table RA4.3. SE Brazil: the link between coastal issues/impacts and land based drivers in Latin American coastal zones.
Overview and qualitative ranking on local or catchment scale:

Coastal impact/issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
		Rio de Janeiro metropolitan area	Category		
Eutrophication	Urbanization (diffuse source of domestic effluents)	Nutrient concentration levels in rivers and anoxia. at the or higher than threshold	10	Increasing	Bidone <i>et al.</i> (1999); Bidone (2000); Knoppers <i>et al.</i> (1999)
Contamination	Urbanization (domestic effluents) and industrialization (industrial effluents)	N-P-C, microbiological, HPA's. heavy metals etc.)	10	Increasing	Bidone <i>et al.</i> (1999); Bidone (2000); Knoppers <i>et al.</i> (1999)
Erosion	Deforestation	Catastrophic effects on slopes/upper sectors of the watersheds in urban areas in rainy station Sedimentation./Sediment accretion in bays. coastal lagoons and estuary zones	10	Increasing	Bidone <i>et al.</i> (1999), Bidone (2000), Knoppers <i>et al.</i> (1999)
			10	Increasing	

Regional Assessment Table 5: Patos Lagoon basin and estuary (southern Brazil), by U. Seeliger

Table RA5.1. Patos Lagoon and estuary: major coastal impacts/issues and critical thresholds; overview and qualitative ranking.
Impact code and relative class of importance: 1 = minimum, 10 = maximum

Coastal impact/issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Eutrophication	Patos Lagoon estuary	a. Chlorophyll <i>a</i> b. Sediment and water column contamination by phosphorus in enclosed bays c. Point source ammonium contamination of water column by domestic/industrial waste	a. 0.6 – 76.8 µg Chl- <i>a</i> l ⁻¹ b. 0.73–8.55 mg kg ⁻¹ P-Total; up to 12 µM P-PO ₄ in the water column c. Up to 45 µM N-NH ₄ in the water column	7	b. Baisch 1997; Baumgarten <i>et al.</i> 1995 c. Almeida <i>et al.</i> 1993
Pollution	Patos Lagoon estuary	a. Point source Pb and Cd contamination of water column by harbor activities. a. Point source phenol contamination of water column by harbor activities. a. Nonpoint source pollution of water column by oil.	a. Pb up to 20 µg l ⁻¹ ; Cd up to 6.5 µg l ⁻¹ b. Phenol up to 30 µg l ⁻¹ c. Oil up to 30mg l ⁻¹	5	a/b/c. Niencheski and Baumgarten 1997
Sedimentation	Patos Lagoon estuary	a. Natural sediment removal to coastal nearshore waters.	a. Annual sediment removal of about 2,500,000 m ³	3	a. Calliari 1980
Dredging	Patos Lagoon estuary	a. Dredge material disposal in nearshore waters.	a. Over 60 dredgings between 1980-95; means per location in the estuary ranged 1,200 to 1,800,000 m ³ .	5	SUPRG 1996
Marsh losses	Patos Lagoon estuary	a. Filling of intertidal and shallow waters for urban development.	a. 10% losses of the total salt marsh area of lower estuary.	5	Seeliger and Costa 1997
Water use	Patos Lagoon watershed	a. Increment in water demand for domestic and industrial use over the last 35 years. b. Increment in water demand for irrigated rice cultivation over the last 35 years.	a. Increase of 0.46– 0.76 km ³ yr ⁻¹ b. Increase of 3.89 to 9.31 km ³ yr ⁻¹	7	Seeliger and Costa 1997
Pesticides	Patos-Mirim complex watershed	a. Excessive application of pesticides over vast areas of agricultural lands (e.g. 890,000 ha of rice plantations).	a. Not quantified	5	Seeliger and Costa 1997

Table RA5.1 continued

Toxic algae	Patos Lagoon and coastal nearshore	<p>a. Blooms of <i>Gyrodinium aureolum</i>, <i>Dinophysis acuminata</i> and recent introduction of <i>Alexandrium tamarense</i> in the coastal nearshore.</p> <p>b. Blooms of <i>Mycrocystis aeruginosa</i> in limnic waters and in the estuary.</p>	<p>a. <i>Gyrodinium aureolum</i> = up to 200 cells l⁻¹; <i>Alexandrium tamarense</i> = up to 10⁶ cells l⁻¹, 180 cysts cm⁻³ of sediment.</p> <p>b. Up to 9,000 µg Chl-a l⁻¹; microcystin concentration up to 1.1 µg mg⁻¹ dry weight.</p>	5	<p>a. Odebrecht <i>et al.</i> 1995; Persich 2001</p> <p>b. Odebrecht <i>et al.</i> 1987; Yunes <i>et al.</i> 1996.</p>
Biodiversity loss and community changes	Patos Lagoon and coastal nearshore	<p>a. Changes in zooplankton community structure; anatomical anomalies in some species.</p> <p>b. Overexploited <i>Neuma</i> spp. stocks.</p> <p>c. Decline of up to 90% in abundance of viviparous sharks (<i>Rhinobatos horkelii</i>; <i>Galeorhinus galeus</i>).</p>		5	<p>a. Montu and Gloeden 1982</p> <p>b. Haimovici <i>et al.</i> 1997</p>
Circulation changes	Patos Lagoon and coastal nearshore	<p>a. Changes in plankton community structure.</p> <p>b. Variability in shrimp production.</p> <p>c. Salt water balance.</p>		?	<p>a. Muelbert & Weiss 1991; Sinque and Muelbert, 1997.</p> <p>b. Castelo & Möller 1978.</p> <p>c. Costa <i>et al.</i>, 1988; Fernandes and Niencheski 1998</p>

Table RA5.2. Patos Lagoon and estuary: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.

