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Brazil Current

GIWA Regional assessment 39

Marques, M., Knoppers, B., Lanna, A.E., Abdallah, P.R. and M. Polette

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Regional assessments

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Series editor: Ulla Li Zweifel

Report editor: Marcia Marques

Editorial assistance: Johanna Egerup, Malin Karlsson

Maps & GIS: Niklas Holmgren

Design & graphics: Joakim Palmqvist

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Preface

This report presents the results of the strategic impact assessment carried out for marine and freshwater resources and the associated living resources of the Brazil Current region, which is part of the Global International Waters Assessment Project GIWA-UNEP/GEF. The scoring procedure was based on: (i) expert opinion obtained during workshops, with the participation of experts on the Brazil Current with different scientific backgrounds and from several institutions and geographical regions of Brazil Current; (ii) expert advice; and (iii) information and data gathered from different sources. The results from the first Scaling & Scoping exercise for the Brazil Current region was based on a workshop with the participation of experts with different backgrounds and regional knowledge. The final scores presented in this report resulted from a revision of the preliminary scored, based on a more detailed assessment, when impact indicators were collected mostly from local, regional and national documentation and scientific publications. This information in the format of impact indicators is presented in the text and/or included in Annex III (Detailed assessment worksheets). Few international databases (e.g. Large Marine Ecosystem programme, FAO database) were accessed. This approach was taken in order to be as precise as possible in the scoring procedure, using specific catchment basins/coastal zone information to substantiate the degree of severity of impacts given to each issue and concern, both present and future (predictive analysis).

To reduce the difficulty of scoring a largely diverse region such as the Brazil Current region, a further sub-division was made during the scaling procedure, leading to the identification of three distinct GIWA sub-regions; 39a South/Southeast Atlantic Basins; 39b East Atlantic Basins and 39c São Francisco River Basin. The scoring procedure was then carried out sub-region by sub-region and the scores obtained were subsequently aggregated for the whole GIWA region 39 Brazil Current.

The Atlantic Basin of Uruguay (Vertiente Atlántica, in Spanish), a narrow strip of land with small sub-basins that drain toward the Atlantic Ocean, could not be classified as Brazil Current according to oceanographic criteria and therefore it is addressed separately in the text. This coastal zone is actually part of the Patagonian Shelf Large Marine Ecosystem.

In each sub-region, environmental impacts were assessed and scored issue by issue (e.g. modification of stream flow, pollution of existing supplies, changes in the water table) and then consolidated with an overall score by concern and sub-region (e.g. Freshwater shortage in South/Southeast Atlantic Basins). Finally, based on three scores given to the sub-regions, an overall score for each concern was given to the Brazil Current (e.g. Freshwater shortage). If differences in fractions between scores resulting from weighting and averaging procedures are taken into consideration (e.g. scores 2.1, 2.3, 2.5), it is possible to identify priorities among concerns, for each sub-region and for the Brazil Current. Using this procedure, São Francisco River Basin, for instance, had as the main concern, Freshwater shortage with the main causative issue being modification of stream flow. South/Southeast Atlantic Basins and East Atlantic Basins had as the main concern Pollution, and the main causative issue, suspended solids. If the fractional differences in the score figures are ignored, impacts caused by four of five GIWA concerns in the Brazil Current (freshwater shortage, pollution, habitat and community modification, overexploitation of fish and other living resources) received moderate overall score. The concern global change, received slight overall score.

Selection based on differences in fractions of the score figures was not considered, in principle, a robust enough procedure to define the main concern. Priority was therefore established according to the precedence of each concern, compared to the other concerns. Coincidently, the priority based on precedence coincided with the priority previously based on differences in fractions among scores. Pollution was the concern that met both criteria.

This precedence was established from the findings that pollution causes increased impacts of freshwater shortage and habitat and community modification and that pollution is also one of the factors that promote reduction of fish stocks, which in turn, contributes to increase the severity of the impacts due to unsustainable exploitation of fish. Pollution is also, among all concerns, the one that shows most evidence of health and economic impacts in the Brazil Current region, mostly associated to microbiological pollution, eutrophication, chemical pollution and spills. The way pollution contributes to the raising of the other concerns is illustrated in different sections of the report.

When analysing the impact indicators included in Annex III, it can be seen that the information/data gathered varies, regarding reliability and quality. It is also observed that more information is available for South/Southeast Atlantic Basins than for the other sub-regions (East Atlantic Basins and São Francisco River Basin). This reflects the historical condition of higher socio-economic and scientific development found in the South and Southeast geographical regions of Brazil, when compared to other regions of the country, a condition that has been gradually changed through a policy of investments and incentives to the other regions of Brazil. Relatively little information was found for the portion of Mirim Lagoon located in Uruguayan territory, as well as the Atlantic Basin of Uruguay regarding environmental and socio-economic impacts associated to water resources, coastal zone and associated living resources, which indicates the need for closer effective cooperation between the countries and for generation of primary data within the area.

Executive summary

Regional definition

GIWA region 39 Brazil Current is a tropical/sub-tropical ocean margin governed by western boundary currents, a passive continental shelf, and moderate continental run-off (Walsh 1988, Ekau & Knoppers in press). It extends along the Brazilian coast from the São Francisco River estuary (10° 30´ S, 32° W) in the northeastern Brazil, to Chui (34° S, 58° W) in the southern Brazil. Its length, excluding contours of bays and islands, is 4 150 km, or 58% of the Brazilian coastline (GERCOPNMA 1996). The Brazil Current region's catchment area inside Brazil is 1 403 million km^2 and the portion inside Uruguay, corresponding to approximately 52% of the Mirim Lagoon Basin (and 2.3% of the Brazil Current continental area), is 33 000 km^2. The Brazilian component of the Brazil Current catchment area includes the entire states of Espírito Santo (ES) and Rio de Janeiro (RJ) and from northeast to south, part of the states of Pernambuco (PE), Alagoas (AL), Sergipe (SE), Bahia (BA), Minas Gerais (MG), Goiás (GO), São Paulo (SP), Paraná (PR), Santa Catarina (SC) and Rio Grande do Sul (RG).

Uruguay is divided in 18 departamentos (political/administrative units). Five of them are partially or entirely included in the Mirim (Merín in Spanish) Lagoon basin and subsequently part of the Brazil Current region. These five departamentos are: Cerro Largo, Lavalleja, Maldonado, Rocha and Treinta y Tres. Two of them (Rocha and Maldonado) also form the Atlantic Basin of Uruguay with a coastal zone with high potential for tourism, that hosts livestock and rice plantation as the main economic activities.

The Brazil Current region encompasses geographical portions of "three Brazils" as revealed by the UNDP Human Development Index (UNDP 2001): the northeastern, southeastern and southern Brazil. In Brazil, the poorest 20% have only 2.6% of the total national wealth; the richest 20% have 65% (IBGE 2001). This extremely uneven wealth distribution has been historically associated with the contrasts between the undeveloped northern Brazil, the often drought-affected northeastern Brazil, and the much more prosperous and industrialised southeastern and southern Brazil. The southeastern and the southern Brazil are together responsible for more than 75% of the Brazilian GDP. Therefore, although Brazil Current region is almost 100% Brazilian territory (excepting 2.3% that belong to Uruguay), it shows an extremely high diversity regarding social, cultural and economic aspects, which in turn, reflect on the nature and severity of the impacts.

In the Brazil Current region, a typical developing economy situation has been established: economic and demographic growth exceed development of necessary urban and industrial infrastructure (Lacerda et al. 2002). Littoralisation, a variant of urbanisation with the movement of people from the countryside to the coastal cities, is the predominant trend in Latin America, which the Brazil Current illustrates quite well. Anthropogenic pressures exhibit two major features; large cities either affect the coastal waters or estuaries directly when located on the coastline, or contribute to coastal change indirectly through their location in catchments which carry the urban waste load. In the Brazil Current, the main pressures/driving forces and the respective environmental issues generated by them are:

- Urbanisation: consumption of water, microbiological pollution, eutrophication, suspended solids, habitat and community modification;
- Industry: consumption of water, chemical pollution;
- Agriculture: consumption of water for irrigation, increased nutrient and suspended solids loads, chemical pollution, eutrophication, habitat and community modification;
- Power generation: stream flow modification due to damming, habitat and community modification;
- Mining: chemical pollution, suspended solids, habitat and community modification;
- Fisheries: reduction of fish stocks, pollution;

- Aquaculture: eutrophication, habitat and community modification;
- Transport: spills.

For the purpose of the GIWA assessment, Brazil Current was divided in three regions: South/Southeast Atlantic Basins, East Atlantic Basins, and São Francisco River Basin. Medium-sized basins or groups of small basins in the sub-regions were numbered according to the former classification by the Brazilian National Agency of Electric Energy (ANEEL) and not the newer sub-division of the Brazilian basins, according to the Brazilian National Agency of Waters (ANA) (PNRH 2003). This presentation is intended to help those readers that are not familiar with the Brazilian or Uruguayan geography to locate, on the map, the basins mentioned in different sections and to identify the areas in Brazil Current where the issues and impacts are occurring.

Assessment

The assessment of the Brazil Current region identified the following priority concerns in the three individual sub-regions assessed: South/Southeast Atlantic Basins and East Atlantic Basins, Pollution with suspended solids as the main causative issue; São Francisco River Basin, Freshwater shortage with modification of stream flow as the main causative issue.

Changes in the suspended solids transport/sedimentation dynamics due to deforestation and erosion is the main cause of silting, modification of stream flow and periods of water scarcity and flooding in South/Southeast Atlantic and East Atlantic Basins (e.g. Itajaí Valley and Doce River basin respectively). Diversion of water from one basin to another to meet the demands for consumption (e.g. transfer of water from Paraíba do Sul River in East Atlantic Basins to supply the Rio de Janeiro littoral basin in South/Southeast Atlantic Basins) has caused increased sedimentation/silting in the estuary that receives the transposed water (Sepetiba Bay in East Atlantic Basins), which generates pollution and habitat modification. At the same time, significant reduction of sediment transport in the original basin due to damming has caused extensive erosion of the coastline, destroying fringes of mangrove forests, dunes and small villages around the Paraíba do Sul River estuary, and promoting depletion of fish stocks.

Eutrophication in lagoons, estuaries and bays along Brazil Current coast placed downstream densely occupied urban areas, industrial activities and agriculture fields is currently a serious environmental issue. In reservoirs for water supply, eutrophication is becoming a serious issue in both South/Southeast Atlantic as well as East Atlantic Basins. Few, but extremely severe episodes of human intoxication due to hepatotoxins released in the water after algal blooms have been recorded, as has the fact that eutrophication has become a common phenomenon in reservoirs (Azevedo 1996, Costa & Azevedo 1994, Teixeira et al. 1993, Proença et al. 1996, Diário do Vale 2001). More frequently recorded has been the association between water pollution and water-borne diseases such as microbiological and parasitic infections (CETESB 1990 in Governo do Estado de São Paulo 2002, IBGE 2001, COPPE & UFRJ 2002, Governo do Estado de São Paulo 2002). Increasing gastrointestinal symptoms related to the time of exposure to polluted beaches was described by CETESB (1990), in Governo do Estado de São Paulo (2002). In Paraíba do Sul River basin (East Atlantic Basins), the incidence of microbiological infection and parasitic diseases varies among municipalities, from 0-30% (IBGE 2001) and is seems to be related to the average income. As regards risks to human health, cases of schistosomiasis have been registered all over the São Francisco River Basin. In the upper portion of the Basin, there are health problems resulting from microbiological factors and problems resulting from chemical pollution are suspected, but not confirmed, due to lack of proper investigations. While the percentage of the population affected is small, the degree of severity is high, due to the poverty level among those affected.

Episodes of temporary freshwater scarcity have been registered, mostly due to chemical pollution caused by industrial activities in some populated basins. In 2003, an accident in a paper-pulp industry located in Minas Gerais state, on a tributary of the Paraíba do Sul River, which flows through Rio de Janeiro state, caused a transboundary issue due to pollution of the downstream portion of the basin, resulting in interruption of the water supplies during weeks, which affected about 600 000 inhabitants of northern Rio de Janeiro state. Therefore, the causative link between Pollution and other environmental concerns assessed as equally severe supported the decision of selecting Pollution as the most important concern for the Brazil Current region. The combined assessment of the three sub-regions resulted in the following ranking of concerns:

1. Pollution;
2. Habitat and community modification;
3. Freshwater shortage;
4. Overexploitation of fish and other living resources;
5. Global change.

Causal chain and policy option analyses

The Causal chain analysis methodology was developed specially for the GIWA project and was previously tested in selected aquatic system in Brazil Current (Marques 2002, Marques et al. 2002). The Causal chain and policy option analyses were carried out for two selected aquatic systems: the transboundary bi-national water body Mirim Lagoon (South/Southeast Atlantic Basins), shared by Uruguay and Brazil and the

Doce River basin, a medium-sized transboundary basin shared by the Brazilian states of Minas Gerais and Espírito Santo (East Atlantic Basins). São Francisco River Basin, a natural candidate for further analyses due to the high importance such river has in the national context, has already been the focus of an important GEF/UNEP project (Diagnostic analysis and strategic action program for the integrated management of the São Francisco River basin and its coastal zone), and only for this reason, was not included in the list of selected aquatic systems. Through these case studies, the causative links and the main root causes responsible for pollution in Brazil Current were addressed. In the particular case of the Patos-Mirim Lagoon system, although the main focus in terms of causal chain and policy options analyses was put on pollution in Mirim Lagoon, a causal chain analysis for the overexploitation of fish was also constructed for the Patos Lagoon. In the case of the Doce River basin, the causal chain was analysed for pollution and the habitat and community modification. It was thus possible to find out that both concerns have some root causes in common. In this model, policy options tailored to reduce one of these concerns will also reduce the other, which represents a desirable win-win situation.

Mirim Lagoon, a truly international freshwater body, is a shallow Atlantic tidewater lagoon on the border between Brazil (state of Rio Grande do Sul) and Uruguay. It is approximately 190 km long and 48 km across at its widest point, covering an area of 3 994 km^2. A low, marshy bar containing smaller lagoons, separates the Mirim Lagoon from the Atlantic Ocean. It drains northeastward into the Patos Lagoon. Mirim Lagoon is considered one of the most important water resources in Uruguay. The main economic activity in the basin is agriculture, mostly rice plantation, which is highly dependent on water from the Mirim Lagoon for irrigation. The main environmental concern is pollution due to the use of chemical fertilisers and pesticides. Root causes behind agricultural practices are: (i) Governance (lack of full implementation of the bi-national basin integrated management plan and lack of autonomy and authority of the control agencies to face pressures from economic development); (ii) Knowledge (insufficient information regarding environmental functions of wetland and lagoon system and insufficient training regarding sustainable use of water and soil); and (iii) Economic (lack of efficient economic instruments to promote sustainable use of water and land).

Nine complementary policy options were proposed for Mirim Lagoon, among them, two were selected as the best candidates to be implemented in a first stage: (i) creation of the bi-national Mirim Lagoon Basin Committee and empowerment of the Brazilian and the Uruguayan Mirim Lagoon Agencies; and (ii) technical and professional training on pollution minimisation and control associated to agriculture activities.

In Doce River basin the major environmental and socio-economic impacts due to pollution have a transboundary nature, since deforestation and land uses practiced by the state responsible for the upstream portion of the basin (Minas Gerais) during decades has caused severe environmental and socio-economic impacts to the downstream portion of the basin, which belongs to another state (Espírito Santo). In brief, the main environmental problems that lead to socio-economic impacts in the basin arise from the following factors (Gerenciamento Integrado da Bacia do Rio Doce 2003): (i) generalised deforestation and mismanagement of agricultural soils that led to loss of fertility and speedy erosion, and consequently, to loss of agricultural productivity, increased rural poverty and migration to the outskirts of large cities; (ii) siltation of riverbeds caused by erosion, leading to reduced stream flow during the dry period and increased problems during floods, with effects on urban supply, irrigated agriculture and public safety; (iii) floods, resulting from natural conditions but worsened by the human flood plain occupation, deforestation, soil erosion and siltation; (iv) vulnerability of reaches where domestic supply intake points are located, considering previous accidental toxic pollution events, in several regions in the basin, with potential risks to public health; and (v) the precariousness of basic sanitation (networks, sewage treatment, disposal of solid wastes) and the lack of drinking water supply in several urban agglomerations and rural communities, reflecting on public health and on the economy. The main root causes for Doce River basin are: (i) Governance (basin-wide management plan not implemented yet, and lack of legitimacy in negotiations commanding decisions regarding investments); (ii) Knowledge (insufficient training regarding best land use practices); and (iii) Economic (existing economic distortions, such as non-correction of negative externalities resulting in pollution and inefficient use of water).

Five policy options were proposed and three of them were selected as those that should be implemented in the first stage: (i) participatory plan for flood control; (ii) production of the manual to prepare City Statutes (Ordinances); and (iii) pilot project for basin reforestation associated with the enhancement of family agriculture.

Challenges and recommendations for future actions

The ranking of environmental concerns and issues in Brazil Current region or any other GIWA region in the world, regarding the severity of their impacts is likely to change as time goes by and also as a result of policies and initiatives implemented and the development of different economic sectors. The transformation of the GIWA assessment from the status of a project into a continuous assessment would represent: (i) significant and continuous support to the decision making process towards a more sustainable use of water and associated living resources;

(ii) better understanding of the environmental problems with updated and easy-to-access information for increasing cooperation between the governments that share the water bodies; and (iii) a valuable source of information/data for development of advanced knowledge and awareness among stakeholders regarding the importance of rational land occupation and use of water resources, costal zones and their associated living resources.

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Abbreviations and acronyms

AB	Abrolhos Bank
AL	Alagoas State
ANA	National Agency of Water (Brazil)
ANEEL	National Agency of Electric Energy (Brazil)
ANTAQ	National Agency of Water Transport (Brazil)
APA	Environmental Protection Area
BA	Bahia State
BC	Brazil Current
BOD	Biochemical Oxygen Demand
CADAC	Environmental Accident Record
CBD	Convention on Biological Diversity
CCA	Causal Chain Analysis
CDZF	Commission for Joint Development of Transboundary Zones
CEPERG	Centro de Pesquisas e Gestão dos Recursos Lagunares e Estuarinos
CETESB	State Company of Environmental Technology and Basic Sanitation (São Paulo state)
CGC	General Commission of Brazilian-Uruguayan Coordination
CIDE	Centro de Informacões e Dados do Rio de Janeiro
CLM	Commission for Development of Mirim Lagoon Basin
COD	Chemical Oxygen Demand
CONAMA	National Council of Environment
CPRM	Company of Mineral Resources Research
CZ	Confluence Zone
DGRNR	General Directory of Renewable Nature Resources
DINAMIGE	National Directorate of Mining and Geology
DNAEE	National Department of Water and Electrical Energy (Brazil)
DNH	Dirección Nacional de Hidrografía (Uruguay)
DNOCS	Brazilian National Department of Works Against the Drought
EEZ	Exclusive Economic Zone
EMBRAPA-CPACT	Brazilian Company Agriculture Research-Temperate Climate Agriculture Center
ENSO	El Niño Southern Oscilliation
ES	Espírito Santo State
FAO	United Nations Food and Agricultural Organization
FAPCZ	Federal Action Plan for the Coastal Zone
FATMA	Santa Catarina Environment Foundation (Santa Catarina State)
FEAM	State Foundation for the Environment (Minas Gerais state)
FEPAM	State Foundation for Environmental Protection (Rio Grande do Sul state)
FUNASA	Fundação Nacional de Saúde / Brazil Ministry of Health
GDP	Gross Domestic Product
GEF	Global Environment Facility
GERCO	Programa Nacional de Gerenciamento Costeiro
GHG	Green House Gas
GO	Goiás State
HDI	Human Development Index
IADB	Inter-American Development Bank
IBAMA	Brazilian Institute for the Environment
IGAM	Minas Gerais Institute of Water Management
INMET	National Meteorological Institute, Brazil
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
IWC	International Wildlife Coalition
JICA	Japan International Cooperation Agency
MERCOSUR	Mercado Común del Sur / Southern Common Market
MG	Minas Gerais State
MMA	Brazilian Ministry of Environment
MRE	Brazilian International Trade Ministry
MSY	Maximum Sustainable Yield

NBC	North Brazil Current
NGO	Non Governmental Organisation
OSE	National Administration of Sanitary Works (Uruguay)
PARNA	National Park of Lagoa do Peixe
PE	Pernambuco State
PLE	Patos Lagoon Estuary
PO	Policy Option
PR	Paraná State
PRENADER	Programa de Manejo de Recursos Naturales y Desarrollo del Riego (Uruguay)
PROBIDES	Conservation of Biodiversity and Sustainable Development Programme for the Eastern Wetlands (Uruguay)
PRODES	Clean-up programme of hydrographic basins
RG	Rio Grande do Sul State
RJ	Rio de Janeiro State
SACW	South Atlantic Central Waters
SACZ	Southwest Atlantic Convergence Zone
SC	Santa Catarina State
SE	Sergipe State
SEAMA	State Secretariat for Environmental Issues (Espírito Santo state)
SEC	South Equatorial Current
SNIU	National Urban Information System (Brazil)
SO	Southern Oscillation
SP	São Paulo State
STW	Surface tropical Waters
TW	Tropical Water
UFAL	Federal University of Alagoas
UFBA	Federal University of Bahia
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

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Regional definition

Marques, M. and B. Knoppers

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the Brazil Current region

Brazil Current, GIWA region 39, is a tropical/sub-tropical ocean margin governed by western boundary currents, a passive continental shelf and moderate continental run-off (Walsh 1988, Ekau & Knoppers 1999).

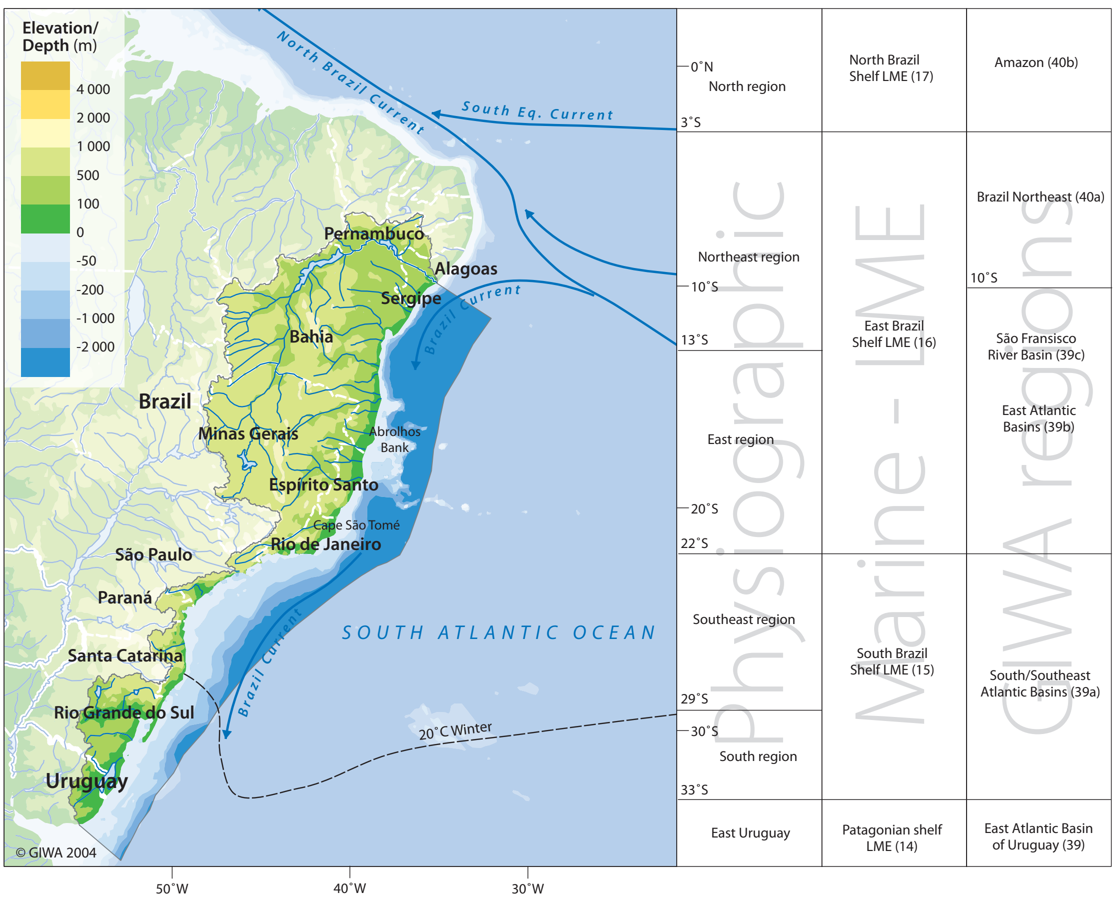

Figure 1 The continent, coast and shelf of the Brazil Current region and surrounding area.

Limits according to: Climate (Nimer 1972); tidal regimes (tide tables, Brazil Navy); western boundary currents NBC, South Equatorial Current SEC and Brazil Current BC (Peterson & Stramma 1990); geological regions (Gerra 1962); geographical regions (Cruz et al. 1985); Large Marine Ecosystems LME 15, 16, 17 (Large Marine Ecosystems 2003) and; Brazil Current GIWA sub-regions South/Southeast Atlantic, East Atlantic and São Francisco River Basin (the delta of the São Francisco River Basin is too small to be shown); and GIWA region 40a Brazilian Northeast and 40b Amazon.

It extends along the Brazilian coast from the São Francisco River delta (latitude 10° 30´ S and longitude 32° W) in the northeastern Brazil, to Chui River (latitude 34° S and longitude 58° W) in the southern Brazil (Figure 1). Its length, excluding contours of bays and islands, is 4 150 km or 58% of the Brazilian coastline (GERCO-PNMA 1996). The total catchment area is 1.403 million km^2 inside the Brazilian territory and 33 000 km^2 (Mirim Lagoon portion) inside the Uruguayan territory. For the purpose of the GIWA assessment, Brazil Current harbours three major, physically and economically distinct, drainage areas with small changes from the original division (ANEEL 2002): the São Francisco River Basin (0.634 million km^2), the East Atlantic Basins (0.545 million km^2) and the South/Southeast Atlantic Basins (0.224 million km^2). The Uruguayan land portion that drains towards Brazilian territory (Mirim Lagoon) corresponds to 2.3% of the total regional area (Figure 2). The Brazil Current includes the entire Brazilian states of Espírito Santo and Rio de Janeiro, and part of the states of Pernambuco (PE), Alagoas (AL), Sergipe (SE), Bahia (BA), Minas Gerais (MG), Goiás (GO), São Paulo (SP), Paraná (PR), Santa Catarina (SC) and Rio Grande do Sul (RG) (Figure 1).

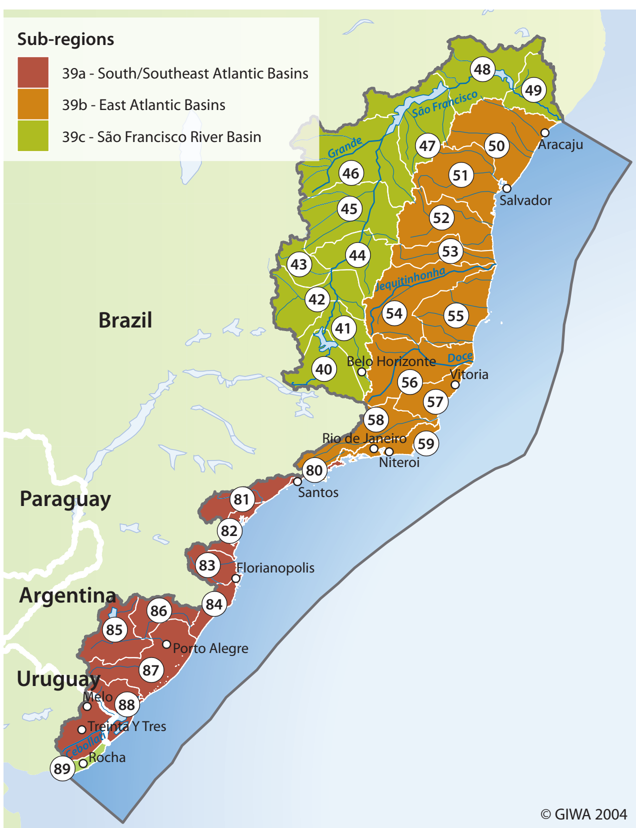

Figure 2 Sub-division of the Brazil Current region: São Francisco River Basin (basins 40-49); East Atlantic Basins (basins 50-59); and South/Southeast Atlantic Basins (basins 80-88).

Note: Each number in the map (originally used by the National Agency of Electric Energy-ANEEL) represents either a medium-sized basin or several small-sized basins. The strip of land marked as 89 in the map forms the Atlantic Basin of Uruguay (Vertiente Atlántica in Spanish), which is assessed separately from Brazil Current.

In Uruguay, five departamentos (political/administrative units) are entirely or partially included in the Mirim's Lagoon catchment area: Cerro Largo, Treinta y Tres, Lavalleja, Rocha and Maldonado.

The Brazil Current offshore-oceanic boundary follows the 200 nautical mile Exclusive Economic Zone (EEZ), as it encompasses the entire shelf down to its base and the western boundary currents. In the north at about 10° S to 15° S it includes part of the South Equatorial Current (SEC), which impinges directly upon the shelf, and from about 15° S to 34° S, the southward meandering Brazil Current (BC) up to the reaches of the Southwest Atlantic Convergence Zone (Figure 1). The tectonically passive Atlantic coast has only one large-sized basin (>200 000 km^2 in area), which is the São Francisco River Basin (40-49 in Figure 2), a few medium-sized basins (10 000-200 000 km^2 in area) and a large number of small-sized basins (<10 000 km^2 in area).

The GIWA region Brazil Current is essentially compatible with the old definition of the Brazil Current Large Marine Ecosystem (Sherman 1993). However, after the recent redefinition of Brazil's LMEs (Ekau & Knoppers in press), the GIWA region Brazil Current now includes about half of the LME 16 East Brazil Shelf and the entire LME 15 South Brazil Shelf (Figure 1). In recognition of the diversity of typological characteristics governing the drainage basins and their adjacent shelf-oceanic realms, as previously mentioned, the Brazil Current region gained three sub-regions:

- 39a South/Southeast Atlantic Basins
- 39b East Atlantic Basins
- 39c São Francisco River Basin

Recently, the Brazilian coastal basins were sub-divided by the National Agency of Water (ANA) (ANA 2002a) in a different number of basins, compared to the former division used by the National Agency of Electric Energy (ANEEL) (ANEEL 2002). However, for the objective of the GIWA assessment and with the sole purpose of facilitating the geographical identification of different basins, it was decided to keep the ANEEL's classification with numbers representing medium-sized basins (52, 54, 56, 58, 81, 83, 87, 88) or areas encompassing several small basins or sub-basins (40-49, 50, 51, 53, 55, 57, 59, 80, 82, 84, 85, 86). Eastern Mirim Lagoon in the territory of Uruguay, has a small strip of land that forms the Uruguay Atlantic Basin or Vertiente Atlántica (89 in Figure 2). From the oceanographic/marine point of view this area cannot be classified as Brazil Current and therefore, it was assessed independently from the rest of the Brazil Current region.

In the next sections, the drainage areas identified with numbers in Figure 2 will be frequently referred to, to facilitate the geographical location of the assessed impacts.

Geographical settings

The GIWA region Brazil Current covers, entirely or partially, three of Brazil's five main economic regions (Silveira 1964, Cruz et al. 1985, see also Socio-economic characteristics of Brazil) and one of Uruguay's regions (Uruguayan East region). Along the Brazilian coast, Brazil Current includes a minor fraction (approximately 310 km) of the Northeastern Brazil (from 10° 30´ S, 42° W to 13° S, 38° W) and the entire Eastern Brazil (13° S, 39° W to 22° S, 42° W), Southeastern Brazil (22° S, 42° W to 28° 30´ S, 52° W) and Southern Brazil (28° 30´ S, 52° W to 34° S, 58° W) geographical regions. The lower sector of the inland of São Francisco River Basin belongs to the Northeastern Brazil and the remainder, together with the entire East Atlantic Basins (Figure 1), belong to the Eastern Brazil. The southern boundary of the East Atlantic Basins at Cape São Tomé (22° S) corresponds to the limit between the Eastern and Southeastern Brazil. The South/Southeast Atlantic Basins includes parts of both the Southern and the Southeastern Brazil.

The Brazilian portion of South/Southeast Atlantic Basins extends between latitudes 22° and 32°S and longitudes 44° to 54°W with a northeast-southwest orientation and drains parts of the states of São Paulo, Paraná, Santa Catarina, Rio Grande do Sul towards the coast. The Uruguayan portion of South/Southeast Atlantic Basins corresponds to the administrative divisions (departamentos) of Cerro Largo, Treinta y Tres, Lavalleja, Rocha and Maldonado included in Mirim Lagoon basin that drains through the São Gonçalo channel into the Patos Lagoon, which in turn is connected to the Atlantic Ocean. South/Southeast Atlantic Basins harbours two distinct sectors: (i) the southern wide sector covering the Uruguay portion of Mirim Lagoon and the Brazilian area of the state of Rio Grande do Sul, the southern part of the state of Santa Catarina, between the cities of Chuy and Laguna, along the coast, and the inland, river carved, Meridian high plain, up to the border with the Paraná River basin; and (ii) the northern narrow sector that extends within parts of the states of Santa Catarina, Paraná, São Paulo and is backed by the Atlantic range parallel to the coast.

The Atlantic basin of Uruguay (89 in Figure 2) is one of the five hydrographical basins of Uruguay. It is formed by part of the Rocha and Maldonado departamentos. It is a narrow strip of land with a coastline about 220 km long (from the Brazil-Uruguay border, down to, and including Punta del Este). This area encompasses part of the Humedales del Este, and has several dunes and lagoons such as Garzón, Rocha, Castillos and Negra. This area has in common with the state of Rio Grande do Sul, southern Brazil, the fact that its dunes are formed by the action of the winds that promote an accumulation of sand taken from the surrounding beaches. Due to the intense accumulation of deposits, these zones became relatively isolated and almost independent from the marine environment. A periodical breaching of the sand bars, allows seawater inflow in some coastal lagoons, connecting them with the Atlantic Ocean and creating an abundant and cyclic biological diversity. Important archaeological sites, approximately 5 000 years old, exist in this area. Evidence is found of the existence of pre-historical communities that constructed monuments known as cerritos de indios, where people were buried.

The East Atlantic Basins (50-59 in Figure 2) extends between latitudes 10° and 23° S and longitudes 37° and 46° W with a north-south orientation and is set between the São Francisco River basin and the coast. It drains parts of the states of Sergipe, Bahia, Minas Gerais and São Paulo and the entire states of Espírito Santo and Rio de Janeiro. Its southern extent is limited by the Mantiqueira range, state of Rio de Janeiro, its western extent by the Espinhaço range and towards the north by the Diamantina Plateau and the Trombador range.

The São Francisco River Basin (Figure 3) covers the area between latitudes 7° and 21° S and longitudes 35° and 47° 40´ W, and 7.5% of the Brazilian territory. It is an inland drainage basin about 2 700 km long with a single outlet at the coast. It is divided into the upper, middle, lower-middle and lower reaches, including the São Francisco delta plain. The upper reaches of the São Francisco River Basin in the south, state of Minas Gerais, are delimited by the Canastra and Vertentes ranges, which separate it from the Rio Grande River basin. To the east, it is separated from the East Atlantic Basins by the Serra do Espinhaço range and the Diamantina Midlands. From south to north, it traverses via an extensive depression created by the Atlantic high plain and the Central Brazilian Plateau, as far as the city of Barra. Henceforth, it diverts towards the northeast reaching the city of Cabrobó and thereafter to the southeast until the São Francisco delta, at the frontier of the state of Sergipe and Alagoas. The upper and middle reaches in the states of Minas Gerais and Bahia comprise 83% of the basin, 16% comprising its lower-middle and lower reaches, in the states of Pernambuco, Alagoas and Sergipe, and the remaining 1% to the west, in the state of Goiás and the Federal District (ANA 2002a).

Figure 3 Aerial view of São Francisco River.
(Photo: José Caldas/SocialPhotos)

Physical characteristics of the Brazilian portion of the region

Drainage basins

The Brazilian portion of the South/Southeast Atlantic Basins comprises nine basin/group of basins (80-88) distributed in two distinct sectors. The average flow in the basins is 4 300 m^3/s, the specific flow 19.2 $l/s/km^2$, the average precipitation 1 394 mm/year and evaporation 789 mm/year (Table 1). The northern sector, between the states of São Paulo (basin 80) and Santa Catarina (basin 84), is characterised by an array of small-sized rivers. The Ribeira-Iguape (state of São Paulo) and the Itajai rivers (state of Santa Catarina) are the most important, they account for about 10% of the entire basin's discharge to the coast. The southern sector (basins 85 to 87) is more complex, comprising inland and coastal basins, some of which are interlinked, and approximately half of the basin 88 lies outside the boundary of the state of Rio Grande do Sul, in the Uruguayan territory. Most of the freshwater input to the coast is delivered via the large Patos-Mirim Lagoon system, the average annual freshwater flow rate through this estuary is 4 000 m^3/s, and the remainder of the coast receives minor freshwater input via coastal lagoons. The most important rivers are the Mampituba, Jacuí, Taquari and Jaguarão.

Table 1 Hydrological characteristics in the Brazilian part of Brazil Current.

Basins/ sub-basins[1]	Area (km^2)	Rainfall (mm/year)	Evaporation (mm/year)	Average flow (m^3/s)	Specific flow ($l/s/km^2$)
80-88	224 000	1 394	789	4 300	19.2
54-59	303 000	1 229	847	3 670	12.1
50-53	240 000	895	806	608	2.8
40-49	634 000	916	774	2 850	4.5

Note: [1]Used by the National Agency of Electric Energy (ANEEL). (Source: ANEEL 2002)

The East Atlantic Basins comprises 10 groups of basins (50-59 in Figure 2) with over 35 small to medium-sized rivers, all oriented towards the coast. The mean annual water volume of the East Atlantic Basins is 117 km^3 and the average flow is 4 350 m^3/s. The Basins are characterised by a climatic gradient with dryer conditions in the middle and upper reaches of the northern watersheds and humid conditions all along the central and southern watersheds. The run-off yield of the rivers increases considerably from north to south. The small southward located basins of Rio de Janeiro state (basins 59 in Figure 2), which drains the coastal lagoons and the Bays of Guanabara, Sepetiba and Angra dos Reis of the state of Rio de Janeiro has been allotted to the South/Southeast Atlantic Basins. In this way, the boundaries of the South/Southeast Atlantic Basins become coincident to the Large Marine Ecosystem (LME) 15 South Brazil Shelf, which makes it possible to share information directly between the GIWA region and the LME 15. The mean annual freshwater input of this sector is 3 670 m^3/s, the run-off yield 12.2 $l/s/km^2$, and precipitation and evaporation, 1 229 mm/year and 847 mm/year, respectively. About 60% of the total mean annual discharge of the East Atlantic Basins is accounted for by the three medium-sized (catchment basins from 50 000 to 100 000 km^2) and transboundary rivers: the Jequitinhonha (393 m^3/s), Doce (947 m^3/s) and Paraíba do Sul (859 m^3/s), and 9% by small-sized catchment basins (from 5 000 to 50 000 km^2). These include the Mucuri (113 m^3/s) and the São Mateus (81 m^3/s), located north of the Doce River, and the Itapemirim (74 m^3/s) and the Itabapoana (57 m^3/s), located between the Doce and the Paraíba do Sul rivers. The stretch between the Jequitinhonha and Doce rivers is characterised by a large number of small-sized rivers, which flow out to sea along the coast of the Abrolhos Bank. Apart from the Mucuri River, their average annual discharge lies in the range of 10 to 30 m^3/s (ANA 2002a).

The São Francisco River Basin is composed of 10 sub-basins (40-49 in Figure 2), feeding the 2 700 km long São Francisco River, at various points along its course. The São Francisco River delivers an average annual water volume of 106 km^3 to the northeastern coast, its average flow is 2 850 m^3/s and the run-off yield is low, at 4.5 $l/s/km^2$. The mean annual precipitation is 916 mm/year and evaporation 774 mm/year (Table 1). Due to its large extension, it is characterised by different climatic and flow regimes. About 50% of the drainage basin lies within the Brazil Drought Polygon of the Northeast. Its river sources lie in the humid Canastra Mountains in Minas Gerais. Part of the middle and the lower-middle sectors are governed by semi-arid conditions and the São Francisco delta by humid conditions. About 84% of the rainfall is lost by evaporation, 11% corresponds to the river run-off and about 5% replenishes the water table. São Francisco River Basin has 36 tributaries, of which 19 are perennial, the most important being the Paraopeba, das Velhas and Verde rivers on the right bank, and the Paracatu, Urucuia, Caranhanha, Corrente and Grande rivers on the left bank. Except for the Verde River, the watersheds of these rivers lie outside the Drought Polygon and, although they represent only 50% of the basin's total area, they account for 85% of low water flow and 74% of the entire basin's flow delivered to the coast (ANA 2002a).

Lakes are scarce in the Atlantic Rainforest region, but the lower São Francisco River and the lower alluvial reaches of the largest rivers of the East Atlantic Basins, contain temporary and permanent flood plain lakes. The rivers of the East Atlantic Basins and particularly the São Francisco River Basin are spiked by many small, medium and large-sized dam reservoirs (ANEEL 2002).

Geomorphology and geology

The coastal zone of Brazil is defined by four geomorphological provinces, the Northern Quaternary (4° N to 3° S) or the Amazon plain, the Eastern Tertiary (3° to 20° S), the Southeastern Granitic (20° to 29° S), and the Southern Quaternary (29° to 34° S) (Figure 1) (Guerra 1962, Asmus 1984, Tomazelli & Villwock 1996). The Tertiary province includes the entire GIWA regions Brazilian Northeast (40a) and East Atlantic Basins, with the hinterland of the lower portion of the São Francisco River Basin. The Tablelands or "Tertiary Barreira Formations", is the most important and extensive geomorphological unit of the area. These have an extremely flat surface with deeply incised flat-bottom valleys, comprised of unconsolidated Late Tertiary alluvial sediments. These may outcrop as fossil bluffs along the shoreline, representing a significant reservoir of sediment to the coastal waters. The coast is largely restricted to a narrow littoral fringe up to a few kilometres wide (Lacerda et al. 1993a), but wider Quaternary coastal plains are embedded with deposits of various origins, such as beach-ridge plains, wetlands and coastal dune fields. The widest plain is found along the northern section of the granitic coast (20° to 23 °S), at the transition between East and Southeast regions, with the Paraíba do Sul River delta. The southern Quaternary coast (southern South/Southeast Atlantic Basins), harbours the extensive Pleistocene/Holocene Patos-Mirim Lagoon system and more than 60 Holocene coastal lagoons.

The Atlantic mountain range of pre-Cambrian metamorphic and igneous rocks runs parallel to the coast along most of the region. The mountain range is set closest to the coast and is steepest in southeastern Rio de Janeiro state and São Paulo, as in the case of the Mantiqueira range, with regional altitudes of 1 200 to 1 800 m. It harbours the mountain peaks of the Agulhas Negras massif up to 2 785 m and the Caparaó massif up to 2 890 m. To the north, the Espinhaço range, backed by the São Francisco Basin, exhibits altitudes of 1 000 to 1 200 m and peaks up to about 2 000 m. Further north, the Diamantina Plateau and the Trombador range, vary in altitudes of 500 to 800 m. Podzols, rich in iron, dominate the southern coastal and inner parts and Latosoils, the central and northern parts of the East Atlantic Basins.