State change dimension: 3 = major; 2 = medium; 1 = minor; 0 = no impact; ? = insufficient information. Time scale: p = progressive, d = discrete

Driver	Pressures	State change (qualitative index)			Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins: active coast	Small basins Passive coast	
Navigation	<ul style="list-style-type: none"> Dredging Increase in runoff Increase in sediment transport Waste effluent Introduction of exotic species 	?	1		2	<ul style="list-style-type: none"> Sedimentation Pollution Changes in communities <p>p</p>
	<ul style="list-style-type: none"> Increase in water and sediment P e N levels Increase in sediment heavy metal levels 	1	2		3	<ul style="list-style-type: none"> Eutrophication Pollution Changes in communities <p>p</p>
Agriculture	<ul style="list-style-type: none"> Freshwater diversion Increase in agrotoxins Increase in sediment transport Land fill and canalization 	1	2		2	<ul style="list-style-type: none"> Salinization Pollution Sedimentation Marshland losses Shallow waters filling <p>p</p>
	<ul style="list-style-type: none"> Harvesting 	0/1	1		3	<ul style="list-style-type: none"> Losses in biodiversity Estuarine habitat destruction Death of marine mammals <p>p</p>
ENSO	<ul style="list-style-type: none"> El Niño (increase in rainfall, freshwater input, and suspended matter to the estuary) El Niño (increase in nearshore phytoplankton production; estuarine fish community changes) La Niña (decrease in rainfall, freshwater input and suspended matter to the estuary; salinization) 	3	3		3	<ul style="list-style-type: none"> Eutrophication Salinization Communities changes Changes in productivity Decrease in pink shrimp recruitment into the estuary (El Niño) Recruitment variability of fishery resources (ENSO) <p>d</p>

Table RA5.6. Patos Lagoon and estuary: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale.

River catchment	RESPONSE catchment scale		RESPONSE Sub regional/ country scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Patos Lagoon estuary	(1) Over 500 scientific papers published on structural/functional aspects of Patos Lagoon estuary and adjacent coast. (2) Monitoring of physico-chemical parameters. (3) Establishment of Brazilian LTER site.	(1) Regulation of estuarine fisheries. (2) Regulation of water use in estuary of the Rio Grande. (3) Estuary Management Program supported by Interamerican Bank for Development.				

Table RA5.7. Patos Lagoon and estuary: Hot spots of land based coastal impact and gaps in understanding, and a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

River catchment	Hot spot Catchment scale		Hot spot regional/ country scale		Hot spot regional scale	
	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach
River						
Patos Lagoon estuary and nearshore zone	Changes in biodiversity and occurrence of harmful algae	Animal and plant community monitoring; Experimental evaluation of sensitivity of organisms				
Patos Lagoon estuary	ENSO-induced changes of hydrology	Biological and physical studies based on long-term ecological researches				
Patos Lagoon estuary and nearshore	Impact of UV radiation increases	Experimental evaluation of organisms sensitivity; UV radiation monitoring and public awareness				
Patos Lagoon estuary	Habitat degradation of shallow waters and marshes	Remote sensing; monitoring				

Regional Assessment Table 6: Rio de La Plata, by J. Cantera

Table RA6.1: Major coastal impacts/issues and critical thresholds in Rio de la Plata area.

Overview and qualitative ranking.

Impact code and relative class of importance: 1 = minimum, 10 = maximum

Coastal impact/issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Erosion	Uruguayan coast	Dune destruction Loss of beaches	Unknown	6	ECOPLATA (1999)
Eutrophication (habitat loss)	Uruguay River Montevideo Bay Samboronbon Bay Buenos Aires coast Paraná River	Frequent algal blooms Wetlands destroyed Low oxygen in estuaries and lagoons Nitrogen concentration very high Fish mortality near beaches	Increased nutrient load is changing the ecosystem. Fresh water inflow is increasing in last years	9	Kurucz <i>et al.</i> (1997)
Coastal pollution	Parana River Uruguay River Montevideo Bay Tributaries of the Uruguayan and Buenos Aires coast (Riachuelo, Santa Lucia, Carrasco, Reconquista rivers)	Urban and agricultural wastes inputs uncontrolled and sewage discharges without treatments	Pollutants reaching threshold values. Heavy metals (mg kg ⁻¹). Cr = 0.75-57; Pb = 0.7-141; Cd = 4-231; Cu = 109 Pesticides 10-250 ng l ⁻¹ (DDT) High heavy metal levels in biota (g kg ⁻¹): Hg = 11-254; Pb = 34; Cd = 0.5-3.7; Hydrocarbons = 0.1-50. Some pollutants in fishes.	10	Moyano <i>et al.</i> (1992, 1993); AGOSBA-OSN-SIHIN (1994) Moyano (1991); CARU (1993); ECOPLATA (1999) Marcovecchio and Moreno (1992, 1993) Segneur <i>et al.</i> (1991)
Biodiversity changes	Location not specified	Species lost. High mammal and fish mortality.	Unknown	8	
Fisheries decreasing	Maritime Front Inner part of Rio de la Plata	Stocks over-exploited. High pollution or marine transport in spawning and nursery areas.	Very near; fisheries decrease drastic during recent years.	8	Graña and Pineiro (1997); Acuña <i>et al.</i> (1997); INAPE reports; INIDEP reports
Algal blooms	Montevideo area Maritime Front	Several times a year there are cyanobacteria and dinoflagellate blooms.			Mendez <i>et al.</i> (1993, 1994, 1996)

Table RA6.1 continued

Increase in introduction of exotic species	Location not specified	<i>Vibrio cholerae</i> Bivalves Other poorly-known groups		6	GEF project text
High sedimentation	Parana River Uruguay River Turbidity-saline front	79x10 ⁶ t yr ⁻¹ 11x10 ⁶ t yr ⁻¹ Maximum sedimentation zone. Sedimentation affects navigation channels necessitating dredging.		10	Lopez (1997)
Changes in land and aquatic uses	Location not specified	Wetlands destroyed to exploit areas for agriculture.		7	GEF project text

Table RA6.2 Rio de la Plata: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting on the coastal zone *versus* catchment size class.