Climate

Air-masses

The Brazil Current region forms part of the Brazilian Inter-tropical Domain, characterised by a warm climate of equatorial and tropical types. It is controlled by the circulation of five air-masses (Nimer 1972): the Inter-Tropical Convergence Zone (ITCZ); the Equatorial Continental (Ec); the Equatorial Atlantic (Ea); the Tropical Atlantic (Ta); and the Polar Atlantic (Pa). Their circulation and spatial extent vary according to season. As hurricanes do not occur in the South Atlantic, the climate is mainly defined by the Tropical and Polar Atlantic air masses associated with ITCZ. The northeastern and eastern coasts are therefore dominated by the south-easterly and easterly trade winds. Along the eastern coast, a divergence zone of the trade winds occurs and northeasterly trade winds blow southwards. The northeasterly winds prevail during austral spring and summer and rarely surpass speeds of 5 m/s. The seasonal variation of the South Atlantic high pressure cell produces an oscillation of the divergence zone between 10° and 20° S and also in the direction of the trade winds. Summer forms the exception as it is the only season during which the Equatorial Continental air-mass (warm and humid) reaches the East Atlantic Basins. Ec, formed in the warm Amazon by the oceanic winds from the North Equatorial air-mass, expands towards the southeast and is responsible for the typical high summer rainfall along the coast. The Tropical Atlantic air mass (warm and relatively humid) from the ocean is dominant along the coast of the South/Southeast Atlantic Basins and is also responsible for the summer rainfall in the area. In fall and winter, Ec retreats north-westwards back to the Amazon. The Equatorial Atlantic (mild and humid at the surface) and the Tropical Atlantic air-masses cover the East Atlantic Basins/São Francisco River Basin and the South/Southeast Atlantic Basins, respectively. They induce a lower rainfall along the coastal zone, but still possess sufficient humidity to deliver rainfall when barred by the Atlantic mountain range, which runs parallel to the coast along most of the Brazil Current region. The ITCZ represents the convergence zone of the southeast and northeast trade winds, driven from the sub-tropical high-pressure systems of both hemispheres to the equatorial through low pressure. The thermal discontinuity is accompanied by frequent torrential rainfall. During summer-autumn, ITCZ migrates southwards towards the transition zone of GIWA region Brazilian Northeast (40a) and East Atlantic Basins/São Francisco River Basin, bringing about intense rainfall and its displacement to the north in winter-spring-induces dry conditions.

El Niño/La Niña

Phenomena such as the El Niño/La Niña also play a crucial role in the Brazil Current region, disrupting some of the "normal" climatic conditions. During El Niño conditions, the polar frontal systems are blocked and diverted eastwards out to the Atlantic and trade winds are barred at the front. The blockage system extends from southern Peru to southern Brazil and its position oscillates in relation to the degree of enhancement of the sub-tropical jet stream and, of course, intensity of the El Niño phenomenon. This situation provokes an anomalously high rainfall in the blocking zone and drought northward, as well as modification of the wind patterns, and consequently of the wind-driven littoral dynamics. The position of the blockage system corresponds more or less to the intense El Niño event of 1982/1983, that is, between 20° S and 25° S. In contrast, when La Niña events prevail, the north of the East Atlantic Basins undergoes intense rainfall.

Köppen type climates and precipitation

Brazil Current presents tropical and sub-tropical climates. According to the detailed climate classification of Köppen (Nimer 1972) Brazil Current encompasses the following specific climatic regimes (Figure 4): "As" (tropical humid with winter/ autumn rainfalls) characterises the northern stretch from São Francisco River delta down to Salvador in Bahia state; "Af" (tropical humid with rainfall all year long) goes from Todos os Santo Bay point down to southern Bahia; and "Aw" (tropical humid with dry winter/wet summer) governs the western São Francisco River Basin and the central part of the East Atlantic Basins down to Rio de Janeiro state. The climate in the eastern, middle and lower São Francisco River Basin as well as the northwestern East Atlantic Basins is "BSh" (semi-arid hot with dry winter). The upper São Francisco River Basin in Minas Gerais and close portions of the East Atlantic Basins are "Cwa" (sub-tropical, wet and hot summer) and Cwb (sub-tropical wet and mild summer). A small portion of the East Atlantic Basins and most of the South/Southeast Atlantic Basins present Köppen climate type "Cfa" (sub-tropical humid, rainfall all year long, hot summer) and "Cfb" (sub-tropical humid with rainfall all year long and mild summer).

The average annual precipitation and evapotranspiration are shown in Figure 5. The annual precipitation along the coast of South/Southeast

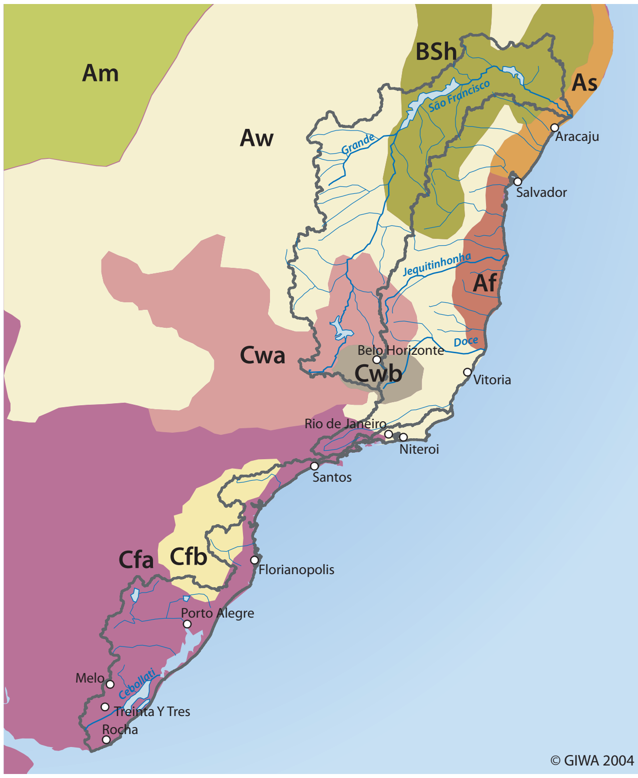

Figure 4 Köppen type climate classification of Brazil and its coastal zone.

As = Tropical humid with winter rainfall; Af = Tropical humid with frequent rainfall; Aw = Tropical humid with wet summers; Aw= Tropical humid with wet autumn and summers; Cfa = Temperate humid and warm summers; Cfb = Sub-Tropical humid with uniformly distributed rainfall, cool summer and white frost winter; Cwa = Highland Tropical wet summers and dry winters; Cwb = Highland Tropical wet and cool summers and dry winters; BSh = Tropical dry semi-arid winter rainfall.

(Source: Nimer 1972)

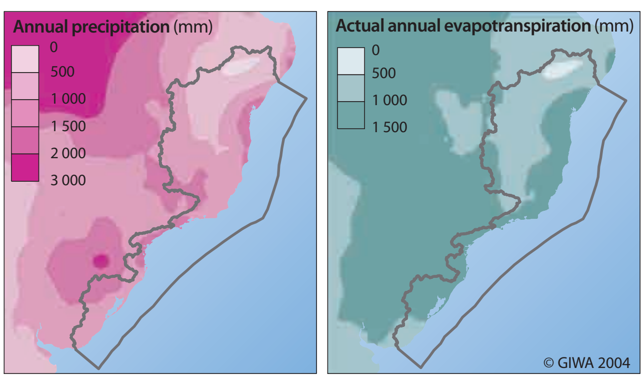

Figure 5 Annual precipitation and evapotranspiration.

(Source: USGS 2002)

Atlantic Basins and East Atlantic Basins is between 1 000 and 1 500 mm, except for some sectors of the states of Rio de Janeiro and São Paulo ("Aw") with 1 500 to 2 000 mm and the coast of the state of Bahia with 1 850 to 2 400 mm ("Af") (Nimer 1972). Precipitation exhibits a typical unimodal seasonal pattern, with highest rainfall in austral spring (September to November) and summer (December to February) and lowest in fall (March to May) and winter (June to August). In contrast to the coast, the hinterland of the northern portion of East Atlantic Basins and of the lower portion of São Francisco River Basin is tropical dry with semi-arid conditions (Köppen type "BSh" in Figure 4). Autumn-winter rainfall occurs from March to August and the dry season is from September to February.

Currents

Western boundary currents

The surface waters of the Brazil Current region are governed by the South Equatorial Current (SEC) in the northeast, the southward meandering Brazil Current (BC) in the east, southeast and south (Figure 1) and the Brazil Undercurrent or South Atlantic Central Waters (SACW), which flow northwards below BC along the shelf-edge.

Three branches of the South Equatorial Current (SEC) impinge directly upon the shelf and coast between 7° and 17° S (Figure 1) (Stramma et al. 1990). This area represents the Northern tropical transition zone of East Atlantic Basins/São Francisco River Basin and GIWA region Brazilian Northeast (40a). At about 7° to 10° S, a total of 12 Sv (1 Sv = 1 million m^3/s), or more, from the SEC flows northwestward as the North Brazil Current (NBC) (da Silveira et al. 1994) and, at around 15° S, only 4 Sv form the weak southward flowing Brazil Current (BC). More is transferred from the SEC to the BC along the eastern and southeastern Brazil, at a rate of 5% per 100 km (Evans & Signorini 1985, Peterson & Stramma 1991). The Abrolhos bank and the Vitória-Trindade ridge form a topographical barrier to the BC, inducing fundamental changes and spatial variability in physical, chemical and biological features over the shelf and along the shelf edge (Castro & Miranda 1998, Ekau & Knoppers 1999). Eddies along the eastern shelf edge and cyclonic vortices at the southern edge (i.e. Vitória Eddy) (Schmid et al. 1995) of the Abrolhos bank are generated. Coastal upwelling of nutrient-rich South Atlantic Central Waters (SACW) characterises the area south of Abrolhos in spring and summer (Summerhayes et al. 1976), resulting in higher primary production (Gaeta et al. 1999). Off the state of Rio de Janeiro, where the coast and shelf abruptly deflects in an east-west direction, one encounters the focus of the Cabo Frio upwelling, enhanced by the frequency and intensity of the northeast trade winds and the specific geomorphological configuration of the shelf. At Cabo Frio, mesoscale eddies are detached from the BC. Some are driven southwestwards to the coast of the state of Rio de Janeiro. The impact of the Brazil Current on the coast and middle shelf system from Cape São Tomé and the South Brazil Bight gradually diminishes towards the south. The BC meanders along the shelf-edge and its Surface Tropical Waters (STW) mix with shelf waters. The Southeast and South regions are subject to more intense shelf edge and wind-driven coastal upwelling of the SACW, particularly in summer and at Cape Santa Martha (28° S) (Bakun 1993, Garcia 1997).

The sector between 28° and 37° S is considered as the Southern Sub-tropical Transition Zone of the Brazil Current and Patagonian Shelf regions. It is affected by the Southwest Atlantic Convergence Zone (SACZ), which expands and contracts at the shelf and offshore, coastal and shelf-edge upwelling of SACW, freshly fuelled by the Malvinas Current, and the La Plata River plume edging northwards along the coast. The continent and inner shelf also harbours the large Guaraní Aquifer, shared by both regions.

Coastal currents, waves and tides

Information on the behaviour of coastal currents is relatively scant, except for some regions characterised by intense port activities. In general, they flow northwards parallel to the coast, particularly during calm weather conditions, but their behaviour becomes highly dynamic during the seasons characterised by the frequent alternation between northeast trade winds and the passage of southeast fronts. Off the state of Rio de Janeiro, the coastal current regime is more complicated, due to the east-west orientation of the shoreline, and the impact of upwelling and eddies. At the coast of the Abrolhos bank, coastal currents are directly affected by the configuration of the coast parallel reefs, they flow southward during prevalence of northeast winds and velocities are augmented in the narrow reef channels. The south-southeastern and part of the eastern coasts up to the Abrolhos bank are dominated by semi-diurnal microtides (0-2 m) and the remainder of the eastern coast by mesotides, up to 3 m. The entire coastal region is classified as a high wave energy coast, conditioned by the variation in trade winds along the east, and is related to movements of the offshore high-pressure centres. The sea waves generally impinge the coast at periods less than 7 second and more than 50% have amplitudes of more than 1 m. Eastern waves dominate the East Atlantic Basins/São Francisco River Basin throughout the year and southeast waves in the south, particularly in winter.

The shelf

The shelf (Figure 1) has a diverse geomorphological configuration, with eminent differences between East Atlantic and South/Southeast Atlantic Basins (Martins & Coutinho 1981, Knoppers et al. 1999b). The shelf area, delimited at the shelf-edge by the 200 m isobath, is 107 000 km^2 for the East Atlantic Basins/São Francisco River Basin and 303 000 km^2 for the South/Southeast Atlantic Basins. The shelf of the East Atlantic Basins includes three well-defined sectors. A northern sector, from the São Francisco River delta to the Royal Charlotte Bank (20-50 km wide), a central sector corresponding to the Abrolhos Bank, with maximum widths of about 245 km, and a southern sector up to Cape São Tomé, with widths of 45 to 90 km. The narrowest shelf with a width of 8 km is found off Salvador, Todos os Santos Bay, state of Bahia. The sector including the Royal Charlotte and Abrolhos banks to Cape São Tomé, is denominated by Castro & Miranda (1998) as the Abrolhos-Campos Region (15° to 23° S). The Abrolhos Bank accounts for 56% of the shelf area of the East Atlantic Basins/São Francisco River Basin and lies directly in the pathway of the southward flowing Brazil Current, inducing fundamental changes of its physical regime. The shelf of the South/Southeast Atlantic Basins is less diverse, as the shelf-edge essentially follows the perimeter of the coastline, being concave in the southeast and more or less rectilinear in the south. Shelf widths vary between 80 and 220 km, being widest off Santos Bay, state of São Paulo. The shelf break varies in depth from 40 to 80 m in the east, similar to that of the GIWA region Brazilian Northeast (40a), and 100 to 160 m in the South/Southeast Basins. The depth of the base of the shelf slope is from 1 600 to 3 600 m in the East Basins and 2 000 to 3 600 m in the South/Southeast Basins. The slope gradient in the east and northeast is high (1:5, 11°) and reaches a maximum of 28° at the Abrolhos bank.

The continental shelf bottom

The East and South/Southeast Brazil Shelf sectors differ considerably in their sediment distribution and benthic habitats (Milliman 1975, Lana et al. 1996). The transition zone between tropical habitats of the north and sub-tropical to temperate habitats of the south is set between Cape São Tomé and Cabo Frio, state of Rio de Janeiro. In general, the sediments to the south contain less carbonates, in comparison to the north (Melo et al. 1975, Summerhayes et al. 1976). The South/Southeast Shelf harbours several sedimentary provinces (Milliman 1975, Mahiques et al. 1999). Sediments with more than 50% of calcium carbonate are encountered off Cabo Frio and to the north. These also form a band along the outer shelf between Cabo Frio and Rio Grande do Sul, with coralline algae progressively being substituted by molluscs, cirripeds and Foraminifera.

The sediments of the shelf-edge and slope are fine, with a sandy fraction dominated by planktonic foraminiferans. Some muddy deposits at the edge harbour remnants of crinoids, anthozoans and polychaete tubes. The internal and middle shelf areas off Cabo Frio are rich in quartz and the mid-shelf sediments to the south are mainly made up of silt and clay. The coastal sediments are composed of 90% well worked sand and gravel and finer terrigenous material at river mouths. Typical organic rich sediments, as found in regions with continuous upwelling, are not present. The main invertebrate groups of unconsolidated intra-littoral sediments are the molluscs, decapods, echinoderms and polychaetes.

Off Rio Grande do Sul state (South/Southeast Atlantic Basins), 234 macro-invertebrate species are found, with most belonging to the mid-shelf area between 60 and 120 m depth, characterised by silty-clay sediments (Lana et al. 1996). The East Brazil Shelf is dominated by carbonate sediments over its entire mid- and outer regions (Melo et al. 1975). Bioclastic carbonate gravel and sands with free living non-articulated coralline red algae *Halimeda*, benthic Foraminifera and mollusc debris are also encountered in some regions of the inner shelf (Martins & Coutinho 1981). The inner shelf is a mixing zone of siliclastic and carbonate sediments. The siliclastics originate from the rivers, coastal erosion of the fossil bluffs of the Tertiary Tablelands, and from earlier deposits during lower sea level stands (Leão 1996). The carbonates are autogenic from growth of calcareous organisms, including red and green algae.

At the mouths of the São Francisco, Jequitinhonha, Doce and Paraíba do Sul rivers siliclastic sediments are deposited and interrupt the dominance of the carbonate facies (Martins & Coutinho 1981, Leão 1996). Coral reefs occur along most of the carbonate province and the main carbonate sediments are mollusc shells, debris of calcareous algae, bryozoans, benthic Foraminifera tests, and echinoids.

Water masses and nutrients of shelf-oceanic waters

The region is characterised by four main water masses (Castro & Miranda 1998): the Brazil Current; Surface Tropical Waters of the Brazil Current; South Atlantic Central Waters; and Coastal Waters. Apart from the South Atlantic Central Waters, which represent the source of coastal and shelf-edge upwelling, all are oligotrophic in nature, poor in nutrients and phytoplankton biomass.

The main physical-chemical characteristics of the water masses are presented in Weber et al. (1994), Nienscheski & Baumgarten (1997) and Castro & Miranda (1998). The Coastal Waters are in general restricted to a very narrow band along the shore and may only be encountered a few kilometres off the coast in front of the larger river systems of the East Brazil Shelf. The nutrient and phytoplankton biomass concentrations of the Coastal Waters are low due the small nutrient yields of the watersheds and the efficient dilution by the Surface Tropical Waters of the Brazil Current (Ekau & Knoppers 1999). Coastal upwelling is seasonal and foci occur from the southern part of the Abrolhos Bank to about Cape Santa Marta in the south (Castro & Miranda 1998, Ekau & Knoppers 1999).

Productivity of the shelf waters

The most productive regions of the Brazilian shelf are the North Brazil Shelf LME 17 (part of GIWA region 40b Amazon) and the South Brazil Shelf LME 15 (South/Southeast Atlantic Basins, plus basins 59 in Figure 2, corresponding to Rio de Janeiro littoral basins). The least productive is the East Brazil Shelf LME 16 (basins 58-50 of East Atlantic Basins and part of part of GIWA region 40a Brazilian Northeast). South Brazil Shelf corresponds to a Class II LME with moderately high productivity (Sherman 1993). The productivity is high in the south and decreases towards the southeast. East Brazil Shelf corresponds to a Class III LME, with a low productivity and a diverse food web (Sherman 1993).

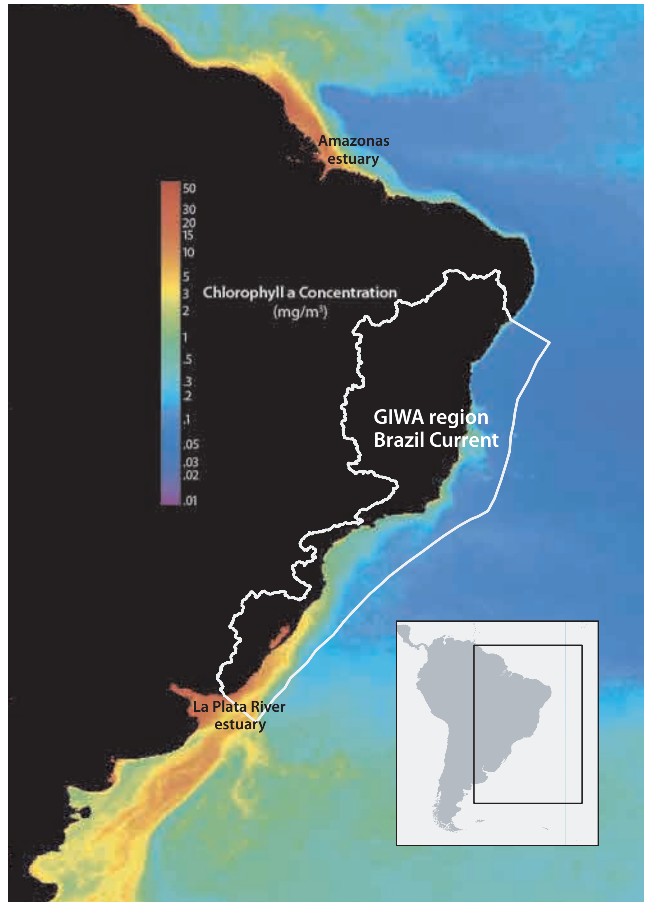

Figure 6 Chlorophyll a concentration in the coastal area.

Chlorophyll a concentration from satellite Aqua-MODIS, average for 2003. The figure includes from north to south: GIWA region 40b Amazon, GIWA region 40a Brazilian Northeast and GIWA region 39 Brazil Current, followed by the small upper portion of GIWA region 38 Patagonian Shelf with the La Plata River estuary in the bottom of the figure showing a high concentration of chlorophyll a.

(Source: NASA 2004)

The composite plot of chlorophyll a concentrations from the SeaWiFS satellite image in Figure 6 reflects the higher potential for primary production in the south portion of the South America Atlantic coast (upper portion of GIWA region 38 Patagonian Shelf and the South/Southeast Atlantic Basins) as well as the upper coast corresponding to GIWA region 40b Amazon. In the south, multiple sources sustain production, such as the Patos-Mirim Lagoon system and La Plata River, and coastal, shelf-edge and offshore (cyclonic vortices) upwelling (Seeliger et al. 1997). Primary production is marked by spatial and seasonal variability. Rates are higher during summer, when upwelling of SACW is frequent.

Table 2 Physical and chemical characteristics of Brazil Current.

Parameter	Brazil Current	Surface tropical waters	South Atlantic central waters (upwelling at 50 m)	Coastal waters
Temperature (°C)	>22	>18	>6>18	>18
Salinity (‰)	>39.9	>35.9<36.9	>34.6<35.9	<35.9
Dissolved oxygen (mg/l)	4.5-5.0	4.2-5.0	4.5-5.5	4.0-5.5
Orthophosphate (µM)	0.05-0.2	0.05-0.3	0.8-1.5	0.1-0.4
Dissolved inorg. nitrogen (µM)	0.1-0.5	0.1-0.6	10-18	0.3-3.0
Dissolved silicate (µM)	1.0-4.0	2.0-5.0	5-15	2.0-6.0
Chlorophyll a (µg/l)	0.05-0.2	0.2-0.4	0.2-6	0.4-2.0

(Source: Knoppers et al. 1999a)

Table 2 shows the physical and chemical characteristics of Brazil Current. Primary production rates in coastal and upwelling waters off Rio de Janeiro vary between 0.3 and 1.3 gC/m^2/day. In the mid- and outer shelf waters off the coast of the Sao Paulo and Paraná states, between 0.1 and 0.5 gC/m^2/day, and in the south off the Rio Grande state between 0.3 and 2.9 gC/m^2/day. The average annual primary production of the shelf off the Patos Lagoon system is 160 gC/m^2/day (Brandini et al. 1997, Seeliger et al. 1997, Ekau & Knoppers 1999).

The East Brazil Shelf harbours low productive regions, as indicated by the distribution of chlorophyll a (Figure 6), due to the impact by the SEC. The productivity of the SEC and the western boundary currents lies within the range of 0.02 to 0.2 gC/m^2/day. The Brazil Current off Cabo Frio has a primary productivity of 0.2 gC/m^2/day. The coastal, shelf and offshore waters of the East between 16° and 22° S are characterised by a high spatial variability of primary production.

At the Royal Charlotte Bank, towards the north of the Abrolhos Bank, primary production rates in fall lie within the range of 0.1 to 0.5 gC/m^2/day, over the Abrolhos Bank within 0.3 and 0.8gC/m^2/day, and the south of the Abrolhos Bank within 0.3 and 1.1 gC/m^2/day (Gaeta et al. 1999).

Highest rates have been recorded at the inner shelf, where coastal upwelling waters of SACW proliferate along the bottom at 50 m depth. Medium to high rates characterise the oceanic waters south of the Abrolhos Bank in the cyclonic Vitória Eddy (Schmid et al. 1995). The eddy moving towards the shelf creates upwelling of nutrient-rich SACW, enhancing productivity in sub-surface waters. The lower southern part of the East region seems to be a distinct functional region, where primary production may temporarily be sustained by three different sources, the medium-sized Paraíba do Sul and Doce rivers, coastal upwelling and probably also the Vitória Eddy, when it reaches the shelf (Ekau & Knoppers 1999).

The plankton communities

The complex pattern of water mass distribution of the LME East Brazil Shelf and especially around the Abrolhos Bank (AB) is reflected by the distribution of plankton biomass and composition (Brandini et al. 1997). Highest biomass and individual densities of pico-, nano-, micro- and macro-plankton characterise the southern coast and the Abrolhos Bank (Susini-Ribeiro 1999). The microplankton community in the East Brazil Shelf is dominated by pico- and nanoplankton, showing concentrations typical for shelf and oceanic habitats. Among these, autotrophic picoplankton forms the dominant group in the cold-water mass, reaching concentrations of up to ≈110 µg C/l on the southern shelf. The very high ratio of total heterotrophic bacteria versus total heterotrophic nanoplanktonic flagellates suggests that the system is dominated by microbial processes, which means flagellates transfer bacterial biomass directly to higher trophic levels. The microbial-planktonic food web is heterogeneous and very diverse (Susini-Ribeiro 1999). The distribution patterns of different taxonomic groups and the microplankton are defined by a clear separation of the SACW-upwelling impacted shelf community coming from the southern part, and the warm-water community influenced by the BC (Brandini et al. 1997, Ekau & Knoppers 1999).

Indicator species such as several copepods e.g. *Clausocalanus furcatus*, *Undinula vulgaris*, *Nannocalanus minor*, *Scolecithrix danae*, *Lucicutia flavicornis*, *Euchaeta marina* for tropical water; *Temora stylifera, Calanopia americana*, *Acrocalanus longicornis* and *Calanoides carinatus* for neritic water, shows that the area between the southern edge of Abrolhos Bank and Cape São Tomé/Cape Frio is a transition zone from a northern tropical warm water community to a southern colder, upwelling community with changes in the trophic web structure. The macrozooplankton is dominated by calanoid and cyclopoid copepods. The oligotrophic character of the eastern shelf system and its diverse food web structure is in clear contrast to the Southeast-South shelf system. Mesopelagic species dominate the ichthyofauna community in the Brazil Current with water depths more than 200 m. On the Abrolhos Bank, demersal ichtyoplankton species dominate the system, largely herbivorous fish, possibly relying on the primary production of benthic algae. Thus the food web here with a high diversity in herbivorous fish is in sharp contrast to the southeast Brazilian system, where diversity is low at the herbivorous level with only three species: sardine (*Sardinella brasiliensis*), anchovy (*Engraulis anchoita*) and *Maurolicus* spp. (Matsuura pers. comm.).

Biomes

The predominant original forest covering the Brazil Current (land area) was the Atlantic Rainforest, which stretched from north to south of the Brazilian Atlantic coast (the origin of the forest's name), and has

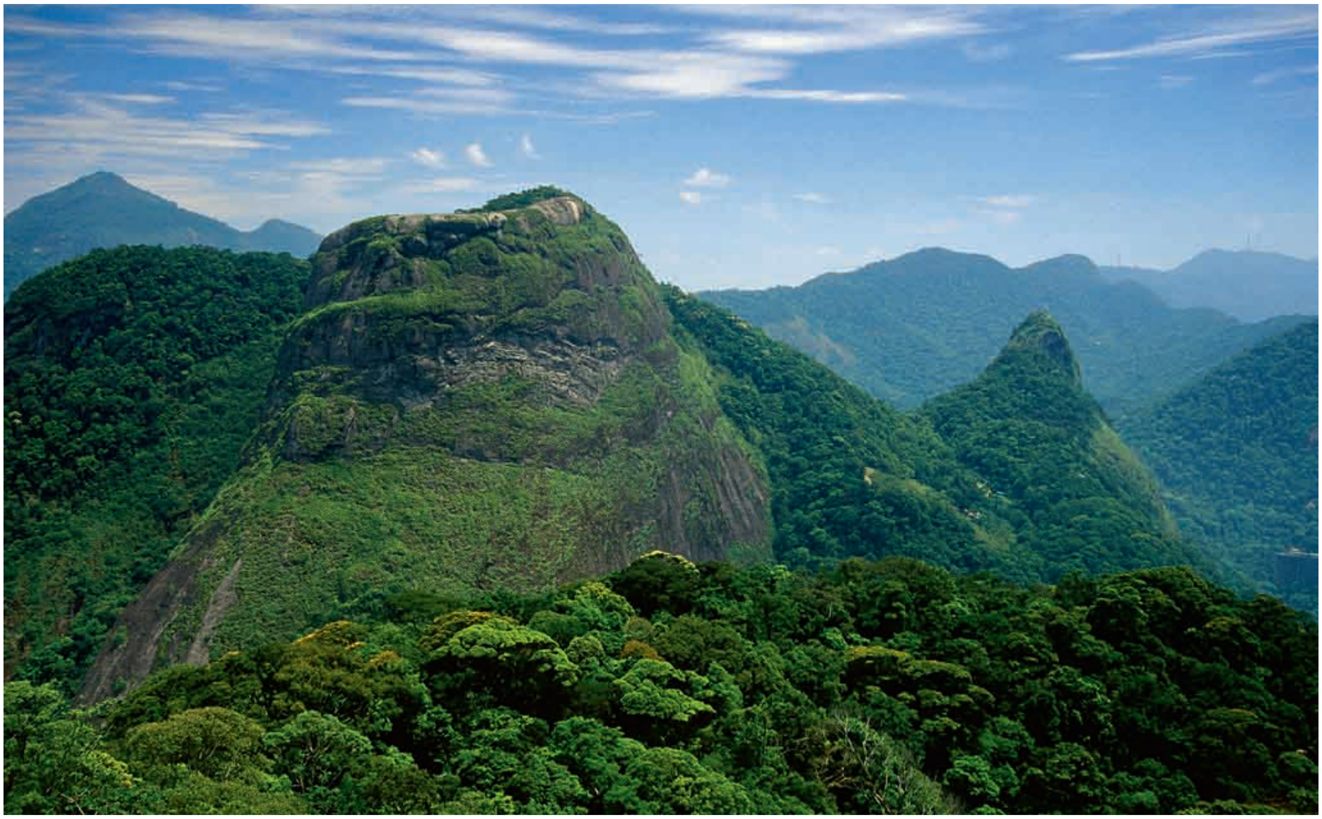

Figure 7 Overview of the Atlantic Forest: Tijuca National Park in Rio, the largest urban forest in the world.
(Photo: Corbis)

been severely impacted by human activities, mostly in the portion included in the Brazil Current. Fragments of Atlantic Rainforest are found in the whole Brazil Current region. Another biome, "Caatinga", or dry thornbush, adapted to severe climate conditions is found in the East Atlantic Basins and São Francisco River Basin. Finally, "Cerrado", or high plain bush, biome is found in small areas of the East Atlantic Basins and approximately half of the São Francisco River Basin. The natural moorland formations Sulinos Fields, which appears mainly in the high areas of the south of the South/Southeast Atlantic Basins in Rio Grande do Sul state has been greatly altered by forest fires, cattle raising and crop plantation. Approximately 2.5% of the area is conserved with the original vegetation. Araucária Forest exists in small sections in high areas (above 600-800 m), and has been also impacted by intense human activities, mainly as a result of the timber trade at the start of the last century. Salt marshes and mangroves are found along different portions of the Brazilian coast, the Brazil Current portion being the most impacted due to anthropogenic activities.

Atlantic Rainforest

The domain of the Atlantic Rainforest biome includes a group of forest formations encompassing 17 Brazilian states, among them, all 12 states that are entirely or partially included in the Brazil Current region: Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Rio de Janeiro, Minas Gerais, Espírito Santo, Bahia, Sergipe, Alagoas, Pernambuco and Goiás. The other Brazilian states that host part of the Atlantic Rainforest are: Rio Grande do Norte, Ceará, Piauí (GIWA region 40a Brazilian Northeast); Mato Grosso and Mato Grosso do Sul (GIWA region 38 Patagonian Shelf).

The most important fragments of Atlantic Rainforest are found along the southern granitic sector of the South/Southeast Atlantic Basins, along stretches of the steep relief coastal mountain range of the states of Santa Catarina, Paraná, São Paulo and Rio de Janeiro. In the East Atlantic Basins, the most important forest fragments are located in the southern part of the state of Bahia, between the Jequitinhonha and the Caravelas coastal plains; the Pardo River basin harbours a lush rainforest reserve close to the coast. About five centuries ago, when Brazil was colonised by Portugal, the Atlantic Rainforest covered 15% (1.29 million km^2) of Brazil's territory (Figure 8). About 92.7% of this coverage has disappeared. Only 7.3% (94 000 km^2) of the original forest remains today (Fundação SOS Mata Atlântica & INPE 2002). The Atlantic Rainforest is the second most endangered ecosystem in the world, after the already almost extinguished forest of Madagascar Island off the coast of Africa. Based on recent studies, the Atlantic Rainforest

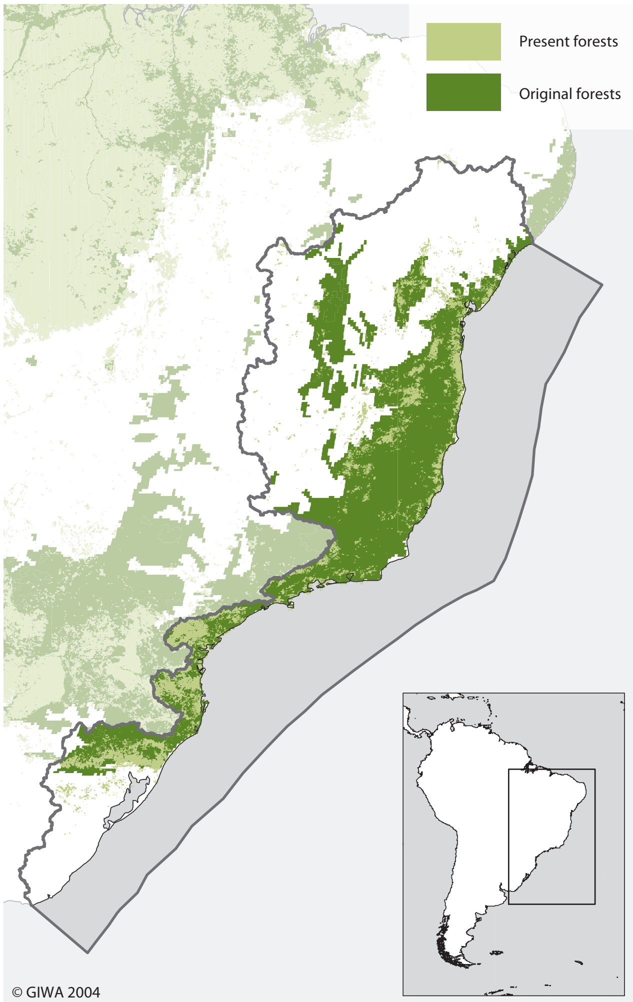

Figure 8 Present and original cover of the Atlantic Rainforest.
(Source: Loveland et al. 2000, UNEP-WCMC 2004)

has been considered the highest priority for biodiversity conservation in the American continent. Even the remaining 94 000 km² are not equally distributed among the different forested areas that form the biome. Several of these forest areas are almost extinguished, in bad conservation, or not properly protected in conservation units. The Atlantic Rainforest hosts a unique biological diversity, with extremely high degree of endemism, resulting from the evolutionary process that made it geomorphologically isolated from other areas.

Particularly in the Brazil Current, the Atlantic Rainforest had an important influence on the existing biodiversity of aquatic species that present the highest degree of endemism among fish species. The devastation process suffered by the Atlantic Rainforest due to anthropogenic pressures in the Brazil Current is a valuable indicator of the pressures also imposed on the aquatic systems nourished by the forest. Most of the Brazilian plants and animals listed as endangered species are endemic to the Atlantic Rainforest. The majority belong to the East Atlantic Basins. It is estimated that the rainforest hosts 261 species of mammals (73 of them are endemic species), 620 species of birds (160 endemics) and 260 species of amphibians (128 endemics). For some groups, such as primates, more than two thirds are endemic species. Seven species that disappeared recently were from the Atlantic Rainforest. Among 202 species threatened, 171 are found in Atlantic Rainforest. Among 10 000 species of plants, 50% are endemic. The level of endemism increases significantly when the species are separated by groups: 53.7% of trees; 64% of palm trees; and 74.4% of bromeliads. Many plants with pharmaceutical values which have not been properly studied are found in the Atlantic Rainforest. Even in the fragmented shape it is today, the forest guarantees water supply and quality of life for more than 70% of the Brazilian population. The regulation of water flow, the soil fertility, climate and stability of hills have been attributed to the forest. The deforestation rate of the Atlantic Rainforest is extremely high: 2.5 times the deforestation rate observed in the Amazon Forest during the period 1990-1995 (Fundação SOS Mata Atlântica & INPE 2002). During this period, 500 317 ha of forest were deforested. If this rate continues, in 50 years the forest will disappear from the private properties. The Brazilian state that had the highest deforestation rate was Rio de Janeiro: 140 372 ha, or 13.13% of the state's forest in only five years.

Biodiversity in freshwater fish associated to the Atlantic Rainforest

The existence of a high number of independent and relatively small drainage basins, additionally separated by the mountain chains, favoured the reproductive isolation during the evolutionary process in the Atlantic Rainforest. As a consequence, a very high degree of endemism, mostly of small-size freshwater fish is found. Among 38 identified hotspots in terms of fish endemism in the Atlantic Rainforest, 29 are placed in the region Brazil Current and one is partially located in Brazil Current and partially located in the biome South Fields of Brazil (which is part of GIWA 38 Patagonia Shelf) (MMA 2000).

Mangrove

(Extracted from Dov Por 2003)

The Brazilian coast has, in a surface of around 20 000 km², from Cape Orange, in Amapá (GIWA region 40b Amazon), to the municipality of Laguna, in Santa Catarina (South/Southeast Atlantic Basins), a narrow strip of mangrove forest called "manguezal" or "mangue" (Figure 9) or mangrove swamp. This is composed of a small number of tree species and develops mainly in estuaries and river mouths, where there is salt water and places semi-protected from the action of the waves, but open to receive sea waters.

Figure 9 Red mangrove tree in clear waters. Boipeba Island, southern Bahia state, East Atlantic Basins.
(Photo: Luiz C. Marigo/Still Pictures)

According to Dov Por (2003), the mangrove ecosystem is an environment with a good supply of nutrients, where under the muddy soils there is a tissue of roots and vegetable matter partially decomposed, a kind of peat. In the estuaries, the muddy beds are crossed by tidal creeks ("gamboas") used by fauna for movement between the sea, rivers and the mangrove. Brazil has one of the largest extensions of mangrove in the world. Underrated in the past because the presence of the "mangue" was intimately associated to yellow fever and malaria, the mangrove has long been considered an inhospitable environment, due to the presence of different species of mosquitoes. Until the mid 1970s, the "progress" of the coast was considered to be equivalent to clean beaches, landfills, ports confined by concrete, and cultivation areas. Despite the great economic and social importance of this biome, during decades such perception was in part responsible for the construction of ports, bathing resorts and coastal roads, reducing the extension of the mangroves. Contrary to other forests, mangroves are not rich in species, but stand out for the great abundance of the populations living in them. For this reason, they may be considered one of the most productive natural biomes in Brazil. Three main tree species constitute the mangrove forests: the red or "bravo" mangrove *Rhizophora mangle*, the white mangrove *Laguncularia racemosa* and the "seriba" or "seriuba" black mangrove *Avicennia germinans*. A few species can be added to the flora of mangrove such as ferns, *Spartina grass*, the bromelia *Tillandsia usneoides*, the lichen *Usnea barbata* and the yellow hibiscus. In the north of the country, the thick mangrove forests have trees which might reach 20 m of height. In the northeast of Brazil, there is a kind of mangrove known as "dry mangue", with small-sized trees in a sub-stratum of high salinity. In the southeast of Brazil, the mangrove has the aspect of a shrub forest. Rich algae communities grow over the buttress roots of trees, in the area covered by the tide. The trunks permanently exposed and the tree tops are poor in epiphytic plants. The fauna includes various species of crabs, forming enormous populations in the muddy beds. Many fish species of the Brazilian coast depend on the food sources of mangrove at least in their young phase. Oysters, mussels and barnacles feed by filtering small fragments of vegetable residues, rich in bacteria, from the water. Prawns also enter the mangroves to feed during high tide. Typical birds are few, due to the small diversity of flora. The abundance of fish attracts predators such as some species of shark and dolphins. The yellow chin alligator *Caiman latirostris* and the frog *Bufo marinus* may occasionally be found there.

Mangroves, used by the "sambaqui" men (tribes which inhabited the Brazilian coast during the pre-Columbian period) more than 7 000 years ago, and since then by the populations who succeeded them, have provided, and provide protein rich food for the Brazilian coastal population.

Restinga

(Extracted from Mantovani 2003)

Restinga is a term used to designate the coastal plains lowland biome covered by marine deposits, resulting from the retreat of ocean levels around 5 000 years ago, during the Quaternary. Following the retreat, lacustrine and fluvial deposits have occurred, containing, in part, material originating from the Crystalline Complex escarpments, characteristic in the south and southeast coasts of Brazil, or from the sandstone of the Formação Barreiras. These plains lowlands are situated within humid tropical climate, with no dry season, and average annual rainfalls of around 1 700 to 2 000 mm (Mantovani 2003).

Caatinga

(Extracted from Rodrigues 2003)

Right in the sub-equatorial zone, between the Amazon Forest and the Atlantic Rainforest, are found the caatingas in the northeast of Brazil. They cover around 700 000 km^2, approximately 10% of the national territory. The climate is semi-arid, with average annual temperatures between 27°C and 29°C, and with rainfall averages less than 800 mm. The inhospitability of the caatinga climate arises especially from the irregularity in the distribution of rain in time and space. The superficial drainage is intense, since the soils are shallow and situated over crystalline rocks (Rodrigues 2003).

Cerrado

(Extracted from Pivello 2003)

Cerrado is the regional name given to the Brazilian savannahs. Around 85% of the great plateau which occupies Central Brazil was originally dominated by the cerrado landscape, representing around 1.5 to 2 million km^2, or approximately 20% of the country's surface. The cerrado region's typical climate is hot, semi-humid and notably seasonal, with rainy summers and dry winters. The annual rainfall is around 800 to 1 600 mm. The soils are generally very old, chemically poor and deep (Pivello 2003).

Physical characteristics of the Uruguayan portion of the region

Uruguay is one of the smallest of the South American republics. Geographically, Uruguay is situated in the southern sub-tropical zone of the South American Continent, between 30° and 35° S and 53° and 58° W. It is bounded to the north by Brazil, to the southeast by the Atlantic, and is separated from Argentina by La Plata River in the south and by Uruguay River in the west. The country has an area of 176 215 km^2. Topographically, it is located in the transition area from the Brazilian plateaux to the Pampean plains. The landscape is made up of hilly meadows broken by streams and rivers. There is a string of beaches along the coast. The country enjoys 680 km of fine sandy beaches on the Atlantic and the La Plata River. The country is divided in 19 political and administrative divisions (departamentos). The northern and the northeastern frontiers separating Uruguay from Brazil follow natural geographical lines. The eastern frontier is the Atlantic Ocean. Uruguay's capital is Montevideo.

Boundary between Brazil and Uruguay

The boundary between Brazil and Uruguay is approximately 985 km long. It is demarcated by marker pillars and rivers, including the Jaguarão River (Yaguarón in Spanish) and the Quarai River (Cuareim in Spanish). In addition to the rivers, which comprise about 60% of the boundary, the boundary line passes through Mirim Lagoon (Merin in Spanish) and follows the hills of Cuchilla de Santa Ana and the Cuchilla Negra. Disputes existed about the sovereignty of Brasileira Island at the mouth of the Quarai River and to the identity of the Arroio Invernada. The boundary between the mouth of the Arroio São Miguel (Arroyo San Miguel in Spanish) in Mirim Lagoon and the headwaters of the Arroio da Mina was determined by the treaty of October 30, 1909. On May 7, 1913, the boundary in the Arroio São Miguel was modified by a convention signed in Rio de Janeiro. Between 1920 and 1935, the land segments of the Brazil-Uruguay boundary were demarcated by pillars. On December 20, 1933, a convention was signed in Montevideo with respect to the legal status of the boundary. Subject to various fluctuations, the mouth of the Arroyo Chuy was established officially by an exchange of notes between Brazil and Uruguay on July 21, 1972 (International Boundary Study 1979).

Climate

Uruguay is the only South American country totally included in the temperate zone. The climate in Uruguay is almost homogeneous and in the whole country it is defined as temperate-humid "Cfa" type, according to Köppen's classification. The average annual temperature is 16°C in the south and 19°C in the north. The monthly average temperature varies from 7°C in July up to 31°C in January. The monthly precipitation is uniformly distributed during the year, with a slight increase during the autumn. Periods of drought and intensive rainfalls that cause floods are frequent during the summer. The relative humidity varies from 70% to 75% (Severova 1997). The rainfall regime according to the average values from 400 monitoring stations in Uruguay, shows few contrasts regarding space and time (Corsi 1978). The rainfall spatial distribution shows a decreasing gradient in the section northeast-southwest, with a maximum annual value of 1 400 mm in the northeast, the boundary between Uruguay and Brazil where Mirim Lagoon is found, and the minimum values of 900 mm at the La Plata River (Corsi 1978). March is the month with the highest values (maximum of 140 mm) and December shows the lowest values (minimum 60 mm in Rocha). Regardless this distribution of average values, rainfall in Uruguay is marked by very high irregularity and variability. Extreme events have been recorded such as drought periods during 1891-1894, 1916-1917, 1942-1943, 1964-1965 and 1988-1989. Years with especially high rainfall and many flooding events were recorded for 1914, 1959, 1983 and 1992 (Severova 1997).