State change dimensions: major; medium; minor; no impact; ? = insufficient information
Time scale: p = progressive; d = discrete

Driver	Pressures	State change (qualitative index)				Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins active coast	Small basins passive coast		
Agriculture	Waste/nutrient (excess fertilizer) effluent	medium	medium		major	Eutrophication; Contamination;	p
	Increasing sediment transport	major	major		major	Siltation	p
	Water extraction	minor	minor		medium	Algae blooms	p
	Excess of biocides	minor	minor		minor	Anoxia	p
Damming	Nutrient and sediment sequestration Changing hydrological cycle	?	?			Decreasing light for photosynthesis Decreasing ecological flow	p
					medium	Contamination	d
Deforestation	Sediment budget alteration	minor	major		major	Coastal erosion; Nutrient depletion; Decreasing ecological flow	p
	Organic matter inputs	minor	medium		major	Siltation; Sediment accretion Decreasing oxygen concentration	d
Navigation	Waste effluent	medium	major		No impact	Contamination; siltation	d
	Dredging Channels	major	major		No impact	Re-suspension of sediments Interfering life cycles of fishes	d
Urbanization (point source effluents)	Domestic pollution	medium	major		major	Decreasing of oxygen concentration; Colliform contamination	p
	Industrial pollution	major	major		major	Heavy metals, hydrocarbon pollution	d/p
Fisheries	Over-exploitation	major	medium	minor	minor	Decreasing biodiversity and stocks	d
							p

Table RA6.3. Rio de la Plata basin: the link between coastal issues/impacts and land based drivers.

Impact category: 1 = low; 10 = high

Coastal impact/issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
			Category		
Erosion	Damming	80% runoff reduction	9	Stable	
	Deforestation	TSS concentration	9	Increasing	
	Diversión	?....	6		
Eutrophication	Agriculture	Residual nutrient reduction	9	Increasing	
	Municipal waste	Local urbanisation areas increasing	10	Increasing	
Water pollution	Municipal and industrial waste	Industrial areas established in the river border	10	Increasing	

Table RA6.6. Río de la Plata basin: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale.

n.a. = not applicable

River catchment	Response catchment scale		Response Sub regional/ Country scale		Response Regional scale	
	Scientific	Management	Scientific	Management	n.a.	n.a
Río Uruguay	CARU Studies 1997,1998 Data Source: INAPE, INIDEP, SOHMA	Administrative Commission of the Uruguay River (CARU) Programa de calidad de aguas en el Río Uruguay SOHMA, DINAMA, IMM	CARU studies 1997,1998. Source: INAPE, INIDEP, OHMA		n.a.	n.a
Río Parana	Environmental stress of Parana River. Flood plain interactions in the Parana River.	?	Medición de caudales Ríos Parana y Uruguay			
Río de la Plata	ECOPLATA Project Gestión Integrada de la zona costera Uruguaya del Río de la Plata	DINAMA, IMM INAPE University de la República	GEF: Environmental Protection of Río de la Plata Program. Transboundary Diagnostic Analysis. Monitoring GOOS. Mareographic Web. Algal blooms. Monitoring of <i>Vibrio cholerae</i> Meso-scale atmospheric modelling.	Plan de Investigación Pesquera Strategic Action Plan of Administrative Commission of the Río de la Plata and Technical Commission of the Maritime Front 2000-2004		
Uruguayan coast and small streams	ECOPLATA Project	IMM MVOTMA		ECOPLATA Project Gestión Integrada de la zona costera Uruguaya del Río de la Plata		
Argentinian coast and small streams	Monitoring of Sanboronbon Bay	Environmental management of the Cuencas of Matanza and Riachuelo.	National Environmental System	Atlas of areas of coastal zone sensitivity in Argentina		

Table RA6.7. Rio de la Plata basin: hot spots of land-based coastal impact and gaps in understanding, and a preliminary overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).

River catchment	Hot spot Catchment scale		Hot spot Sub regional/ country scale		Hot spot Regional scale	
	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach	Key issue, trend and gaps	Scientific approach
Rio de la Plata			Water circulation	Model applications <i>In-situ</i> measurements Remote sensing		
			Water pollution Sediment pollution Pollution from hazardous substances	Pollution in Uruguayan Coast Pollution in Argentinean coast Campaigns to study common zone		
			River and marine biodiversity Exotic species Red tides	Binational strategy for aquatic and marine biodiversity		
			Population biology of fisheries resources	Biology studies of main commercial species		
			Pollutants accumulation in trophic chain	Studies of pollutants in high levels of trophic chain		
			Social situation	Social diagnostics		
			Legal situation	Study of existent legal instruments		
			Economic situation	Study of existing economic instruments		

Regional Assessment Table 7: Argentine (tectonically passive) coast by P.J. Depetris

Table RA7.1 Argentine coast: major coastal impacts/issues and critical thresholds, overview and qualitative ranking.

Impact code and relative class of importance: 1 = minimum, 10 = maximum.

Coastal impact/ issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ data source
Erosion (coastal geomorphology)	SW of Buenos Aires Province, Mar del Plata, Patagonian coastline	Unknown. Presently, there is a significant retreat of the coastline and strong evidence of erosion.	Current sediment delivery is probably 70-80% of the critical load.	7	Cionchi <i>et al.</i> (1993); López and Marcomini (1998); Violante <i>et al.</i> (2001); Isla (1997)
Sediment depletion/sorting	Northern Patagonian rivers (Colorado, Negro, and Neuquén)	Several dams affect each basin, retaining sediment and nutrients. Critical bedload is possibly ca. 10^5 t yr ⁻¹ .	Still undetermined. Probably the net effect of damming is a reduction of 20-40% of sediment supply.	6	Depetris <i>et al.</i> (in prep); Isla and Bujalevsky (1995); Pasquini <i>et al.</i> (1997)
Nutrient depletion or eutrophication	Estuaries of northern Patagonia rivers (Colorado, Negro, and Neuquén)	Current total POC flux is ca. 4.1×10^4 t yr ⁻¹ ; total PN flux is ca. 1.1×10^4 t yr ⁻¹ ; total PS flux is ca. 2.0×10^4 t yr ⁻¹ .	Historical evolution unknown. Nutrients are depleted in reservoirs.	5	Depetris <i>et al.</i> (in prep); Gaiero <i>et al.</i> (1999)
Eutrophication and/or pollution	Small rivers in the Buenos Aires Province coastal zone	Unknown. Critical threshold is still beyond reach but human impact is discernible.	Unknown. Processes are basically not chronic although they are critical in several areas along the coastline.	4 - 5	Bilos <i>et al.</i> (1998); Manassero <i>et al.</i> (2000); Ronco <i>et al.</i> (1995); Manassero <i>et al.</i> (1998).
Pollution	Northern Patagonian rivers (Colorado, Negro, and Neuquén). Austral Patagonia	Unknown. Critical threshold is still beyond reach but human impact is discernible.	Unknown. Processes are basically not chronic although they may be acute in several areas.	4 - 5	Gaiero <i>et al.</i> (1999); Gil <i>et al.</i> (1999); Gaiero <i>et</i> <i>al.</i> (in press); Harvey and Gil (1988); Amin <i>et</i> <i>al.</i> (1996).