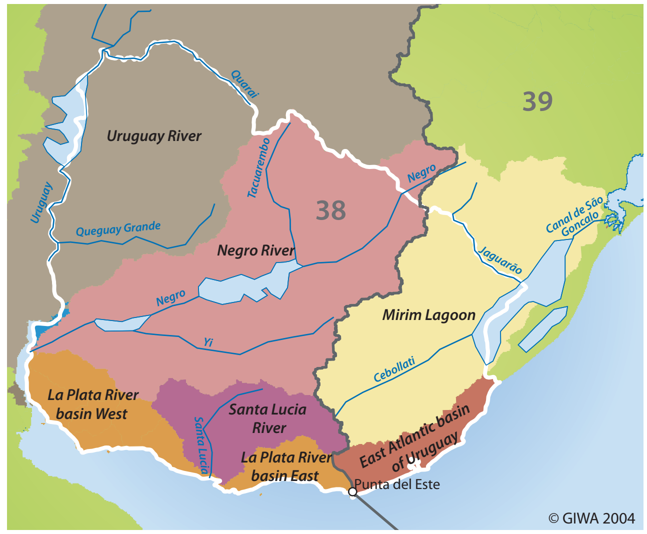

Figure 10 Map showing the area of the six hydrographic basins of Uruguay.
(Source: EROS Datacenter 2003)

Drainage basins

A dense network of rivers covers the Uruguayan territory. Large rivers belonging to the Atlantic slope and important basins exist, such as La Plata River basin and the Uruguay River basin. These rivers and their tributaries are of utmost importance as communications routes. The superficial water flow is approximately 65 000 m^3, with a run-off coefficient of 0.35. According to Dirección Nacional de Hidrografía (DNH), the country is divided in six large hydrographic basins, among them four are considered international water bodies and two are considered national water bodies as following (Severova 1997):

- Mirim (Merín in Spanish) Lagoon basin with 28 278 km^2 in the Uruguayan territory (shared by Uruguay and Brazil and part of the Brazil Current region);
- Atlantic Ocean basins (Vertiente Atlántica) with 9 300 km^2 (assessed independent from the Brazil Current region);
- La Plata River basin with 11 772 km^2 in the Uruguayan territory (shared by Uruguay and Argentina included in GIWA region 38 Patagonian Shelf);
- Uruguay River basin with 45 612 km^2 in the Uruguayan territory (shared by Uruguay and Argentina, included in GIWA region 38 Patagonian Shelf);
- Negro River basin with 69 500 km^2 in the Uruguayan territory and a very small portion in the Brazilian territory (included in GIWA region 38 Patagonian Shelf);
- Santa Lucia River basin with 13 517 km^2 (100% Uruguayan basin, included in GIWA region 38 Patagonian Shelf).

Among these basins, those of importance for the present assessment are Mirim Lagoon and the Atlantic Ocean Basin, which together form the east region of Uruguay, briefly described below.

The Uruguayan east region includes five departmentos that form the Mirim Lagoon basin and the Uruguay Atlantic basins (Figure 10). They are: (i) Cerro Largo, Treinta y Tres, Lavalleja, Rocha and Maldonado that form Mirim Lagoon and (ii) Rocha and Maldonado that form the Atlantic basins. The east region of Uruguay occupies an area of 48 537 km^2 (27.3% of Uruguay territory) and has a population of 390 495 inhabitants, which gives a population density of only 0.8 inhabitants per km^2. The Uruguayan east region extends from the east of the Cuchilla Grande through the Mirim Lagoon to the coast of the Atlantic Ocean. In the north, the Jaguarão River forms the boundary to Brazil and in the south, this region has as the limit, the coastal zone of La Plata River. The Uruguayan east region presents a variety of landscapes with strings, valleys and the coastal plain. La Cuchilla Grande Mountains is prolonged to the west and divides the waters that drain to the Uruguay River and to the La Plata River from the waters that drain to the Mirim Lagoon. The Jaguarão River, originating in Brazil, together with the Mirim Lagoon forms the boundary between the two countries.

Lagoon systems in southern Brazil and northern Uruguay

In southern Brazil and in the coastal portion of the departamentos of Rocha and Maldonado in Uruguay there are several systems of large coastal lagoons and wetlands that support a very rich biodiversity. In Brazil it is worth to mention the group of lakes north of Tramandaí; the group of lakes of Osorio; the sub-system south of Tramandaí; the Banhado Grande system; the Peixe Lagoon system; the Banhado do Taim system; and the Mirim and Patos Lagoon system. Noteworthy in Uruguay are the Rocha Lagoon; Negra Lagoon and Santa Teresa marshes (Laguna Negra y Bañados Santa Teresa); Castillos Lagoon; Garzón and José Ignacio lagoons; Mirim Lagoon and San Miguel marshes (Laguna Merín y Bañados de San Miguel). The Patos Lagoon, the largest one, covers 10 360 km^2 (Diegues 1999). The system of Peixe Lagoon includes five lagoons with a medium depth ranging from 0.3 to 3 m. The combination of factors like sea currents and coastal type, have resulted in the high productivity of Peixe Lagoon system and have made it of international importance for migratory shorebirds, such as *Calidris canutus, C. fuscicollis, Pluvialis squatarola* and *Limosa haemastica*. Peixe Lagoon connects to the sea via a temporary channel, when it functions as an estuary. Pexie Lagoon is designated as a Wetlands of International Importance (Ramsar) (Figure 11).

Name	Country	Area (ha)	Status of protection
Eastern wetlands and coastal fringe	Uruguay	435 000	Wetlands of International Importance (Ramsar) and UNESCO-MAB Biosphere Reserve
Caatinga	Brazil	19 899 000	UNESCO-MAB Biosphere Reserve
Discovery Coast Atlantic Forest Reserves	Brazil	111 930	World Heritage Convention
Historic Centre of Salvador de Bahia	Brazil	0	World Heritage Convention
Historic Centre of the Town of Diamantina	Brazil	0	World Heritage Convention
Historic Town of Ouro Preto	Brazil	0	World Heritage Convention
Peixe Lagoon National Park	Brazil	34 400	Wetlands of International Importance (Ramsar)
Atlantic Rainforest Biosphere Reserve*	Brazil	29 473 484	UNESCO-MAB Biosphere Reserve
Sanctuary of Bom Jesus do Congonhas	Brazil	0	World Heritage Convention
Southeast Atlantic Rainforest Reserve	Brazil	1 691 750	World Heritage Convention

** The Atlantic Forest Biosphere Reserve (RBMA) covers about 1/3 of the Atlantic Rainforest's biome area (17 states, 3 408 municipalities), where about 119 million inhabitants are to be found, almost 68 % of the Brazilian's total population. The RBMA Core Zones includes several parks and other protected areas, such as the Discovery Coast Atlantic Forest Reserve.*

Figure 11 International protected areas and reserves in Brazil Current region.
(Source: UNEP-WCMC 2003)

Socio-economic characteristics of Brazil

Brazil and Uruguay form, together with Argentine and Paraguay, the Common Market of the South (MERCOSUR). With the MERCOSUR, about 200 million consumers representing 75% of the gross national product of the whole of South America, as well as an important source of raw materials, constitute one single market. This common market implies the free circulation of goods, services and productive elements between the member states, with a common external tariff for the goods coming from third countries. The region Brazil Current encompasses portions of Northeast, Southeast and South regions of Brazil and on average it can be said that the economic growth rate in Brazil Current during 1985-1997 varied from below to equal the national economic growth rate (IBGE 2000a).

In Brazil, 27 states form five geographical regions that are identified from the social, cultural and economical points of view (Figure 12). Patterns of development and sectorial activities follow different dynamics in these geographical regions. The regions are: North, Middle-West, Northeast, Southeast and South (Figure 12). Most of social and economic information made available by the official sources is aggregated according to these geographical regions (IBGE 2000b). GIWA region 39 Brazil Current includes parts of three geographical regions: Northeast, Southeast and South. In this section, the social as well as the economic characterisation of the Brazil Current will be presented, as much as possible for the whole region or for each sub-region: South/Southeast Atlantic Basins, East Atlantic Basins and São Francisco River Basin. Where such level of aggregation is not possible, the information is presented by geographical region; in the format it is available in official publications. The economic analysis will focus on the last 10 to 20 years and trends for the next 10 to 20 years.

GIWA region 39, the Brazil Current, encompasses geographical portions of the "three Brazils", as revealed by the UNDP Human Development Index (UNDP 2001): the Northeast, Southeast and South regions. In

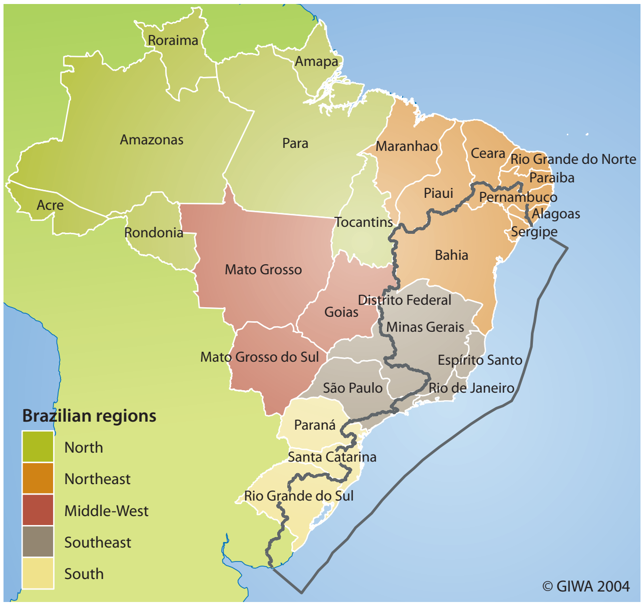

Figure 12 Brazilian regions.

From north to south, region 39 includes part of the states of Pernambuco PE, Alagoas AL, Sergipe SE, Bahia BA (northeast region), a small portion of Distrito Federal DF, states of Minas Gerais MG, Espírito Santo ES, Rio de Janeiro RJ, São Paulo SP (southeast region), Paraná PR, Santa Catarina SC, Rio Grande do Sul RS (south region).

Brazil, the poorest 20% have only 2.6% of the total national wealth; the richest 20% have 65% (IBGE 2001). This extremely uneven wealth distribution has been historically associated to the contrasts between the undeveloped northern Brazil, the often drought-affected northeastern Brazil and the much more prosperous and industrialised southeastern and southern Brazil. The Southeast and the South regions are together responsible for more than 75% of the Brazilian Gross Domestic Product (GDP) (Table 3). Therefore, although the Brazil Current region is almost 100% Brazilian territory (except for the catchment area of Mirim Lagoon in Uruguay), it shows an extremely high diversity regarding social, cultural and economic aspects. The North region, which has an area bigger than the Southeast and South together (Figure 12), generates less than 5% of the GDP. The next biggest region from the geographical viewpoint, the Middle-West, generates just over 5% of the GDP, although a trend towards an increase in the rate of development growth has been observed (IBGE 2001).

Table 3 Contribution of each region to the Brazilian GDP.

Region	% of GDP
North	4.4
Middle-West	5.3
Northeast[1]	13.8
Southeast[1]	59.4
South[1]	17.1
Total	100.0

Note: [1]Partially included in the GIWA Brazil Current region. (Source: IBGE 2000a)

During 1985 to 1997, the Brazilian economy increased at an average rate of 2.7% yearly, with a recessive period at the beginning of the 1990s (Reis 2000). From 1995 to 2002 the average rate was even lower: 2.3% yearly (Mercadante 2003). In 1999, the Gross Domestic Product (GDP) had attained 480 billion USD. Approximately 62% of the GDP are generated by the service sector, 35% by manufacturing, mining and quarrying (including construction and public utilities) and only 8% by agriculture (Reis 2000). The importance of the service sector reflects, on one hand, the economic and technological trends typical of the contemporary world and, on the other, the absorption of labour by the informal sector during two decades of relatively low availability of formal jobs. Economic growth differed among the Brazilian regions during 1985 to 1997, as follows:

- The Middle-West and the North (the only two Brazilian regions that do not form part of the Brazil Current) have been the frontiers of the economic growth, presenting economic growth rates 1.5 to 2 times higher that the national average rate, during this period;
- The Northeast followed the national economy pattern of growth;
- The Southeast presented a relatively lower growth rate during the period until 1994, matching the national average afterwards;
- The South inverted this pattern, with a higher growth rate until 1994 and a lower growth rate from 1995 to 1997.

Demography

The average demographic density in Brazil is approximately 20 inhabitants per km^2, ranging from 1.9 inhabitants per km^2 in the Amazon region to 126 inhabitants per km^2 in the southeastern Brazil. Some drainage areas in Brazil Current are particularly populous, and the Rio de Janeiro littoral basins (59 in Figure 2) have the highest population density: 606 inhabitants per km^2 (PNRH 2003).

Recent data show a profound transformation in the Brazilian demographic dynamics. The results of the demographic surveys carried out in 1991 and 2000 (IBGE 2000b) confirm a deceleration in population growth rate nation-wide, which resulted in a similar growth rate in those regions that form the Brazil Current (Figure 13). The growth rate for the Brazilian population, which was 2.8% in the period 1950-1980, fell to 1.9% in the period 1980-1991 and to 1.5% in the period 1991-2000 (Ferreira 2000). Additionally, the recent demographic dynamics show a new feature: not only has the fertility fallen to levels lower than ever in the history of Brazil, but other components of demographic dynamics, mortality and migration, no longer behave as in the past. The transformation in the age structure shows clearly the population aging (Ferreira 2000). All these changes indicate that Brazil is moving towards a more developed-country demographic structure type. Even so, the absolute number of inhabitants to be added to the present population

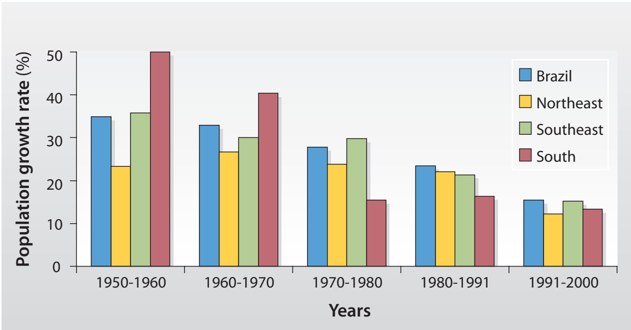

Figure 13 Population growth rate per decade in Brazil and three Brazilian regions partially included in the Brazil Current region: the Northeast, Southeast and South regions.
(Source: IBGE 2000b)

during the next 20 years may be considered huge. Projections of the Brazilian population indicate that the population of 169.5 million inhabitants (IBGE 2000b) will become 207.6 million inhabitants in 2020. This implies 38 million more people, with a lower proportion of young people and a higher proportion of elderly. About 58.43 million inhabitants (approximately one third of Brazilian population) live in the Brazil Current region (IBGE 2000b).

Urbanisation and littoralisation trends

The demographic density of Brazil Current is shown in Figure 14. A trend towards urbanisation and littoralisation has been observed in the Brazil Current region. During the last decades, the percentage of the population living in urbanised areas varied from 67% in Bahia (the least urbanised state in the region) to 96% in Rio de Janeiro state (the most urbanised state in the region) (IBGE 2000b). In most states, the rural population growth was negative (Table 4).

Table 4 Population growth rate in Brazilian states entirely or partially included in the Brazil Current region.

	Population growth rate (annual average %)					
	Total population		**Urban population**		**Rural population**	
Brazilian state	**1980-1991**	**1991-2000**	**1980-1991**	**1991-2000**	**1980-1991**	**1991-2000**
Pernambuco	1.36	1.18	2.66	2.05	(-) 1.15	(-) 1.23
Alagoas	2.18	1.29	3.87	2.93	0.23	(-) 1.51
Sergipe	2.47	2.01	4.50	2.70	(-) 0.60	0.48
Bahia	2.09	1.09	3.79	2.52	0.11	(-) 1.33
Minas Gerais	1.49	1.43	2.50	2.47	(-) 0.95	(-) 2.30
Espírito Santo	2.31	1.97	3.68	2.79	(-) 0.70	(-) 0.72
Rio de Janeiro[1]	1.15	1.30	1.49	1.39	(-) 3.73	(-) 0.74
São Paulo	2.13	1.78	2.56	1.85	(-) 2.01	0.78
Paraná[1]	0.93	1.39	3.01	2.58	(-) 3.03	(-) 2.62
Santa Catarina	2.06	1.85	3.69	3.10	(-) 0.90	(-) 1.77
Rio Grande do Sul	1.48	1.22	2.64	1.95	(-) 1.48	(-) 1.52

Note: [1]The only states where the annual population growth rate increased during the period.
(Source: IBGE 2000b)

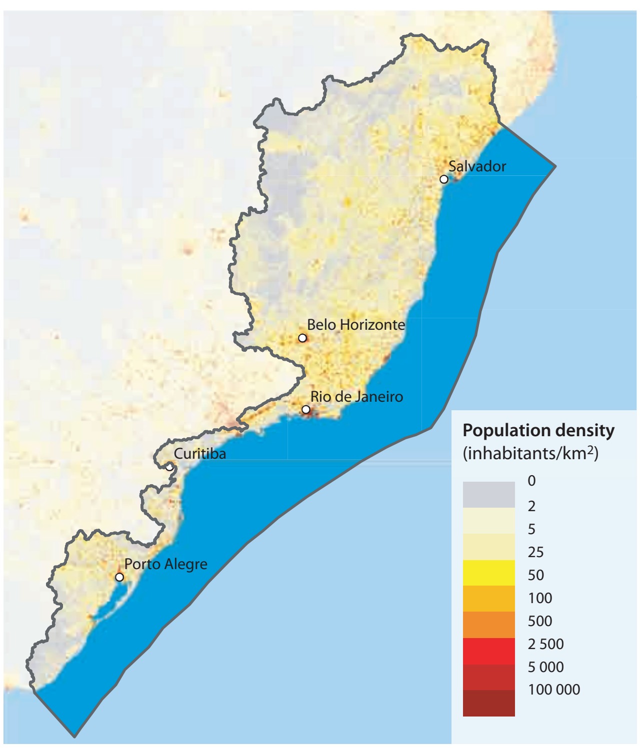

Figure 14 Brazil Current population densities.
(Source: ORNL 2003)

The South/Southeast Atlantic Basins host a population of 6.81 million inhabitants and the East Atlantic Basins have an estimated population of 48.86 million inhabitants (IBGE 2000b), among them, 11.19 million live in the Rio de Janeiro state littoral (basins 59 in Figure 2). The São Francisco Basin hosts about 13.95 million inhabitants (IBGE 2000b), distributed among 503 municipalities, with 26.4% living in the Belo Horizonte metropolitan area (state of Minas Gerais) - only 1% of the whole drainage area (Plano Nacional de Recursos Hídricos 2003).

The majority of the population is living in cities and in most states of the region, littoralisation (increasing concentration of the population and economic activities in coastal cities) is observed (Figure 15). The pressure on the water resources and further demand for sanitation infrastructure (water supply, sewage collection, solid waste collection) is a priority issue, particularly in the coastal cities.

Economic sectors

Tourism

Tourism is one of the most important driving forces towards coastal occupation in Brazil and it is expected to expand further during the coming years. The participation of tourism in the national economy has

Figure 15 Ipanema beach, Rio de Janeiro: Example of littoralisation observed along Brazil Current coastal zone (East Atlantic Basins).
(Photo: Ricardo Funari/SocialPhotos)

increased regularly since 1993, moving from 1 091 million USD in that year to 3 996 million USD in 1999 (IBGE 2000a), following the increase in the number of tourists that visited Brazil during the same period. For this reason, the Federal Government and a large number of state and city administrations have given increasing attention to this sector. The annual average rate of increase during the 1990s was 14.3%, surpassing the world average rate of growth for tourism, which was 10% per year during the same period (IBGE 2000a). However, these values are still very low when compared with those of leading countries in the world as tourist destinations (e.g. France and Spain). About 30.3% of all the tourists visiting the region come from Argentina, making the Brazilian revenue from tourism to a large extent dependent on Argentina's economy. The Argentinean tourists come mostly to region Brazil Current coastal cities, in Santa Catarina, Paraná and Rio de Janeiro states. The economic crisis faced by Argentina during recent years has probably affected this tourism. The second largest group of tourists coming to Brazil is European (Ryff 2000). Tourism is particularly accentuated on the Brazilian coast due to its exceptional landscape, open oceanic beaches, dunes, pleasant climate and cultural attractions. The coastal zones of the GIWA region Brazil Current and Brazilian Northeast comprise the most visited area of Brazil by national and international tourists. Among the 18 Brazilian cities that received the highest number of tourists during the 1990s, nine cities are located on the coast of Brazil Current. Rio de Janeiro city continues to be by far the most visited Brazilian city by foreign tourists. Florianópolis is ranked second, due to the Argentinean tourists (Ryff 2000). Adequate sanitation infrastructure is particularly important to keep the attractiveness of these tourism centres.

In South/Southeast Atlantic Basins, tourist attractions additional to the beaches are the thermal waters in Rio Grande do Sul (Iraí) and Santa Catarina (Gravatal and Santo Amaro da Imperatriz), and the water sports practiced in the lagoon systems.

In East Atlantic Basins, the importance of tourism is illustrated by (FGV 1998):

- More than 2 000 km of coastline, from the São Sebastião Island (SP) to Aracaju (SE);
- Several coastal cities have become tourist centres, such as: Salvador, Ilhéus and Porto Seguro (BA); Vitória and Guarapari (ES); Rio de Janeiro, Cabo Frio, Búzios, Angra dos Reis and Parati (Figure 16) (RJ); Ubatuba, Caraguatatuba and Ilha Bela (SP);
- Non-coastal cities of historical importance in Minas Gerais, National Parks for ecotourism in Serra da Bocaina, Caparaó, Chapada Diamantina, Monte Pascoal;
- Rivers intensively used by the local communities for leisure and water sports (e.g. Jequitinhonha River, basin 54 in Figure 2).

Figure 16 Parati, Rio de Janeiro state littoral, one of the cities attractive due to both history/architecture and nature values (East Atlantic Basins).
(Photo: Corbis)

São Francisco River Basin has a considerable potential (not yet developed) to become a tourism attraction for sport fishing, additionally to those already well-visited historical cities such as Ouro Preto and Sabará (both in MG).

Industry

The industrial sector in Brazil suffered major oscillations during the 1990s and went through a significant structural change, as a response to external and domestic economic changes. During this period, industry shrank in relative terms, as the average growth rate (1.4% per year) was lower than the general economic growth. The average for the five years of expansion observed in the mid-1990s was only 4.5% (IBGE 2000a). Growth restrictions were mainly high interest rates and low levels of incentives for exportation. On the other hand, during this period, as a response to the increasing competition, companies became more efficient and the productivity increased at an average annual rate of 8.78% during the 1990s. Efficiency and competitive advantage also brought greater environmental awareness. Particularly in large enterprises, a greater care and efficiency when using natural resources (water, energy, raw materials in general) and policies for waste minimisation, has been announced. Some important initiatives, in this period, can be seen in the control of water resources pollution. The National Law for Water Resources No. 9 433, of 1997, established the national policy for the water resources and created the national system for water resources management. Although the implementation of the law has been slow and not implemented yet in most of the country, some progress can be observed. It is expected that the polluter pays and the user pays principles, associated to a decentralised management, will result in the financial resources generated through water use charging in a given basin, being invested in the same basin.

In South/Southeast Atlantic Basins, the main industrial areas are (FGV 1998):

- In São Paulo littoral, the industrial pole of Cubatão works closely integrated to the Port of Santos. Main industries are petroleum, petrochemical and chemical.
- In Paraná littoral basins, the industries operate integrated to the Port of Paranaguá. Mining activities are widely spread all over these basins.
- In Santa Catarina littoral, 10 000 small, medium and large-sized industries represent two thirds of the whole industrial park of the state, and employ the major part of the state labour force. 415 large-sized industries operate their own water supply system with surface or groundwater origin.
- In Rio Grande do Sul state, 11 000 industries are concentrated in the Porto Alegre Metropolitan region (Guaíba Lake) making it the biggest industrial park of the south of Brazil, followed by the valley of Taquari-Antas River. The industrial activities include: textile, metal-mechanical, leather, chemical, computer, electric material and communication. About 90% of the existing mineral coal in Brazil is found in Rio Grande do Sul state and Santa Catarina. Rio Grande do Sul state also hosts the largest industrial park for wheat and soybeans processing, and some other important food industries of the country.

In East Atlantic Basins where the industrial activity achieves the greatest economic importance, there are six identified important areas as follow (FGV 1998):

- The Aracaju Metropolitan region (basin 50 in Figure 2, Sergipe state) with many industries related to petroleum exploitation processing, non-metal mining and food processing (e.g. orange juice).
- The metropolitan region of Salvador (basin 51 in Figure 2, Bahia state), with the Petrochemical Pole of Camaçari, metal-mechanical and food processing.
- The "Steel Valley" in the Upper Doce River (basin 56, Minas Gerais state), with metallurgy, paper and pulp, food processing, besides an intensive mining activity.
- The Vitória Metropolitan region (basin 57, Espírito Santo) with the steel company of Tubarão, Vale do Rio Doce Company, Aracruz (cellulose), Garoto (confectionery) among others.
- The Valley of Paraíba do Sul River (basin 58, São Paulo, Minas Gerais and Rio de Janeiro states) with the largest industries in the municipalities of Resende, Barra Mansa and Volta Redonda (RJ), such as the National Steel Company, Dupont of Brazil and Cyanamid. In São Paulo, the main production is chemical, petrochemical, steel, mechanical, food, clothes and the only Brazilian aeronautic industry. In Minas Gerais, the industrial activities are metallurgy, chemical, textile, paper, and food processing.
- The Rio de Janeiro Metropolitan region (part of basins 59, Rio de Janeiro state) includes petroleum, ship construction, metallurgy, chemical, besides food processing, textile, clothes, and pharmaceutical, among others. In the Guanabara Bay basin, for instance, there are 7 000 industries of different sizes, typologies and polluting potential.

According to the environmental protection agencies of three states (RJ, SP and MG) that are part of Paraíba do Sul River basin, Rio de Janeiro has 700 industries registered, São Paulo has 2 370 (mostly in the municipalities of Jacareí, São José dos Campos and Taubaté), Minas Gerais has 2 000 (approximately half of them, in Paraibuna River basin, especially in the municipality of Juiz de Fora). Other municipalities in Minas Gerais with industrial activity of importance are Cataguazes and

Ubá (FGV 1998). Other areas where industrial activity has some regional importance are Feira de Santana (BA), Vitória da Conquista (BA), Ilhéus (BA) and Cachoeira do Itapemirim (ES) (FGV 1998).

In São Francisco River Basin the main industrial areas correspond to: Belo Horizonte in MG (upper São Francisco); Barreiras in western Bahia (middle São Francisco); Petrolina, Juazeiro (lower-middle São Francisco) and Jaguarari (BA); and Arapiraca in AL (lower São Francisco). The main industrial sectors in the Basin are chemical, metallurgy, non-metal minerals, textile, clothes, and food processing with emphasis on vegetal oil processing (Haddad in FGV 1998). Municipalities that have recently developed special industries are Barreiras (soybean and other vegetable oils), and Petrolina (fertilisers, soil amendment products). Only in Belo Horizonte city, in São Francisco Basin, the number of jobs offered in the industry sector increased during the period of 1985 to 1994 (Oliveira & Lacroix in FGV 1998). This study also showed that in some areas, the population employed by the industry was reduced significantly during 1985 to 1994. This effect was observed in the food processing industry of Petrolina and Juazeiro (BA) and Montes Claros (MG). The same study pointed out that in national terms, the new industries have been concentrated in the northeastern Brazil littoral or in south/southeast cities.

Agriculture

The last decade confirmed the success foreseen in years past and showed levels of production and productivity beyond the expectations in the agricultural sector. This occurred, despite the Brazilian energy crisis and rationing that affected especially the Brazilian East and Northeast (both included in the Brazil Current region) after an unusual prolonged drought period, as well as the near collapse of the Argentine economy and international conflicts. The Brazilian agriculture sector has never exported as much before, reaching a record in productivity, new agro-industrial efficiency gains and new markets. Gaps that appeared in foreign markets because of the reappearance of the mad cow disease in Europe, along with foot and mouth disease were filled mainly by Brazilian exports. From January to September 2001, according to data from the Development Ministry Foreign Trade Department, shipments were worth 2.1 billion USD, a 50% jump on the figures for the same period the year before (Caixeta 2001).

Agriculture GDP, which currently stands at around 34 billion USD (80 billion BRL) was expected to grow 4.1% in 2001 compared with 1.7% growth in the economy in general (Caixeta 2001). Productivity of grain production jumped from 57.8 million tonnes of grain produced on 37.8 million ha (1990/1991) to 100 million tonnes of grain in almost the same area (38.3 million ha in 2001/2002). Pork meat exports increased from 84 million USD in 1995 to 300 million USD in 2001 (Caixeta 2001). Chicken meat exports went from 641 million USD to 1.3 billion USD and bovine meat exports grew from 180 million USD to 800 million USD over the same period (Caixeta 2001). Other factors, apart from the external market, which contributed to production and export growth were: changes in technology, such as direct planting, increasing sanitary control and changes in logistics following investment in transport infrastructure (Caixeta 2001). The development occurred mainly in the states of Paraná, Bahia, São Paulo (included in the Brazil Current region), Goiás, Mato Grosso do Sul and Mato Grosso (GIWA region 38 Patagonian Shelf). The agricultural development in different systems of Brazil Current is presented below.

In the littoral portion of South/Southeast Atlantic Basins agriculture activity is less developed than in other parts of the Basins due to physiographic conditions (soil, water availability and climate) and socio-cultural characteristics (FGV 1998). The exceptions are the basins of Patos and Mirim Lagoons that have soil particularly suitable for irrigated rice, and the basins of Vacacaí, Taquari-Antas, Alto, Baixo Jacuí, Pardo, Sinos, Caí and Gravataí rivers, in Rio Grande do Sul state (FGV 1998). The agriculture economically important in the Rio Grande do Sul portion of the Basins (Figure 17) includes rice, potato, orange, apple, soybean and wheat. Subsistence agriculture includes beans, manioc, corn, and potato. The commercial plantations in South/Southeast Atlantic Basins are banana (found all over the littoral), coffee (SP, PR) and sugar cane (SC, RS). Livestock for meat, milk and wool production in Rio Grande do Sul represents 80% of the total animal raising in the Basins, where large areas of natural pasture exist due to the biome Southern Fields (Campos Sulinos in Portuguese).

Figure 17 Rural workers in Rio Grande do Sul state.
(Photo: Ricardo Funari/SocialPhotos)

In East Atlantic Basins, agriculture is one of the most important supports of regional development. The basins of Vaza-Barris, Real and Itapicurú rivers as well as in the Recôncavo, northern Bahia (East Atlantic Basins, part of 50 in Figure 2), developed consortia cultivations that combine corn with beans, manioc with sisal, and have a number of typical fruits cultivation such as acerola, cashew, pineapple, orange, passion fruit, besides cacao (FGV 1998).

Agriculture in the São Francisco Basin has expanded, due to irrigated plantations and integration between agriculture and industry (agro-industry). When large-scale production increases, the agro-industry is a decisive instrument to guarantee the sale of the harvest. This close association is observed in Petrolina and Juazeiro (BA) and in northern Minas Gerais, which have 150 000 ha irrigated. The main result has been an increasing growth of non-traditional crops with high market value. Irrigation in lower-middle São Francisco increased fruit production (papaya, mango, watermelon and grapes). Cultivation in favourable climatic strips in the arid regions has resulted in increased cocoa and pineapple production. Increases in tomato, coffee and rubber production are due to favourable ecological conditions in specific physiographic zones in the northeast portions of the Basin: the lower-middle São Francisco, the Agreste, the Cerrado and the Zona da Mata. However, serious environmental issues have arisen in São Francisco Basin due to agriculture activities, such as: (i) soil salinisation in some areas as a consequence of improper irrigation techniques; and (ii) modification of stream flow of São Francisco River as a result of the cascade of dams originally constructed for energy purposes, also affecting the transport of sediments to the coast.

Energy

The energy crisis faced by the country during 2001, due to water shortage in reservoirs, highlighted the need for an efficient strategic plan, changes in the energy matrix and significant investments. An unusually long dry period of two years brought the levels of reservoirs in the Middle-West and Southeastern Brazil down to 20% and in the Northeast down to almost 8% of their capacities. The energy shortage associated to international economic factors affected the Brazilian economy and reduced the GDP expectations for 2001. Regions part of the Brazil Current were among the most affected in the country. However, the energy crisis in 2001 had a positive effect as it brought the issue to the public discussion with participation of different stakeholders. The need of significant investments to expand the energy supply has been emphasised (hydroelectric and thermo-electric plants as well as the distribution and transmission system). Privatisation and large-scale use of natural gas are likely to result in changes regarding environmental impacts from energy production and consumption.

Brazil has been changing gradually from an almost exclusively hydropower source of electricity supply, to a combined matrix that includes other energy sources. According to the Thermoelectric Priority Plan (PPT) (Plano Prioritário de Termelétricas), announced by the Federal Government at the beginning of 2000, 49 thermal units for energy production will be in place by the year 2003. These new thermoelectric plants will generate 16 200 MW. Of these, 42 will run on natural gas, and 17 will be located in the state of São Paulo.

The intensification of use of natural gas to generate electricity has some controversial aspects. One of them is that such a policy will increase Brazilian dependency on non-renewable energy resources, which already represent 58% of the total energy supply in Brazil (Santos in John & Campanili 2000). According to thermodynamic calculations, 58.2% of the energy comes from non-renewable sources and 41.8% from renewable sources. From the total amount of energy supply (renewable and non-renewable), about 46.7% comes from petroleum and only 14% comes from hydropower plants (Santos in John & Campanili 2000). Another controversial aspect is that, despite the fact that natural gas is cleaner than oil, the Brazilian contribution to greenhouse gases emissions and other important gases is likely to increase (e.g. nitrogen oxides that contribute to the formation of "bad ozone" at low altitude, and sulphur dioxide that contributes to the acid rain). The water demand for cooling systems of thermal power plants, existing or under construction, is not a significant environmental issue, due to the use of closed systems.

The South/Southeast Atlantic Basins is supplied by the South/Southeast/Middle-West Interconnected Electric System, whose electricity comes from Itaipu and Paraná systems, Iguaçu, Uruguay and Jacuí rivers (part of GIWA region 38 Patagonian Shelf), complemented by coal-based thermoelectric plants (Candiota, Tubarão and Charqueadas) (FGV 1998). Thus, although several small and medium-sized hydropower plants and thermoelectric plants exist in South/Southeast Atlantic Basins, this basin imports most of its energy from another basin. Any expansion of electricity generation inside the South/Southeast Atlantic Basins would be thermoelectric and use coal and gas imported from Argentina and Bolivia because the possibilities for expansion of energy generation from hydropower sources are limited in the Basins. However, there are several possibilities for construction of small hydropower plants, mostly in the states of Santa Catarina and Rio Grande do Sul (Table 5). According to the National Plan for Electric Power 2015 prepared by Eletrobrás, the South/Southeast Atlantic Basins represents 2.7% of the hydroelectric power in the country (FGV 1998).

In the East Atlantic Basins there are several hydropower plants, from large-sized (Funil, Ilha dos Pombos, Mascarenhas and Salto Grande) to small-sized plants (less than 5 MW). Additionally, large-sized industries operate their own generation systems (e.g. Usina Sá Carvalho by Acesita, Usina Brecha by Aluminas and Usina Piracicaba by Belgo-Mineira). The National Plan 2015 includes the following new hydropower plants for the East Atlantic Basins, representing more than 3 000 MW of installed power:

- Basin 51 Paraguaçu River: Pedra do Cavalo plant (300 MW);
- Basin 54 Jequitinhonha River: Irapé (420 MW) and Itapebi (375 MW);
- Basin 56 Doce River: Aimorés (396 MW), Resplendor II (363 MW), Baguari I (169 MW) and Pilar (150 MW), Porto Estrela (112 MW), Picada (100 MW), Manhuaçu (100 MW);
- Basin 58 Paraíba do Sul River: Simplício (180 MW) and Sapucaia (300 MW).

São Francisco River Basin supplies hydroelectricity to the Northeast region and the state of Minas Gerais and is an important connection between two large electricity generation systems in the country: the South/Southeast/Middle-West system and the North/Northeast system. Regardless the hydro-meteorological difference between the North/Northeast and South/Southeast regions of Brazil, the hydropower potential is shared between these two systems. São Francisco River Basin has a hydroelectricity potential estimated at 21 000 MW. The Basin has 14 hydroelectric power plants installed, although an inventory carried out identified the potential for 180 medium to large-sized plants. The capacity installed at present generates more than 50 million MW annually, which represent 19% of the national hydroelectricity generated in the country. The hydroelectric power plant Três Marias is electrically connected to the South/Southeast/Middle-West system and hydraulically connected to the rest of the São Francisco system, which includes the hydroelectric power plants: Sobradinho, Itaparica, Moxotó, Paulo Afonso and Xingó, all of them placed in cascade, which gives to the system low operational flexibility (FGV 1998).

Table 5 Hydroelectric power plants in South/Southeast Atlantic Basins 1997-2006.

Hydroelectric plants	River	State	Installed capacity (MW)	Start of initiation of operation
Palmeiras (expansion)	Bonito	SC	7	Jan/1999
Passo do Meio	Antas	RS	30	Jul/1999
Monte Claro	Antas	RS	130	Jul/1999
Guaporé-APE	Guaporé	RS	20	Dec/1999
Cubatão -Sul	Cubatão	SC	45	Jan/2000
Salto-aml.	Itajaí-Açu	SC	8,1	Mar/2000
D.Francisca	Jacui	RS	125	Dec/2000
Portobello-APE	Garcia	SC	15	Mar/2001
Bom Retiro	Taquari	RS	25	Aug/2002
Salto Pilão	Itajaí-Açu	SC	220	Oct/2002
Funil-Ribeira	Iguape	SP	150	Apr/2004
Capivari	Braço do N.	SC	25	Apr/2004
Tijuco Alto-APE	Iguape	SP	144	Jan/2005
Batatal	Iguape	SP/PR	75	Apr/2007

(Source: ELETROBRÁS National Plan for Electric Power 1993-2015)

Navigation

In the South/Southeast Atlantic Basins waterways are relevant in the state of Rio Grande do Sul, mostly in the Patos Lagoon, Guaíba Lake and Jacuí River, with the ports of Rio Grande, Porto Alegre and Estrela that make access to the petrochemical pole of Triunfo, with approximately 600 km navigable. The São Gonçalo Channel make navigation possible from Uruguay to the Port of Rio Grande and the Porto Alegre Metropolitan region (RS). In Santa Catarina state, waterways are active in the following rivers: Tubarão (40 km), Araranguá (40 km) and Una (30 km), in the south littoral and in the rivers Itajaí-Açu and Western Itajaí (130 km) in the Itajaí River basin only during some periods of the year. In São Paulo state, the rivers Ribeira do Iguape (70 km), Juquiá (54 km), Una D'Aldeia (62 km) and Itanhaém/Iguapeú (60 km), have only local significance as waterways.

The waterway transport in East Atlantic Basins have no longer the importance it had in the past. Roads replaced the waterways as the main transportation system in these Basins, and only a small-scale transportation of people and goods remains. The topography of the region, as well as the highly variable river flows are the main limiting factors. Additionally, as a consequence of deforestation and inadequate use of soil in agricultural areas, advanced process of silting is observed in several rivers, as for instance, the Doce River, making fluvial transport impossible in 143 km, previously used for transport, in the section between Regência (foz) and Mascarenhas (MG) (FGV 1998).

The São Francisco River has two main waterway sections and a third one with limited use: the first (1 312 km), between Pirapora/MG and the cities of Juazeiro (BA) and Petrolina (PE) presents navigable conditions all year; the second (208 km), between Piranhas (AL) and the river mouth. A third section (150 km) is from Juazeiro (BA) downstream to Santa Maria da Boa Vista (PE). The Grande River is navigable along 370 km of its extension, between Barreiras and the mouth. The Corrente River is navigable along 110 km, from the mouth to Santa Maria da Vitória (BA). Despite the strategic location of São Francisco River Basin as an important interregional connection, its use as waterway is currently very reduced, differently from the recent past, when fluvial transport made possible development of economic centres, such as Juazeiro, Petrolina, Barra, Xique-Xique, Pirapora and Januária. The decline of this activity is illustrated by the transport of goods that in 1987 was 120 000 tonnes, but in 1994 was only 26 000 tonnes. Since then, the activity has been further reduced (FGV 1998).

Fisheries

Despite the relatively small relevance in terms of contribution to GDP, fisheries in Brazil have the highest social significance. Along the Brazilian coast, and especially along the Brazil Current region, fishing is a dynamic activity. It represents a labour-intensive activity, responsible for about 800 000 direct jobs, and approximately four million people depend on the sector.

Annually, Brazil produces about 700 000 tonnes of fish. Approximately 70% come from the ocean, 20% from freshwater source and nearly 10% from fish-farming, a practice which has grown considerably during recent years. There is still room to expand the national fishery industry. However, the supposedly enormous potential that might be indicated by thousands of kilometres of coast and some of the largest watersheds in the world is not entirely real, in large part due to environmental reasons. The most productive coast of the Brazil Current, the South/Southeast Atlantic Basins correspond to the Large Marine Ecosystem LME 15 South Brazil Shelf, which is considered a Class II, moderately high productivity ecosystem (150-300 gC/m^2/year), based on SeaWiFS global primary productivity estimates (Ekau & Knoppers in press). Food webs are moderately diverse, but productivity is extremely high in the southern portion. Productivity decreases towards the north. Primary production is marked by spatial and seasonal variability. Rates are higher during the summer, with the upwelling of South Atlantic Central Water. The South Brazilian Bight is very productive and accounts for over 50% of Brazil's commercial fisheries yield. The marine annual catch during the period of 1950-2000 in the Large Marine Ecosystem 15 South Brazil Shelf is shown in Figure 18.

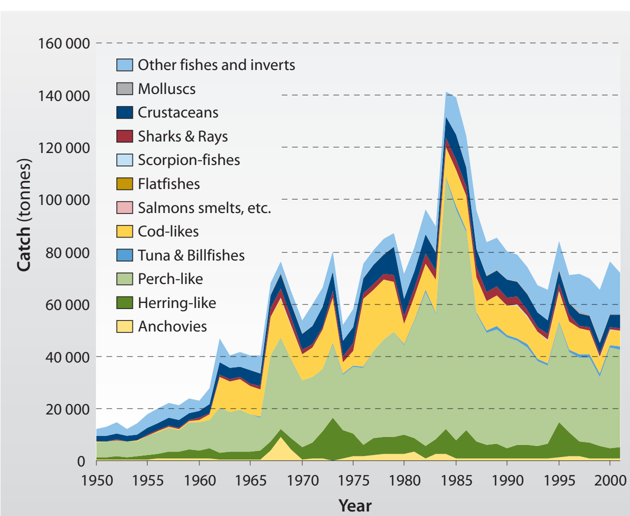

Figure 18 Catch in Large Marine Ecosystem 15, South Brazil Shelf (1950-2000), corresponding to sub-region South/Southeast Atlantic Basins and the Rio de Janeiro littoral.
(Source: Large Marine Ecosystems 2003)

The commercial species in this LME include sardines, oysters, shrimp, anchovy and hake. Information on the exploitation of fish stocks is not available for all areas and species. Regarding freshwater fisheries, the South/Southeast Atlantic is a privileged area, mostly due to Patos and Mirim Lagoons (RS), and the group of lagoons in the littoral of Rio Grande do Sul state and Santa Catarina state. The fishery potential is likely to be bigger in the coastal zones, close to the lagoon systems where crustaceous and other estuarine species complete their reproductive cycle.

The coast of East Atlantic Basins together with the estuary of São Francisco Basin are included in the Large Marine Ecosystem LME 16, East Brazil. It is considered a Class III, low productivity (<150 gC/m^2/year) ecosystem based on SeaWiFS global primary productivity estimates (Ekau & Knoppers in press). It has a more diverse food web than the LMEs to the north (LME 17 North Brazil Shelf) and to the south (LME 15 South Brazil Shelf), but lower production. Studies on primary productivity for this LME are scant. Information on the exploitation of fish stocks is not available for all areas and species. The annual catch during the period of 1950-2000 in the LME 16 is shown in Figure 19, which aggregates the coast of the East Atlantic Basins and São Francisco to two sub-regions of another GIWA region; Brazilian Northeast.