Table RA7.2. Argentine coast: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone *versus* catchment size class.
n.p. = not present, 1 = minor, 2 = medium, 3 = major, p = progressive, d = discrete

Driver	Pressures	State change (qualitative index)	State change (qualitative index)	Impact on the coastal system	Time scale
Damming	Sediment trapping Altering nutrient balance Altering water balance Decrease of flow transport capacity	Small size basins n.p.	Medium size basins (3)	Sediment depletion/sorting Depletion of nutrients Stable water flux Erosion Increasing marine sand supply	p
Agriculture	Decrease of water volume and flow transport capacity due to water withdrawal for irrigation Facilitating soil erosion Pollutant emission Altering nutrient fluxes	2	(2)	Sediment depletion Enrichment of nutrients Stable water flux	p
Sand mining	Sediment remobilization Sediment withdrawal Altering river morphology (banks and bottom)	1	(2)	Sediment depletion Sediment sorting Altering flow patterns Altering ecological conditions	p
Aquaculture	Changes in hydrochemistry Increasing nutrient load	n.p.	n.p.	Altering food webs and trophic status	d/p
Urbanization	Pollutant emission Altering nutrient fluxes	3	(0)	Altering food webs and trophic status	p
Deforestation	Facilitating soil erosion Altering sediment balance	2	(1)		p

Table RA7.3 Argentine coast: the link between coastal issues/impacts and land based drivers. Overview and qualitative ranking on local or catchment scale:

↑ - increasing, ⇒ stable.

Coastal impact/issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
		River	Category (1 low – 10 high)		
Erosion	Poor management practices	Buenos Aires Province coastline	8	↑	e.g., Cionchi <i>et al.</i> (1993); López and Marcomini (1998); Violante <i>et al.</i> (2001); Isla (1997)
Sediment depletion and sorting	Damming	Colorado, Negro, Chubut	5	↑	e.g., Isla and Bujalevsky (1995); Pasquín <i>et al.</i> (1997)
	Sand mining	Negro	4	⇒	e.g., Cionchi <i>et al.</i> (1993); Pasquini <i>et al.</i> (1997)
Nutrient depletion	Damming	Chubut , Colorado, Negro	8	↑	Depetris <i>et al.</i> (in prep.); Gaiero <i>et al.</i> (1999); Gaiero <i>et al.</i> (in press)
Altering food webs and trophic status	Damming	Chubut	1	↑	Depetris <i>et al.</i> (in prep.); Gaiero <i>et al.</i> (1999); Gaiero <i>et al.</i> (in press)
Eutrophication	Agriculture	Negro, Chubut	3	↑	Depetris <i>et al.</i> (in prep.); Gaiero <i>et al.</i> (1999); Gaiero <i>et al.</i> (in press)
	Urbanisation	Chubut	7	↑	Depetris <i>et al.</i> (in prep.); Gaiero <i>et al.</i> (1999); Gaiero <i>et al.</i> (in press)
	Industrialisation	Chubut	2	↑	Depetris <i>et al.</i> (in prep.); Gaiero <i>et al.</i> (1999); Gaiero <i>et al.</i> (in press)

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Appendix I Meeting Report

The South American Basins (**SAmBas**) assessment and synthesis was carried out in two phases. A first, general workshop (**SAmBas 1**) was held in Bahia Blanca, Argentina in November 1999, in association with the 4th LOICZ Open Science Meeting. A second workshop, SAmBas 2, held in Fortaleza, Brazil in May 2001 refined the assessment and focussed on the human dimension. SAmBas 2 also worked towards a sound scientific basis on which to develop project proposals addressing indicators for coastal monitoring as well as river-based and coastal management issues. The SAmBas network was expanded in this second phase involving new participants from the west coast of South America and socio-economic experts.

SAmBas 1

SAmBas I was held in Bahia Blanca, Argentina, on 11-13 November 1999, with participants staying on for the subsequent 4th LOICZ Open Science Meeting. There, international exchange with other basins-related studies was continued and a working group on basins issues in island-dominated regions was set up. This resulted in the LOICZ Caribbean Basins study, CariBas, and a desk study on the South Pacific region. The island working group recommended to investigate closer links to initiatives of UNESCO/IOC, namely the C-GOOS (Coastal module of the Global Ocean Observing System) and the ICAM (Integrated Coastal Area Management) programme. Terms of reference, participants, the agenda and important acronyms are given in the appendix to this report jointly with SAmBas 2 information.

Following the official opening of this first SAmBas workshop by Prof. Gerardo Perillo and Prof. Wim Salomons, Dr Hartwig Kremer provided the background to the global **LOICZ Basins** project, its goals and perspectives, then Wim Salomons followed with a detailed outline of the scientific approach taken in assessment and synthesis of the “human dimensions” of flux changes to the coastal sea. In order to achieve the integration needed in such a regional assessment, the group made reference to the LOICZ Integrated Modelling Guidelines (Turner *et al.* 1998, www.nioz.nl/loicz/) which stresses the applicability of the Drivers, Pressures, State, Impact, Response framework, DPSIR. This was introduced by OECD in the early 90's and subsequently developed further within LOICZ (particularly the Basins program) as a means of standardise cross disciplinary regional analysis. It ultimately allows combination of results from the natural and social sciences as well as investigation of feedback from and to policy/management.

In two working groups led by Profs. D. de Lacerda and B. Kjerfve relying mainly on existing data, the drivers–pressures–state and state change information was reviewed and compiled for countries such as Colombia, Venezuela, Brazil, Uruguay (partly) and Argentina. Key aspects addressed:

- major coastal issues in the South American coastal zone;
- material flow to the coastal zone of water, sediments, nutrients and priority substances (past, current, future trends);
- socio-economic drivers which have changed or will change these material flows; and
- indicators for impacts on coastal zone functioning from which to derive an approximation of distances of system states and fluxes from "critical thresholds" for coastal functioning.