The importance of freshwater fisheries in East Atlantic Basins may be illustrated by the production in 1993, in only four dams operated by

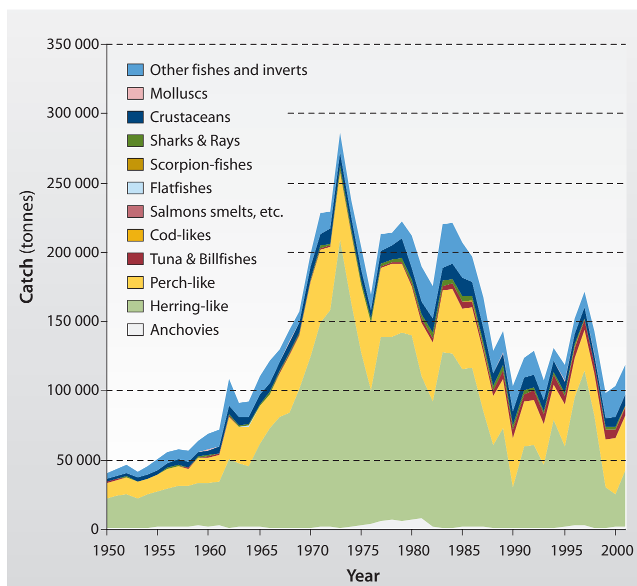

Figure 19 Catch in Large Marine Ecosystem 16, East Brazil Shelf (1950-2000), corresponding to East Atlantic Basins excluding the Rio de Janeiro littoral, plus the GIWA region Brazilian Northeast.
(Source: Large Marine Ecosystems 2003)

the departamento Nacional de Obras contra a Seca (DNOCS), which was over 1 300 tonnes (Agostinho 1994). Freshwater fishing is carried out by small fishing communities in the rivers of East Atlantic Basins. Low productivity is essentially due to great seasonal variation in flows, with drastic reduction of accumulated volumes during the dry season, which explains the ichthyofauna concentration in large reservoirs. Therefore, the management of these artificial lakes through the release of juveniles has a great regional importance as an alternative to the consumption of meat as a protein source, and creation of new jobs in the contexts of existing deficiencies. In basins 50, 51 and 52 there are six aquaculture stations, with a capacity to produce more than 12 million juveniles per year.

A study for the National Plan of Water Resources (FGV 1998), emphasised the need for systematic studies to produce bio-statistical data in São Francisco Basin making it possible to estimate the stocks of the existing fish species. More recent studies show a drastic reduction of ichthyofauna, associated to changes in sediments and nutrients transport in the São Francisco River and estuary (Machmann de Oliveira 2003).

Aquaculture

Brazilian aquaculture is a young entrepreneurship developed largely over the last three decades. Its historical development and fast growth harbour some interesting features. The 1970s were characterised by experimental cultivation at universities and specific research centres, the 1980s by the movement from the laboratories to the fields, the implementation of commercial projects and adaptation of technologies, and the 1990s by its consolidation in various sectors and enhanced governmental support. Its consolidation in the early 1990s, with an annual production of 30 000 tonnes, emerged at a time when the commercial fisheries sector was experiencing its decline and a lack of organised information and definition at the institutional level still existed. By the late 1990s, the production increased to about 115 358 tonnes (1998) with a gross income of 200 million USD and the Brazilian government implemented the programme "Aquaculture for Sustainable Development" (Castagnolli 1996, Valenti 2000). In 1999, the Brazilian fisheries production through capture was estimated at 655 000 tonnes and the aquaculture production was at 119 750 tonnes (FAO 2000). Estimates indicate that aquaculture production in Brazil may reach 500 000 tonnes by the end of the next decade (Valle & Proença 2000). Brazil now occupies rank 26 of the world's production by weight and rank 22 by gross income (FAO 2000).

The states entirely or partially included in the South/Southeast Atlantic Basin, are responsible for 77 465 tonnes or 63% of Brazil's production of 115 398 tonnes in 1998. Santa Catarina leads with an annual production of 22 650 tonnes, followed by Rio Grande do Sul (17 448 tonnes), Paraná (16 537 tonnes), São Paulo (15 830 tonnes) and Rio de Janeiro (4 500 tonnes). The production of the states entirely or partially included in the East Atlantic Basins/São Francisco River Basin is 13 474 tonnes or about 12% of the national production. Bahia leads with 8 070 tonnes, followed by Rio de Janeiro (4 500 tonnes), Pernambuco (1 910 tonnes), Sergipe (1 703 tonnes), Espírito Santo (970 tonnes), Minas Gerais (500 tonnes), the Federal District (216 tonnes) and Alagoas (105 tonnes) (Ostrensky et al. 2000, Pereira et al. 2000, Pezzato & Scorvo Filho 2000, Poli et al. 2000).

The six categories of cultured organisms are freshwater fish, prawn, frogs, marine shrimp, clams and oysters (Valenti 2000). Freshwater fish represent about 80%, marine shrimp about 14% and the remainder, including oysters and mussels, 6% of the total. Of the 67 freshwater species being produced, tambaqui (*Colossoma macroporium*), tilapia (*Oreocromis niloticus*), common carp (*Cyprinus carpio*) and the prawn *Macrobrachium rosenbergii* are the major players. Tilapia and tambaqui are now also reared in dam reservoirs, river lakes and net cages along the São Francisco River Basin; the lower river portion is now under intensive development. Tilapia, carp and also trout (mountainous regions) are intensively reared in the south and in part in the southeast, and freshwater shrimp largely in the northeast of Brazil. Mariculture also comprises both native and exotic species, including the mussels *Perna perna*, *Mytella falcata* and *Mytella quyanensis*, the oysters *Crassostrea gigas* and *Crassostrea brasiliensis*, and the shrimp *Litopenaeus schimitii* and *Litopenaeus vannamei* (Brandini et al. 2000).

In 1996, the state of Santa Catarina alone was responsible for an annual production of 7 500 tonnes of the mussel *Perna perna* and 314 tonnes of the oyster *Crassostrea gigas* (Poli et al. 2000). Today, the state is the largest mussel producer of Latin America with 11 500 tonnes for the year 2000 (FAO 2000). Aquaculture of the shrimp *Litopenaeus vennami* has also found wide acceptance and now represents 95% of the shrimp cultivated. Its total production attained 25 000 tonnes (6 500 ha) in the year 2000 and is one of the major export products of the industrial fisheries.

Obtaining reliable statistical data for aquaculture in Brazil is a complex issue. The socio-economic relevance of Brazils' aquaculture cannot solely be measured by its total production and gross income, but particularly also by its role for the sustenance of local populations. About 100 000 registered aquafarmers with an area equivalent to 80 000 ha are spread over the countries vast territorial area (many being remote) and the long coastal zone, spiked by manifold mangrove estuaries, coastal lagoons and rocky shores.

Before aquaculture was recognised as an economically viable activity and organised statistical data collection existed, many species were being utilised at the subsistence level by local populations, such as fresh water fish and shrimp in small water reservoirs and marginal river lakes of the northeast, and mussels and oysters of the southeastern coast. Many of these activities are now controlled by cooperative units, some of which are included in the statistics and others not. A large number of the small-scale production units have recently been implanted for "catch and pay" sport fisheries, responsible for part of the fast growth of aquaculture. They are widespread and their production is relatively difficult to ascertain. Another important sector undergoing fast growth in the South and Northeast regions of Brazil is larviculture of fish, molluscs, shrimps and lobsters. One of the purposes is to restock with larvae and juveniles some of the species commercially overexploited by the fisheries industries, particularly shrimps and lobsters.

Harbour activity

According to the Directory of Ports and Marine Coasts of Brazil (IBAMA 2002) the Brazilian ports trade a total of 400 million tonnes per year, which represent 40 million tonnes of ballast water discharged every year in Brazilian coastal waters. The majority of Brazilian ports have no adequate infrastructure from the environmental viewpoint, for management of residues generated by the dock activities, nor contingency plans for accidents or port expansion and modernisation. In the Brazil Current, there are 33 ports that can potentially generate impacts on the littoral due to intense dock activities, and represent a risk of spills both at the coast and in the ocean. In 2001, according to the National Agency of Aquatic Transport (ANTAQ 2001), the movement of goods (export and import) in 10 ports of the South region (RS, SC, PN, SP) was 75.7 million tonnes; in 16 ports in the Southeast (SP, RJ, ES, MG) was 277 million tonnes, and in 7 ports in the Northeast region included in the Brazil Current (BA, SE, AL, PE) it was 38.3 million tonnes. Thus, in 2001, 387.7 million tonnes of goods were shipped through the Brazil Current region 170.8 million tonnes of this in the South/Southeast Atlantic Basins and 216.9 million tonnes in the East Atlantic Basins/São Francisco River Basin (Table 6).

Table 6 Ports in Brazil Current with annual movement of goods above 10 million tonnes.

Brazil Current	Port (state)	Goods (million tonnes 2001)
East Atlantic Basins	Aratu (Bahia)	20.6
	Praia Mole (Espírito Santo)	19.0
	Tubarão (Espírito Santo)	68.2
	Ponta do Ubu (Espírito Santo)	10.9
	Rio de Janeiro (Rio de Janeiro)	15.5
	Sepetiba (Rio de Janeiro)	39.1
	Angra dos Reis (Rio de Janeiro)	18.2
South/Southeast Atlantic Basins	São Sebastião (São Paulo)	46.9
	Santos (São Paulo)	48.2
	Paranaguá (Paraná)	28.3
	São Francisco do Sul (Santa Catarina)	14.0
	Porto Alegre (Rio Grande do Sul)	10.3
	Rio Grande (Rio Grande do Sul)	17.6

(Source: ANTAQ 2001)

The most important ports in South/Southeast Atlantic Basins are:

- Port of Santos (SP): Exports represented 63% of the total amount (14.4 billions USD) and the imports, 13.4 billions USD (Companhia Docas do Estado de São Paulo 2003).
- Porto of São Sebastião (SP): The main commodity circulating is petroleum and its derivatives, by Petrobrás.
- Port of Paranaguá (PR): The main export corridor for grains and wood from the South region. The first product is wood, with 1.26 million tonnes exported in 2002, followed by the second product - paper, with 276 000 tonnes exported, and 23 000 tonnes imported in 2002 (Administração do Porto de Paranaguá 2003);
- Port of Rio Grande (RS): Soybean alone represents 8 million tonnes exported (Porto do Rio Grande 2003).

East Atlantic Basins also host important ports, such as:

- Port of Tubarão (ES): This private port in Vitória municipality, belonging to the Vale do Rio Doce Company. It is considered the largest maritime port for movement of iron ore and pellets in the world. The movement of goods was 65 million tonnes of iron mining and pellets per year but its capacity is for 80 million tonnes. This port also has a movement of 1.5 million tonnes of grains per year. Recently, an expansion enlarged its capacity by 6 million additional tonnes used by Petrobrás, among others.
- Port of Rio (RJ): Movement of goods at the harbour: steel products, paper, wheat, vehicles and containers. Outside the harbour: petroleum and its derived products.
- Port of Sepetiba (RJ): The main goods circulating through the Port of Sepetiba are: coal, aluminium, zinc and iron.
- Port of Angra dos Reis (RJ): The main goods are: steel and wheat, petroleum and petroleum-based products.

Oil exploitation

Oil exploitation and shipping in the coastal zones, although on a lesser scale than oil and gas offshore activities, represent one of the greatest pressures on the coastal ecosystems (IBAMA 2002). The ending of Petrobrás's exploitation monopoly had as the immediate consequence, a large increase in the number of exploited areas (Figure 20).

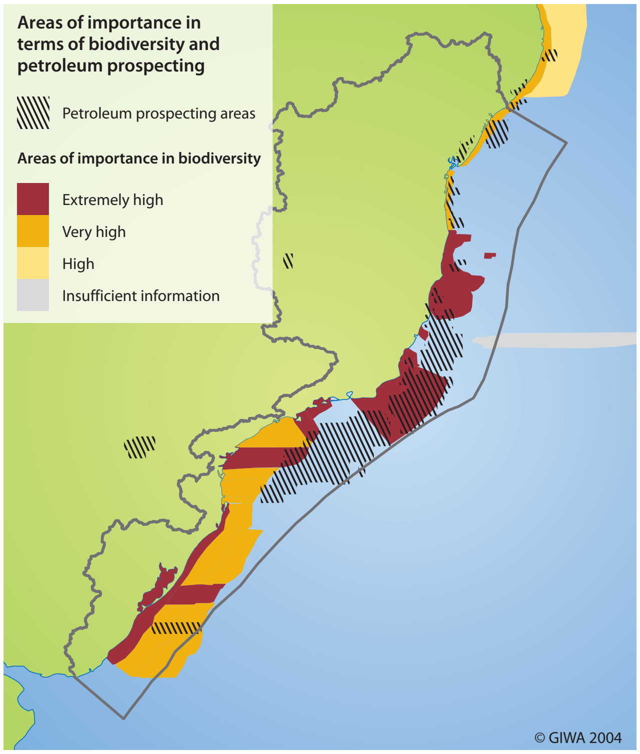

Figure 20 Areas of importance in terms of coastal/marine biodiversity in Brazil Current and some petroleum prospecting areas.
(Source: Claudio Egler, pers. comm.).

In mid-1998, the National Contingency Plan to Combat Oil Spills was drafted and since then it has been slowly consolidated. Petrochemical activity affects mainly the coast included in Brazil Current, where there are oil terminals and oil pipeline networks with adjacent petrochemical complexes. Low altitude coastal areas, subject to flooding, are particularly vulnerable to oil spills.

Besides the dockside activities of the oil sector, there are large oil drilling platforms in the southeast and northeast regions of Brazil. Petrochemical centres close to oil refineries near the coastal zone represent high environmental risks, associated to the vulnerability of natural systems.

The primary source of sea-based pollution is related to the offshore drilling for oil and gas, which impact the marine environment in the following ways: oil spills and emissions, including dissolved organic compounds, chemicals, trace metals, radioactive materials and inorganic salts; and pipelines and installation of infrastructure to receive material produced at the platforms. However, most of the accidents are related to the load-unload of oil and derivatives at the terminals operated by Petrobrás and the ageing of the world fleet, as well as the deficiency in professional training (IBAMA 2002).

Sanitation

At the present, sanitation in Brazil demands very high investments to achieve an acceptable level of coverage. At least 1.3 to 2.5 billions USD must be invested annually over a 10 year period to improve the current low coverage, particularly for sewage, and fulfil the future demand. Presently, 52.5% of the municipal sewage in Brazil is collected and only 18% is treated (IBGE 2001). Since 1998, investments in sanitation have been awaiting better definition of the rules and legal instruments for the sector. Clear definition of ownership, and therefore responsibility (Federal, State, Municipal) has been needed for enabling fundraising. However, a considerable level of investments may be expected in this sector over the next 20 years, as well as a more active participation of the private sector, stimulated by the new national sanitation policy.

A regional analysis (Table 7) reveals that the Northeast region (partially included the Brazil Current region) has the poorest sewerage infrastructure among all Brazilian regions.

Table 7 Sewage coverage in Brazil.

Region	Sewerage connection (%)	Other forms (septic tank etc.) (%)	No sewerage facility (%)
North	54.7	40.8	4.5
Northeast[1]	36.3	38.7	25.0
Southeast[1]	84.2	13.8	2.0
South[1]	69.0	28.8	2.3
Middle-West	41.1	54.0	4.8
Total in Brazil	64.6	26.9	8.5

Note: [1]Partially included in the GIWA Brazil Current region. (Source: FGV 1998)

The analysis carried out state by state reveals aspects that have been hidden in the regional analysis presented in Table 7. The sanitation indicators show that in the states entirely or partially included in the Brazil Current, the percentage of urban households connected to the water supply, possessing internal plumbing and general network, ranges from 97.8% (São Paulo) to 80.2% (Alagoas). The highest percentage of urban households connected to the sewage collection system is 86.6%, also found in Sao Paulo and the values fall significantly below the national average in seven states that form the Brazil Current (Table 8).

Regarding the percentage of treated sewage, the state of Bahia, with 39.8%, although part of Northeast region, presents a coverage better than the national average (20.7%), whilst the states of Pernambuco, Alagoas, Sergipe, Minas Gerais, Espírito Santo (Southeast region), Santa Catarina and Rio Grande do Sul (South region) are placed below the national average. The transboundary basins in the East Atlantic

Table 8 Basic sanitation indicators for urban households in Brazil.

State[1]	Water supply (%)	Sewerage (%)	Treated sewage (%)
Pernambuco	83.1	24.9	14.9
Alagoas	80.2	11.0	3.1
Sergipe	84.4	21.9	19.5
Bahia	81.9	37.9	39.8
Minas Gerais	94.3	84.2	5.8
Espírito Santo	95.5	60.8	19.9
Rio de Janeiro	88.7	58.6	32.2
São Paulo	97.8	86.6	32.5
Paraná	96.4	38.8	20.0
Santa Catarina	90.7	11.1	11.6
Rio Grande do Sul	93.1	12.1	6.4
Total in Brazil	89.2	52.5	20.7

Note: [1]Brazilian states entirely or partially included in Brazil Current. (Source: FGV 1998)

Basins, Doce (Minas Gerais and Bahia) and Paraíba do Sul (Sao Paulo, Minas Gerais and Rio de Janeiro), show coverage levels as following (FGV 1998):

- The percentage of urban households connected to the water network ranges from 75% in the Doce River basin to 91% in the Paraíba do Sul River basin.
- The percentage of urban households connected to sewerage ranges from 45% in the Doce River basin to 69% in the Paraíba do Sul River basin.
- The percentage of sewage treated ranges from values close to zero in basin 59 (Rio de Janeiro state coastline) and Doce River basin, to 11.2% in the Paraíba do Sul River basin. Of the basic sanitation services, that concerning sewage is the least present in Brazil.

These figures reveal that the water supply coverage is acceptable in national terms. The situation as regards sewage collection is severe in states from all three different regions that form the Brazil Current, not only the poorest one, the Northeast. This may be interpreted as the result of insufficient public investments, still unclear rules for the private sector participation and areas of poverty also found in the most economically developed regions.

Legal framework

A list with the main environmental conventions and agreements associated to water resources and coastal zone management in the Brazil Current, particularly those between Brazil and Uruguay, is presented in Annex V. This section focuses on the general legal framework and current national policy, directly related to water resources and coastal management. The 1988 Federal Constitution of the Republic provides the basis for a Brazilian programme for the conservation of biodiversity and its sustainable use, as well as for implementing measures to meet the commitments undertaken by Brazil in relation to the Convention on Biological Diversity (CBD). An entire chapter (Chapter VI: article 225) of the Federal Constitution is devoted to the environment.

Federal Water Law No. 9 433 of the 8th of January, 1997

Adequate drainage basin management is decisive for the conservation of biodiversity in the different Brazilian biomes, as well as for the maintenance of the social and economic activities in each basin. For this reason, the approval by the national congress of the Water Resources Law No. 9 433 in 1997 was of major importance, which established a new National Policy for Water Resources (Política Nacional de Recursos Hídricos) and established the principles for their adequate management. These principles are:

- The water belongs to public domain;
- Water is an asset in short supply and of economic value;
- In case of water shortage, priority will be given to domestic and then animal supply;
- Multiple uses must be considered during planning and management;
- The use of water requires permission;
- The use of water must be paid for;
- Water resource management will be managed in units comprised of drainage basins, a group of basins, a single basin or sub-basin, supervised by committees, with the regional Water Board as the Executive Secretary, and representatives from the state, sectorial users, and civilian society.

Ever since the Water Code in 1934, the energy sector has been the prevalent sector when planning water resources management, particularly for surface waters. Since the National Agency of Waters (ANA) was created (Law No. 9 984, 17 July, 2000), multiple uses gains the ruling position in strategic planning. Water resource plans are being prepared using the drainage basin as the basic management unit. These plans will allow for a diagnosis of the current status of water resources; an analysis of alternatives for population growth, productive activities and changes in soil use; a comparison between availability of water resources and future demand; the definition of strategies and priorities to improve water quality and its rational use; the definition of priority measures and programmes; the definition of priorities for granting access; guidelines and criteria for water rates; and the definition of proposals for creating areas subject to restriction for the protection of water resources. The National Plan for Management of Water Resources is in preparation, and adjustments will have to be made to state management plans already existing so as to make them compatible. Since 2000, additionally, technical support and new programmes implemented by ANA with the support of the National Secretariat of Water are changing the scenario towards more efficient sanitation systems.

Integrated coastal management

The Brazilian Government became involved in coastal preservation and management during the 1970s when degradation of ecosystems increased due to industrialisation and urban growth (Lamardo et al. 2000). Coastal management is supported by the Federal Constitution in Brazil, which defined the coastal zone as national property (1988). In the same year, the government implemented the National Plan of Coastal management PNGC with the Law No. 7 661. In 1995 the National Programme of Coastal Management (GERCO) (Programa Nacional de Gerenciamento Costeiro) proposed decentralisation with the objective of giving more initiative to the states and municipalities, according to the local conditions and demands. In parallel with the Ecological-Economic Diagnosis, the Ministry of Environment (MMA) has coordinated the implementation of the National Programme for Coastal Management involving all of 17 coastal states and their municipalities, along the Brazilian Atlantic coast. The main objective of GERCO is to realign public national policies which affect the coastal zone to integrate the activities of the states and municipalities and incorporate measures for sustainable development. To this end, GERCO has been involved in: (i) a training scheme which has included many technicians of state and municipal environmental agencies, as well as manuals and guides on coastal management techniques and options; (ii) a project for the elaboration of models and alternatives to improve the methodological basis for coastal zoning (diagnoses and scenarios); (iii) mapping; (iv) norms for management plans; and (v) the construction of an analytical economic model, specifically to meet the needs of the programme.

Socio-economic characteristics of Uruguay

Demography

In 1999, Uruguay had a population of 3.314 million inhabitants (Guia do Mundo 2002) with an average population density of 19 inhabitants per km^2. Approximately 70% of the country's population lives by the coast and 90% in the main cities (the capitals) of the political units (departamentos). Montevideo, the capital of Uruguay is the most densely populated city, with 1.4 million inhabitants. According to the same census, in 1996 the rural population represented only 9.2% of the total population. The average population growth rate during the period 1970-2000 was 0.6% per year. This is one of the lowest population growth rates in South America and the country presents one of the highest levels of literacy in South America: 97.3% (CIA World Factbook 2003).