Horizontal flux and retention models as applied in Europe (MONERIS) were presented and considered for application in the region, and case studies with similar key questions e.g., the Mississippi system. Emphasis was also directed towards the development of classifications and qualitative ranking for river catchment-coastal system classes and the degree of pressures, observed change and expected trends in systems of various catchment size. It was pointed out, however, that this aspect needed further work and would become a major objective of the second phase workshop to be conducted after 1 or 1.5 years, when this first regional assessment would be refined to enable better comparability with **LOICZ Basins** analysis elsewhere and to improve the set of potential entry information for the LOICZ typology effort.

Key outcomes and findings from the workshop:

The regional assessment conducted in Bahia Blanca provided a comprehensive overview of the current understanding of catchment–coastal sea interaction in South America. Using geomorphologic and hydrologic characteristics, the working groups provided an initial classification of the river systems into four catchment size sub-categories (large, medium, small active and small passive). Drivers, pressures, state

changes and especially potential coastal impacts were reviewed and analyzed against these sub-categories. Information was provided to the best currently available level.

The DPSIR scheme was evaluated and applied to standardize the descriptive approach and enable cross-regional comparison. Scales varied from catchment via country to sub-regional level, acknowledging that the large stream systems inherently provide a sub-regional perspective of coastal issues due to catchment size and run off and – regarding the response – the transboundary issues involved.

A first set of qualitative typological classes of drivers and changes was developed and again reviewed against the catchment size based sub-classes of river–coast systems. The information compiled in this process will be developed further to an “expert-classification” of the regional systems and their change under various forcing in a second step (SAmBas 2). Ultimately the DPSIR-based ranking is expected to form an interface to the joint LOICZ/BAHC typology, a tool continuously developed for interregional and global comparison of scenarios, visualization and upscaling. Among the features considered were:

- Coastal geomorphology
- Coastal habitats/biodiversity
- Climate influence
- People relationships (demography and drivers)
- Catchment size and seasonal runoff features
- Land use and cover characteristics

It was agreed to provide a regional synthesis in the format of a LOICZ Reports & Studies Volume, by distilling the information from an improved set of **LOICZ Basins** assessment tables. Those are to be produced based on the global set of first regional workshops by the **LOICZ Basins** principal network members. **SAmBas 1** provided an important starting point for this development.

Products from **SAmBas 1** (as approved in the closing plenary discussion):

- A multiauthor LOICZ Meeting Report providing a first regional picture, designed along the DPSIR framework and setting the stage for the refined synthesis and proposal development in a second workshop. The refined regional assessment is to become an entry into the first global LOICZ synthesis book at end 2002;
- A first indication of information needs and gaps in understanding, such as descriptions of systems along the west coast and, more generally, the socio-economic dimensions as well as a list of sites with negative trend expectations - “hot spots”. This information, together with suggestions on templates for future project design will form the basis of the terms of reference for the second regional assessment workshop. (Combination and potential for a final link to similar activities in the Caribbean under the LOICZ frame – CariBas – were considered)

The workshop was hosted by the Instituto Argentino de Oceanografía in Bahía Blanca, Argentina. LOICZ is grateful for this support and indebted to Dr Gerardo Perillo and Institute staff, and to the resource scientists for their contributions to the success of the workshop. LOICZ gratefully acknowledges the efforts and work of the participants not only for their significant contributions to the **SAmBas** goals, but also for their continued interaction beyond the meeting activities.

SAmBas 2

An introduction to the Land Ocean Interactions in the Coastal Zone, LOICZ, core project of the International Geosphere Biosphere Project, IGBP, given by Dr Hartwig Kremer provided the background of the second global **LOICZ Basins** assessment of catchment/coastal sea interaction and human dimension studies in South America. Developments made in the methodology since **SAmBas 1** in 1999 were presented, in particular the standardised regional assessment tables developed for global application in the **LOICZ Basins** core project. The strong focus on driver/pressure and response aspects characterising the evaluation of changes reflected the increasing recognition of community issues in the LOICZ work.

Major thrust for the **LOICZ Basins** project came from the recommendations and commitment of participants of the 4th LOICZ OSM.

Profs Drude Lacerda and Bjoern Kjerfve summarised the key findings of the first meeting (see above and Meeting Report No. 37 – LOICZ 2001) and the IOC representative Julian Barbière outlined the relevance of the **LOICZ Basins** approach and findings for the global efforts of UNESCO/ IOC in their Integrated Coastal Area Management, ICAM and C-GOOS initiatives. The results generated on regional levels and in particular the pilot studies to be addressed in future research under the aegis of a continued LOICZ would certainly prove valuable sites within IOC's networks. IOC will support further development of **SAmBas**-related project proposals in South America.

A detailed introduction provided the background and scientific rationale of the key questions leading through the set of seven assessment tables. Dr Kremer, Prof. Lacerda and Dr Horst Behrendt (member of the **LOICZ Basins** task team) explained the input expected for each of the tables and how to process available information for upscaling from local to regional (sub-continental) scales. Critical loads and thresholds were emphasised. These allow determination of the current state of coastal systems in the context of expected trends of change and, where information is sufficient, the derivation of semi-quantitative measures of critical loads status and metrics needed for sustained system functions.

Presentations of catchment–coast biogeochemical and socio economic information

The key LOICZ questions posed were:

- how are humans altering the mass balances of water, sediment, nutrient and contaminant fluxes, and what are the consequences?
- how do changes in land use, climate and sea level alter fluxes and retention of water and particulate matter in coastal zones, and affect morphodynamics?
- how can we apply knowledge of processes and impacts of biogeochemical and socio-economic changes to improve integrated coastal management?

Site descriptions and regional synthesis were provided for river/coast systems in various sub-regions, including:

Pacific coast

Southern Pacific Coast (Chile)
Central Pacific Coast (Chile/Peru/Ecuador)
Northern tropical Pacific Coast (Colombia/Ecuador)

Caribbean coast

North East Brazil (sub tropical Atlantic)

Central Brazilian coast (Guanabara and Sepetiba Bay)

La Plata region Atlantic coast (SE Brazil, Uruguay, Argentina)

SE Atlantic, Argentina – Patagonia

In two breakout groups addressing separately the Atlantic and Pacific coasts of South America, the draft versions of assessment tables produced prior to the meeting were revised and amended taking into consideration both the results of the **SAmBas I** workshop and new information. Gaps from the first phase were the lack of information on west coast systems and on socio-economic issues. Special attention was paid to indicators and critical loads. While there is some information on fluxes and land-use patterns, in some cases covering more than five decades of data-sampling, indicators reflecting human development and its influence on water and material transports are rather scarce. However, methods and potential solutions for this problem were discussed in detail (see Bidone and Lacerda, this report).

The participants identified demonstration sites for continued **SAmBas** work that could be subject of a future interdisciplinary investigation. Following the same sequence of sub-regions as given above those are:

- the Bio Bio, Guayas and Chaira rivers in Chile and Ecuador;
- the San Juan and Patia rivers in Colombia;
- the Magdalena River system in Colombia;
- the Ceará, Jaguaribe and São Francisco rivers, Guanabara and Sepetiba bays and the Patos Lagoon estuary and wider la Plata region;
- Rivers in Patagonia, to address the serious issues of erosion driven by damming and urbanisation in an area with relatively low population density.

Outcomes and Wrap-up

- Assessment tables including the latest information available to the participants (Appendix III) were produced, covering sites as well as sub-regional and regional scales. Trend information on future changes and the current status of response were included where possible. Limited critical load/threshold information was provided for some sites.
- The meeting agreed to produce a multi-author LOICZ R&S, providing first regional pictures designed along the DPSIR framework. Expansion of the extended executive summaries submitted so far (see contributed papers) to full scientific publication for joint publication in the peer-reviewed journal “Regional Environmental Change” by Springer publishers were welcomed by the participants.
- The **SAmBas** network has encouraged the development and design of regional proposals for holistic future work. This work (and task proposals) will be promoted through LOICZ working closely with UNESCO/IOC. Earlier work conducted along these lines such as the SARCS/WOTRO/LOICZ project in South East Asia and the European **Basins** follow up project “**EuroCat**” will provide a sound template for the draft of a “**SAmCat**”. Prof. Lacerda agreed to coordinate this effort in the region. The meeting agreed further to pursue formal and/or operational links to ongoing international efforts such as the ICAM (Integrated Coastal Area Management) and GOOS (Global Ocean Observation System) of UNESCO/IOC, providing ways for global application and use of the outcomes.

SAmBas and the LOICZ IPO expressed their special thanks to Prof. Drude Lacerda and his team for the excellent organization, support and hosting of this second phase of SAmBas. Financial support from the Brazilian Science Foundation, CNPq, UNESCO/IOC and LOICZ was gratefully acknowledged.

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Appendix III Workshop Agenda

South American Basins II (SAmBas II), Fortaleza, Brazil, 2-5 May 2001.

(for SAmBas I agenda refer to LOICZ Meeting Report No. 37, LOICZ IPO, Texel, The Netherlands)

Wednesday 2nd May

9:00 – 9:30 Registration

9:30 – 10:00 Opening Session:

Local Host and IGBP/LOICZ, IPO
Regional task leaders
IOC/UNESCO representative

Prof. Drude Lacerda, Dr Hartwig Kremer
Prof. Drude Lacerda, Prof. Björn Kjerfve;
Dr Julian Barbieri

10:00 – 11:00 Introduction (Prof. Drude Lacerda, Dr Hartwig Kremer)

- **LOICZ Basins:** background, approach, results of other regional **Basins** activities (briefly), products, timelines and outlook
- Status and achievements of South American **Basins**
- Links to international organisations here: IOC/UNESCO.

11:00 – 11:15 *Coffee Break*

11:15 – 11:45 1. Plenary Session on Typology and upscaling

- Introduction (if possible online) in the LOICZ Typology and LOICZVIEW software
- Parameterisation and ranking of BASINS information for upscaling and comparison

11:45 – 12:30 2. Plenary Session on Coastal Issues, Drivers, Pressures and State/State-Changes in South America – overview of SAmBas I results and gaps:

- The regional assessment of SAmBas I;
- what are gaps and needs to refine the synthesis? – brief introduction into assessment tables;
- Discussion

12:30 – 14:00 *Lunch (same time each working day)*

14:00 – 15:30 3. Working groups on Coastal Issues, Drivers, Pressures and State/State-Changes in South America –assessment tables 1-7 (with 10 minutes plenary introduction).

The Groups will workshop through the regional assessment tables distributed prior to the workshop; new information, rank-orders, refined regional synthesis and gaps will be addressed along the following steps:

- Background of the tables, how they have been developed;
- how to fill in the tables and synthesise on various scales, subject to what has been provided to the meeting in preparation;
- organisation of breakout groups (along division of the coastal zone by sub-regions);

Assessing and ranking Issues/Impacts (critical thresholds) based on coastal change in the region (Assessment Table 1).

Key questions:

- What are the major **Impacts** (Coastal issues) on the coastal zone and do we know anything on
- How close they are to a **critical threshold** of system functioning?

Assessment, synthesis and ranking of (maximum 10) major **Driver/Pressure** settings generating the coastal **Impact**/Issues (Assessment Table 2)

Key questions:

- What are major (max. 10) catchment-based driver/pressure settings causing coastal change?

- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues (e.g. land-based coastal impact the level of which is determined by the size of the catchment)?

Assessment, synthesis and up-scaling of links between coastal issues/impacts and land based pressures and drivers on catchment, sub regional and full regional scale (Assessment Tables 3 - 5).

Key questions:

- What are the major Driver/Pressure settings causing coastal impact observed and what are the future trends (expert judgement) on local or catchment level?
- on sub-regional (or island) level?
- on full regional or sub-continental level?
- Can we derive a first expert typology of catchment-coast interaction and human dimensions in South America?

15:30 – 15:50 *Tea Break (same time each working day)*

15:50 – 17:00 4. Working groups on Coastal Issues, Drivers, Pressures and State/State-Changes in South America – Assessment Tables 1-7 continued:

Assessment of scientific and/or management **Response** on the various scales. Identification of major regional hot spots and gaps in understanding to be addressed by further investigations in an holistic multidisciplinary scientific project (Tables 6 – 7).

Key questions:

- Given the issues identified, what is the current status of response taken on scientific or policy/management levels on local, sub-regional and regional scales?
- What are major gaps in our current understanding of river catchment – coastal sea interaction and which hot spots should be addressed in a future integrated scientific effort/proposal including natural science and socio economic disciplines?

17:00 – 17:30 5. Plenary Session on Coastal Issues, Drivers, Pressures and State/State-Changes in South America – reporting back from the working groups

- chairs/rapporteurs give a short report
- discussion

Thursday 3rd May

09:00 – 10:45 1. Plenary Session – Socio economic aspects of catchment – coastal sea interaction – the human dimensions of land-based coastal change:

- presentations from the socio-economics experts

11:00 – 11:45 2. max. 3 breakout groups (Chairs & Rapporteurs: TBA):

- revisit the tables against the new information on human dimensions (drivers, feed-back, critical loads and indices of change and trends)

11:45 – 12:30 3. Plenary: Reporting back of the working groups: Response, research needs and potential methodologies (available data) in view of human dimensions

- the first full regional assessment results and ways ahead
- drawing a qualitative and/or semi-quantitative picture of change and impact affecting South American catchment-coast systems;
- leading to the proposal development

14:00 – 14:45 4. Plenary discussion on hot spots and proposal

- Discussion – response success and failure, classes of change, where to set up pilot sites,
- Links and synergies with IOC C-GOOS and ICAM,
- potential templates for project design (other **Basins** studies such as **EuroCat**, **SWOL**),

- plenary approval on suggested sites and studies.

14:45 – 15:30 5. Breakout groups **SAmBas** proposals (Chair & Rapporteur: TBA):

- developing/refining the suggestions for demonstration project/s and drafting a first design for the “**SAmCat**” studies.

15:50 – 16:30 6. Breakout groups continued:

- developing/refining the suggestions for demonstration project/s and drafting a first design for the studies

16:30 – 17:00 7. Reporting back from the drafting process

Friday 4th May

09:00 – 09:15 1. Morning Plenary

- first 15 minutes: short recall of the previous day (e.g., presentation of tables short explanations).

09:15 – 12:30 2. Breakout groups **SAmBas** proposals (Chair & Rapporteur: TBA):

- finishing the first draft of a design for the future **SAmCat** study.

14:00 – 14:45 3. Afternoon Plenary

- review and discussions on the first draft proposals from the working groups.

14:45 – 16:30 4. Breakout groups **SAmBas** proposals continued (Chair & Rapporteur: TBA):

- refining the first draft for the future study

16:30 – 17:00 5. Plenary

- Reporting back and discussion on potential funding agencies and funding mechanisms to be considered

Saturday 5th May: Proposals, study design, implementation and workshop results

09:00 – 10:45 1. Plenary:

- Chairs and rapporteurs to report back from the working groups and presenting of the study proposals, discussion (also with IOC representatives)
- Discussion:
What, Why (Regional and Global Relevance), Where, How, (incl. Structure), Who, (identify coordinators and get commitment to finish and submit proposal/s), Funding, Timelines.

11:00 – 12:30 2. Final Plenary

- Approval of products, proposal suggestions, commitments and timelines by the plenary
- Strengthening the South American **Basins** Network
- Conclusion (synthesis and proposals) and Outlook
- Closure of the meeting

Afternoon - departure of participants (key persons local and external to continue drafting the report).

LOICZ South American Basins (SAmBas) II
South American River Catchment–Coastal Zone Interaction and Human Dimensions
Fortaleza, Universidade Federal do Ceará, Brazil, 2-5 May 2001
(for TOR of SAmBas I, see LOICZ Meeting report No. 37, LOICZ IPO, Texel, The Netherlands)

Introduction - the LOICZ Basins background

Discussion on global change issues in coastal zones and integrated coastal management focuses increasingly on the interplay between river catchments and the coastal sea. Coastal zone processes and issues are considered to be a systemic i.e., receiving, part of a water continuum. The International Geosphere Biosphere Programme, IGBP, has responded by concentrating effort on the human dimension of global change issues within the whole water cascade. Parts of this issue is being addressed by LOICZ through the **LOICZ Basins** core project. This workshop aims to refine results and undertakings developed in the earlier **SAmBas 1** workshop, held in Bahia Blanca (November 1999) and to extend the basin assessments and develop appropriate regional research proposals.

Specific Workshop Objectives

1. Review, complete and/or develop further, the **system state reports** of river catchment – coastal sea interactions developed in Bahia Blanca 1999 which set up a first qualitative or semi-quantitative system to **categorise** key pressures and state change settings, providing an **indexed data entry** for upscaling purposes (see 2);
2. **Scale up the information** to regional and global levels via developed index system by identifying and clustering areas of similar change features.
Due to the large differences in coastal change, uses, management status and legislation among the different countries participating in South American **LOICZ Basins**, upscaling in a typology approach may not be a simple exercise. Identifying **simple proxies for coastal change** observed and adapting and optimising them to the regional reality should also constitute a major objective of the present workshop.
3. Provide the regional data and information base for **an inter-regional/global LOICZ Basins project synthesis** by late 2001, aiming to summarize the available regional information to a first global LOICZ Basins synthesis.
4. Review, based on earlier and new assessment information, the set of pilot areas discussed in Bahia Blanca and identify possible new ones. This is aimed at **developing proposals** for specific case studies that integrate natural and socio-economic sciences and elaborate on the “human dimensions” of global change in the catchment – sea water continuum;
5. **Strengthen a regional South American LOICZ Basins network** to continue the science and synthesis and to strengthen existing and seek new **links** to other regional and international projects and organisations e.g., UNEP, GIWA, **UNESCO/IOC (GOOS and ICAM)** and START. This will be facilitated through the LOICZ platform; but will only be possible with the involvement of national scientific programs and agencies.

Focus of workshop:

To achieve the objectives outlined the workshop will follow the framework of the DPSIR scheme. The process of *assessment, analysis, categorisation and indexing* will make use of a tabulated approach which is also being applied in other regional **LOICZ Basins** studies to assist global evaluation.

For clarification of nomenclature in the DPSIR scheme as a descriptive framework:

Catchment-based activities (land use and land use change) with consequences for the coastal zone are **(DRIVERS)** such as:

- Effects of damming and other huge constructions;
- River diversion and effects of irrigation and water supply activities (abstraction);
- Influence of industrial, agricultural and domestic wastes (urbanisation);
- Mining activities;

DRIVERS cause **PRESSURES** on ecosystem and social system functioning, affecting and changing the **STATE** of the coastal environment due to natural and anthropogenic forcing. This follows the guidelines of the LOICZ research approach, considering:

- Water, nutrient and sediment transportation throughout the catchments as key indicators for change across the boundaries of the water pathway. (Indicators are designed to give an overview of the environmental status and its development over time and finally allow the development of the critical load information and index systems linked to pressures);
- Geomorphologic settings, erosion, sequestration (retention times in catchments); and
- Economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity

IMPACTS, which are observed effects on coastal systems and how they are expressed, i.e., habitats, biodiversity, social and economic functioning and resource and services availability and use. These translate into the coastal **ISSUES** from which the assessment process embarks. And finally the

RESPONSE, reflecting action taken at management and policy levels to either protect against change, ameliorate adverse effects and ensure sustainable use of system's resources.

Products and Expectations

- ◆ The South American **LOICZ Basins** workshop in May 2001 will provide the information needed for the LOICZ *regional synthesis* and outcomes will be included in a LOICZ R&S series volume addressing the following:
 1. Coastal impact/issues (environmental and socio economic focus)
 - 1.1 Development of qualitative indices
 - 1.2 Categorise the relevance of Impacts
 2. Drivers
 3. Pressures
 - 3.1 Development of qualitative indices
 - 3.2 Categorise the relevance of Pressures
 4. States, State changes (fluxes, materials cycles)
 5. Response
 - 5.1 Socio-economic and political/legal settings
 - 5.2 Changes of these settings
 6. Regional up-scaling
 - 6.1 Typology development – Driver/Pressure/State/Impact/Response scenarios employing indices of the various aspects;
 - 6.2 Typology of the regional features;
 7. Trend analysis
 - 7.1 Defining change - the “Delta” - of key parameters and derive first trend prediction;
 8. Gaps
 - 8.1 Data and information gaps;
 - 8.2 Efforts/commitments needed to fill these gaps.
- ◆ Draft of a *research proposal* aimed at integrated cross-disciplinary, pilot studies complementing those under development within the other regional **LOICZ Basins** efforts.
(As outlined earlier, a key criterion for selection is the potential for up-scaling, i.e., to represent a certain type of catchment - coastal sea interaction that is characteristic for a sub-region).

- ◆ Information flow into the first *global LOICZ BASINS Synthesis*, providing input for the current LOICZ Synthesis.

Workplan (tentative)

- The workshop is to be held 2-5 May 2001 in Fortaleza, Brazil;
- Background documents, (**SAmBas I** report (LOICZ Meeting Report No. 37) and LOICZ R&S No. 11 (Turner *et al.*) on Integrated Modelling and the DPSIR (see LOICZ web-page <http://www.nioz.nl/loicz/> for downloading) and a set of **LOICZ Basins** regional assessment tables (including guidelines).
- Participants are asked to **start filling the tables along the key questions** outlined prior to arrival to enable targeted synthesis work during the first half of the meeting. A draft program for the workshop will be circulated by email as well as further background information on the key questions. **LOICZ Basins** regional assessment tables will be provided with some completed examples.
- A participants list will be circulated prior to the meeting.
- The meeting will agree on timelines and approve the schedule and contents for publication and confirm the schedule of drafting (about 4 months).
- Pilot areas will be identified at the meeting and drafting of the proposals will be a participant task during the meeting – subject to agreement by the meeting.

Participants

Attendance will be limited to a maximum of 20 to 25 South American scientists, plus LOICZ resource scientists and local organisers. **Invitation and support will be based on expression of interest and agreement to this TOR.**

Concluding Note

Access to socio-economic information and input to the analysis and development of pressure–state–response indices usually turns out to be a major challenge and gap in networking. This should be a priority issue in further development. **The network is therefore encouraged to identify expertise in their region and encourage participation by such experts.**

In the process of verifying and approving demonstration sites for which to draft project proposals, emphasis will have to be put on the potential to up-scaling and management relevance as well as on broader contribution to global projects such as those coordinated by UNESCO/ IOC.

Appendix V**List of important acronyms and abbreviations**

ANEEL	Brazilian National Electric Energy Agency
BAHC	Biospheric Aspects of the Hydrological Cycle
BID	Inter-American Development Bank
CAAM	Environmental Advisory Commission to the Presidency of the Republic of Uruguay
CariBas	Caribbean Basins Programme
CARU	Uruguay/Argentinean Administrative Commission of the Uruguay River
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CNPq	National Research Council of Brazil
CONICET	National Scientific Investigation Research Council
CPPS	Permanent Commission for the South Pacific, Ecuador
DINAMA	National Environmental Directory, Uruguay
DPSIR	Driver-Pressure-State-Impact-Response Framework
EuroCat	European Catchment Project/part of the “European Land Ocean Interaction Studies”, ELOISE cluster, DG Research
GEF	Global Environmental Facility
GOOS	Global Ocean Observing System
IAI	Inter American Institute for Global Change
ICAM	Integrated Coastal Area Management
ICZM	Integrated Coastal Zone Management
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies of Colombia
IGBP	International Geosphere-Biosphere Programme; A Study of Global Change
ILTER	International Long-Term Ecological Research Network
IMM	Montevideo Municipality
INAPE	National Institute of Fisheries, Uruguay
INIDEP	National Institute of Fishery Research and Development, Argentina
INOCAR	Oceanographic Institute of the Navy, Ecuador
INGEOMINAS	National Institute of Mining and Geology, Colombia
IOC	Intergovernmental Oceanographic Commission (UNESCO, Paris)
IVEMAR	Institute of Marine Research, Punta Betin, Colombia
JOPS	Brazilian-German Joint Oceanographic Programmes
LOICZ	Land Ocean Interactions in the Coastal Zone
LTER	Long-Term Ecological Research
MONERIS	Modelling Nutrient Emission in River Systems
MVTOMA	Ministry of Housing, Land Planning and the Environment, Uruguay
OSM	LOICZ Open Science Meeting
PAB	Policy Advisory Board
PMRC	Coastal Resources Management Program, Ecuador
PNGC	National Coastal Management Programme - Brazil
SAmBas	South American Basins Programme
SARCS	South Asia Committee for START
SOHMA	Uruguayan Navy Oceanographic, Hydrographic and Meteorological Service
START	Global change system for Analysis, Research and Training
SWOL	SARCS/WOTRO/LOICZ – South East Asian LOICZ core project 1996-99
UFC	Universidade Federal do Ceará
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNESCO	United Nations Education and Cultural Organization
WOTRO	The Netherlands Foundation for the Advancement of Tropical Research
WP	Work Package