Economic sectors

Uruguay's economy is characterised by an export-oriented agricultural sector, a well-educated workforce, and high levels of social spending. After averaging growth of 5% annually in 1996-1998, in 1999-2001 the economy suffered from lower demand in Argentina and Brazil, which together account for nearly half of Uruguay's exports (CIA World Factbook 2003). Despite the severity of the trade shocks, Uruguay's financial indicators remained more stable than those of its neighbours. GDP fell by 1.3% in 2000 and by 1.5% in 2001. The GDP (in terms of purchasing power parity-baseline 2001, in CIA World Factbook 2003) was 31 billion USD. The GDP per capita (purchase power parity per capita) was 9 200 USD. The labour force occupation in 2001 was 14% in the industry sector, 16% in the agriculture sector and the remaining 70% in the service sector (CIA World Factbook 2003). In 2001, the agriculture sector (including cattle raising) contributed with 6% to the GDP, and the industry sector (dedicated in large part to the processing of agricultural/ cattle products) contributed with 29% to the GDP. The remaining 65% came from services and others (CIA World Factbook 2003).

The average growth of the GDP during the period 1990-1997 was 3.5% annually (Guia do Mundo, 1997). The annual GDP was 19 971 million USD (Guia do Mundo 2002). The total exports by Uruguay represented 4 511 million USD (Guia do Mundo 2002). During the period 1990-1997, the annual exports increased annually by 4.6% (Guia do Mundo 2002). The main exported products were meat, rice, leather, vehicles, wool and electricity. The total imports reached similar value: 4 563 million USD (Guia do Mundo 2002). During 1990-1997, the import grew annually 17.1% (Guia do Mundo 2002). The main imported products were: fuel, chemical products, electric machinery, metal-manufactured products and transport products (Guia do Mundo 2002, CIA World Factbook 2003, Romero 2003). The main economic partners of Uruguay, in descending level of importance are: Argentine, Brazil and Paraguay (MERCOSUR countries), Portugal, Spain and United States of America.

Agriculture

The agricultural sector is oriented towards the production of cattle in natural pastures, milk (dairy products) and grains (which take up approximately 5% of the Uruguayan territory). The climatic conditions allow the cultivation of both sub-tropical and temperate crops; wheat and barley during winter, and corn, rice, sunflower and sorghum during summer. Most of the products derived from livestock raising (meat, milk and wool), barley, rice and citrus are exported, and represent 85% of the total exports. In the Uruguay East region that encompasses the Mirim Lagoon and the Atlantic Basin of Uruguay (Vertiente Atlántica), agriculture is basically dedicated to livestock, including cattle and sheep. Cattle raising is particularly important in the departamentos of Cerro Largo and Treinta y Tres, where the cattle density is higher than in the rest of the region. Pig raising is the main activity in the departamento of Rocha. In the south of Lavalleja, the production of milk has been intensified but, together with the Maldonado departamento, this area is essentially occupied with arable agriculture; the main products are corn and crops for the food industry, such as sunflower. Rice is mostly cultivated in the lowlands of Treinta y Tres, Cerro Largo and Rocha. The rice fields were established on the margins of the rivers Cebollatí, Olimar, Tacuarí and the Mirim Lagoon. Rice has performed successfully during the recent years and the area planted expanded. In a few years, Uruguay has changed from rice importing to exporting status. Rice cultivation in the region is highly dependent on great amounts of water. Due to this reason the rice fields were established in lowlands of the eastern side and the Mirim Lagoon basin, where the water is taken mostly from the rivers Cebollatí and Olimar. About 89% of the cultivated area corresponds to the Mirim Lagoon basin. The departamentos of Treinta y Tres, Rocha and Cerro Largo concentrate 77.5% of the rice fields. Harvested rice is threshed in rice mills. The rice exported is pre-cooked in plants located in Treinta y Tres. The exportation is directed to the EU, Israel and Chile among others. The domestic market consumes 25% of the whole production.

The country has a dynamic private sector engaged in the development of irrigation. The national policy is to stimulate the diversification and intensification of the agriculture sector (Programa de Exportaciones de Productos No Tradicionales Agropecuarios (PENTA)) through private initiatives. Products with higher commercial value (horticulture for export, such as garlic, onion, strawberry, tomato, etc.) and citrics have received special attention. Increases in the summer cultivation of corn, sunflower and soybeans in rotation with winter grains (wheat or barley) are also planned. The actions of the Uruguayan irrigation programme (PRENADER) for the next years include feasibility studies for construction of small irrigation systems for individual farmers and farmer's associations. Regarding the large or medium sized irrigation projects, studies have been carried out about options to promote projects of collective investments that do not compromise other water uses. The programmes to assist those producers involved with non-traditional agriculture, training in irrigation, assessment of aquifers, use of geographical information systems and the pilot programme of micro-basins will continue.

Fisheries

As mentioned previously, the Uruguayan strip of land numbered as 89 in Figure 2 corresponds to the Atlantic basin of Uruguay or Vertiente Atlántica basin in Spanish and is part of the Uruguayan East region. From the oceanographic and ecosystem viewpoints this area cannot be included as part of Brazil Current. Differently from the Uruguayan portion of the Mirim Lagoon, which drains to Patos Lagoon and then, to the Brazil Current coast, the Vertiente Atlántica is associated to the Large Marine Ecosystem LME 14 Patagonian Shelf, which form GIWA region 38 Patagonian Shelf. This area is here assessed independently from the Brazil Current. Regarding the primary productivity, it is described as the LME 14.

The Patagonian Shelf Large Marine Ecosystem LME 14 extends from Uruguay to the Strait of Magellan. It has a total area of about 2.7 million km^2, but only its northern 200 km coastline portion, down to Punta del Este, are part of the basin 89 Vertiente Atlántica. The continental shelf is relatively narrow in this north portion but widens progressively to the south, after the Atlantic Basin of Uruguay, where it reaches a width of about 850 km. The LME 14 has a distinctive bathymetry and hydrography from LME 15. It is influenced by two major wind-driven currents: the northward flowing Falklands/Malvinas Current and the southward flowing Brazil Current (Bakun 1993). The two currents provide the LME with a distinctive ecological boundary to the east. The LME is therefore, a composite area with a unique combination

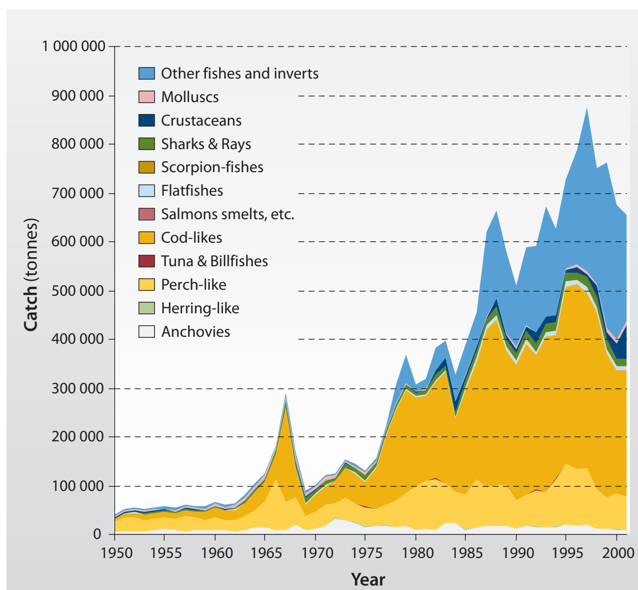

Figure 21 Catch Large Marine Ecosystem LME 14, Patagonian Shelf (1950-2000), where the sub-basin 89 Vertiente Atlántica is included.
(Source: Large Marine Ecosystems 2003)

of characteristics. Differently from the neighbour LME 15 South Brazil Shelf (which is Class II moderately high productivity ecosystem 150-300 gC/m^2/year), the Patagonian Shelf LME is considered a Class I, highly productive (>300 gC/m^2/year) ecosystem based on SeaWiFS global primary production estimates, and so is the basin 89. While the southward flowing Brazil Current is warm and saline, the northward flowing Falklands/Malvinas Current carries cool, less saline, nutrient-rich sub-antarctic water towards the equator. The two currents mix their waters at a Confluence Zone (CZ). The CZ is a wide area characterised by intense horizontal and vertical mixing. The exchange of water masses of different temperatures and salinity affects the biological productivity. The characteristics and dynamics of the CZ, however, are still poorly understood. The LME 14 provides a favourable reproductive habitat for anchovies and sardines, when physical processes such as upwelling and mixing combine favourably in special configurations (Bakun 1993), so that fish larvae remain close to food sources. The LME 14 is rich in a variety of fishery resources (Figure 21), including hake (Common hake and Patagonian hake), anchovy, squid, southern blue whiting, red shrimp and sardines.

Energy sector

The total production of electricity in Uruguay is equivalent to 5.7 billion kWh and the total consumption is 5.89 billion kWh (Guia do Mundo, 1996). The power generation in Uruguay is based on hydropower (95.4%), fossil fuels (3.9%) and others (0.7%) (CIA World Factbook 2003).

Mining

The extraction industry is also of some importance in the East region of Uruguay. In the departamento of Maldonado, stone for civil construction and for ornamentation such as granite and marble are extracted.

Tourism

The tourism sector is increasing in Uruguay, mostly during summer in the coastal zone, due to: (i) investments from the neighbouring countries and from the USA; (ii) investments in highways construction and other infrastructure projects; and (iii) improvement of the service sector. In the East region, the tourism during the summer and the autumn is the main activity in the coastal zone formed by the Vertiente Atlántica. The service sector is intense on the coast. Tourism is more intensively developed in the Uruguayan coastal zone of the La Plata River, where the capital of Montevideo is located. The environmental impacts due to urbanisation are also more significant outside the Atlantic coast of Uruguay where relatively preserved beaches are still found. In the Vertiente Atlántica, Punta del Leste is worth to mention as a traditional tourist city.

Legal framework

The main institutions related to the water resources and associated living resources in Uruguay are:

- The Uruguayan irrigation programme (PRENADER), which is formed by: (i) the government (Ministry of Livestock, Agriculture and Fishing (MGAP); Ministry of Transport and Public Works (MTOP); and the Planning and Financial Office) and; (ii) the farmers representatives, assisted by the World Bank, which has supported the irrigation expansion, according to a sustainable use of water and soil;
- The Department of Water Resources that belongs to the Hydraulic division of the National Directory of Hydrology in the Ministry of Transport and Civil Works, as well as the General Directory of Renewable Nature Resources (DGRNR), in the Ministry of Livestock, Agriculture and Fishing;
- The Ministry of Industry and Energy, through the National Directorate of Mining and Geology (DINAMIGE), in charge of the inventory and management of groundwater resources in Uruguay;
- The National Administration of Sanitary Works (OSE), responsible for the water supply in Uruguay and the sanitation outside the capital Montevideo, where the Municipal authority of Montevideo is responsible for the water supply and sanitation;
- The Ministry of Industry, Energy and Mining is responsible for the energy policy in the country, meanwhile the National Administration of Electric generation and transmission is responsible for generation and transmission of energy. The Technical Commission of Salto Grande (Uruguayan and Argentinean) is in charge of the management of the Hydropower Plant of Salto Grande.

In Uruguay, two laws rule the water uses: the Water Code (Law No. 4 859, 1978) and the Law of declaration of irrigation for agricultural purposes, without risk for the other legitimate uses. Based on the second law, the Adivsory Commission of Irrigation, formed by the MGAP, MTOP, Ministry of Economy and Finances, Ministry of Housing, Territorial Planning and Environment and the representation of private entities, advises the government on the concessions of financial support, irrigation fees and execution of hydraulic works. Regional committees of irrigation, coordinate the users in the equable distribution of water during deficit periods; opinion about new concessions; civil works and other initiatives, updating of the register of hydraulic works and inspection of them. There are also the Agrarian Societies of Irrigation, for those farmers that want to form groups to obtain concessions and other rights and permissions.

Assessment

Marques, M. and B. Knoppers

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 9. Detailed scoring information is provided in Annex II of this report.

Table 9 Scoring table for South/Southeast Atlantic Basins, East Atlantic Basins and São Francisco River Basin.

	South/Southeast Atlantic Basins						East Atlantic Basins						São Francisco River Basin					
	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	1.8* ↗	1.8 ↗	1.0 →	1.7 ↘	**1.7**	3	1.7* →	2.4 ↗	1.4 →	2.7 ↘	**2.1**	3	2.0* →	2.3 ↗	2.3 →	2.6 ↘	**2.3**	1
Modification of stream flow	2						2						3					
Pollution of existing supplies	2						2						1					
Changes in the water table	1						1						2					
Pollution	2.0* ↗	2.7 →	2.3 →	2.0 →	**2.4**	1	2.1* ↗	2.7 →	2.3 →	2.3 →	**2.5**	1	1.9* ↗	1.7 ↗	2.0 →	2.0 →	**2.0**	3
Microbiological pollution	2						2						1					
Eutrophication	2						2						1					
Chemical	2						2						2					
Suspended solids	3						3						3					
Solid waste	2						2						1					
Thermal	1						1						0					
Radionuclide	0						0						0					
Spills	2						2						1					
Habitat and community modification	2.6* →	2.3 →	1.4 →	2.3 →	**2.2**	2	2.6* →	2.3 →	1.4 →	2.3 →	**2.2**	2	2.4* →	2.3 →	1.4 →	2.2 →	**2.2**	2
Loss of ecosystems	2						2						2					
Modification of ecosystems	3						3						3					
Unsustainable exploitation of fish	2.7* →	1.7 ↘	1.0 →	1.0 →	**1.6**	4	2.8* →	2.0 →	1.3 →	2.0 →	**2.0**	4	2.2* →	2.1 →	1.0 ↘	1.5 →	**1.7**	4
Overexploitation	3						3						3					
Excessive by-catch and discards	3						3						2					
Destructive fishing practices	3						3						2					
Decreased viability of stock	2						2						1					
Impact on biological and genetic diversity	2						2						2					
Global change	1.3* →	1.8 →	1.1 →	1.7 →	**1.5**	5	0.9* →	1.1 →	0.7 →	1.4 →	**1.1**	5	1.4* →	1.4 →	1.4 →	1.8 →	**1.6**	5
Changes in hydrological cycle	2						2						2					
Sea level change	1						1						1					
Increased UV-B radiation	0						1						0					
Changes in ocean CO_2 source/sink function	0						0						0					

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter)

IMPACT 0 No known impacts; IMPACT 1 Slight impacts; IMPACT 2 Moderate impacts; IMPACT 3 Severe impacts

The arrow indicates the likely direction of future changes.

↗ Increased impact; → No changes; ↘ Decreased impact

* This value represents an average weighted score of the environmental issues associated to the concern. ** This value represents the overall score including environmental, socio-economic and likely future impacts. *** Priority refers to the ranking of GIWA concerns.

Freshwater shortage

IMPACT **South/Southeast Atlantic Basins** IMPACT **East Atlantic Basins** IMPACT **São Francisco River Basin**

Brazil's territory holds 8% of all the freshwater in the world. However, 80% of this amount is found in Amazon region and the other 20% is unevenly distributed in the rest of the territory where 95% of the Brazilian population is concentrated. Scarcity due to climate conditions is found in the semi-arid region named "The Drought Polygon" that encompasses several states in the Northeast Brazil region. Thus, despite of the total large amount of water in the country, this is a resource that requires efficient regional management and pollution control to avoid conflicts raised by multiple uses.

The concern Freshwater shortage was considered as first priority in São Francisco Basin, and third priority in both East Atlantic Basins and South/Southeast Atlantic Basins. These results illustrate the differences between the sub-regions and the importance of assessing the issues separately in each sub-region, before assessing the whole region. Although freshwater shortage was considered to cause moderate impacts in Brazil Current sub-regions, scarcity of water already occurs in specific areas where a combination of high population density and medium to low specific discharges is found (PNRH 2003). Wherever this situation is controlled by efficient engineering and management practices, such as flow regulation, groundwater exploitation or transfer of water from another basin, environmental and socio-economic impacts due to freshwater shortage were assessed as slight to severe. The scoring procedure for the concern freshwater shortage was based on the degree of severity as a result of anthropogenic pressures. Areas suffering from freshwater shortage due to existing climatic conditions, regardless of human activities, only received high score if the impacts due to natural causes were significantly worsened by anthropogenic pressures.

There are catchment areas in Brazil (particularly in GIWA region 39 Brazil Current) where, despite the high natural availability of water, unplanned and disorganised settlement has created problems of disputes over water, mainly due to scarcity of water of required quality. Portions of the South/Southeast and East Atlantic Basins fit into this category. At the other extreme, there are areas with low natural water availability, such as the semi-arid sub-middle and lower portion of the São Francisco Basin, where an association between low rainfall and high evaporation is found (PNRH 2003). In this area, uneven distribution of rainfall throughout the year and in multi-annual periods further worsens the scarcity of water. It is in the semi-arid areas, such as the lower São Francisco Basin, that drought hits hardest. In contrast, in the upper course of São Francisco River, as well as in most of East Atlantic and Southeast/South Atlantic Basins, freshwater shortage is raised by high and multiple demands and conflictive uses (particularly the excessive use in irrigation), aggravated by pollution, which limits the potential uses of water (PNRH 2003).

According to the indicator "mean discharge per capita", (m^3/year/inhabitant) used to define water availability, the Brazil Current encompasses areas that fit basically in three different categories (PNRH 2003): Regular (1 000-2 000 m^3/year/inhabitant), Sufficient (2 000-10 000 m^3/year/inhabitant) and Rich (10 000-100 000 m^3/year/inhabitant). There are only two exceptions in the Brazil Current that fall below the category Regular availability; the basins in the littoral of Rio de Janeiro state (59 in Figure 2), which is classified in the category Poor (500-1 000 m^3/year/inhabitant), mainly due to high population density, and the upper portion of the East Atlantic Basins in Sergipe and Bahia states (50 in Figure 2), classified in the category of Very Poor (less than 500 m^3/year/inhabitant), mainly due to climate conditions.

Non-consumptive uses of water are those that do not consume water and, for that, do not need to be considered in the water budget. However, these uses may still cause restrictions for the water resources management. Non-consumptive uses are those usually performed directly in the river stream such as electricity generation, transport, aquaculture and leisure/recreational activities. Consumptive uses consume part of the water budget and are basically performed outside the river stream, such as human and animal consumption, irrigation and industrial uses. The consumptive uses, or simply, consumption, of water in each sub-region of the Brazil Current are briefly commented below.

Irrigation is developing along different models. In southern/southeastern Brazil, private investments predominate (similar to irrigation projects in Uruguay), with emphasis on rice fields and grain crops (upper São Francisco River Basin and the southeast portion of South/Southeast Basins). In these areas the investments in irrigation depend on the return obtained from the sale of the crops. In semi-arid portions of the East Atlantic Basins, the public sector is the main investor for stimulating regional development in an area with severe social problems. In this latter region investments in the cultivation of traditional crops, such as corn and beans, have not given the expected return and the focus has moved to irrigated fruit production with greater added value and economic return. This shift has altered the characteristics of both seasonal and total annual demand for water (PNRH 2003).

In Uruguay, hydrological studies have shown that during spring-summer seasons, water deficit is observed in the majority of the soils, which represents a constraint for agriculture development during these seasons. Irrigation became a common practice in Uruguay agriculture after the implementation of the Programme of Natural Resources and Irrigation Development (PRENADER) (Programa de Recursos Naturales y Desarrollo del Riego). About 7 700 km² of land were irrigated in 1993 (CIA World Factbook 2003). Irrigation is used on large scale for rice production, including the Mirim Lagoon basin, under the Law of Irrigation (Ley de riego), which should prevent the soil degradation. Irrigation is also used locally in fruit and vegetable production.

In the South/Southeast Atlantic Basins, irrigation alone is responsible for 77% of the total consumption of water, followed by the human supply, which is about 11% of the total demand (Table 10). Although the Rio de Janeiro Metropolitan region hosts 9 million inhabitants, the littoral of Rio de Janeiro has low water availability (76 m^3/s) and depends on transfer of water for 90% of its demand from another basin, the Paraíba do Sul River. According to the state water sewage company, CEDAE, this water transfer is the only way to supply demand of the Rio de Janeiro littoral (59 in Figure 2), which is situated entirely in the littoral plain (PNRH 2003). Due to the large areas cultivated with rice, irrigation in the Guaíba Lake and Mirim Lagoon basins (both in Rio Grande do Sul state, southern South/Southeast Atlantic Basins) represents almost 60% of the total consumption of water in the South/Southeast Atlantic Basins. If the human consumption in Rio Grande do Sul state (with a high urban concentration in Guaíba River Basin) is added to this figure, more than 75% of the total consumption of the South/Southeast Atlantic Basin occur inside the state of Rio Grande do Sul. As shown in Table 11, the demand in the littoral of Rio Grande do Sul surpasses the water availability (231%) where water supply is achieved through regulation of reservoirs (PNRH 2003).

In the East Atlantic Basins, the urban consumption (26.3%) shows the highest demand compared to the human consumption in other sub-regions (Table 10). This result reflects the strong influence of the Rio de Janeiro Metropolitan area (RJ), Salvador (BA), Vitória (ES) and Aracaju (SE). The Paraíba do Sul River basin (58 in Figure 2), supplies not only the demands in the Basins, but also 9 million inhabitants and activities carried out outside the Basins, in Rio de Janeiro littoral (59 in Figure 2). More than 60% of the total demand for water in the East Atlantic Basins is concentrated in the Paraíba do Sul River basin. The semi-arid portion of the East Atlantic Basins suffers restrictions of water supply for irrigation purposes.

In the São Francisco River Basin, irrigation is by far the main consumptive use of water, corresponding to about 68.1% of the total water consumption in the Basin. It is likely that animal consumption is underestimated due to the following aspects: (i) cattle for milk production mostly in the upper São Francisco usually requires more water due to intensive husbandry; and (ii) the consumption of water by other animals (e.g. pig and chicken) is not included in this calculation. The other consumptive demands come from industry, mostly in the upper São Francisco in Minas Gerais state (responsible for 60% of the industrial uses) and sub-middle São Francisco (e.g. Petrolina/Juazeiro municipalities that host a number of industries). The highest demand/availability ratio (13.5%) is found in the upper São Francisco due to the high urban demand. The lowest ratio (1.4%) is found in the lower São Francisco (PNRH 2003).

Table 10 Water availability and demand per sector.

Sub-region	Availability (m^3/s)	Demand per economic sector (m^3/s)					
		Urban	Rural	Livestock	Industry	Irrigation	Total
South/Southeast Basins	813	41.5	9.1	6.0	34.2	294.9	385.7
% sub-regional demand		10.8	2.4	1.6	8.9	76.5	47.5
East Atlantic Basins	1 063	65.7	31.3	12.1	35.8	104.6	249.6
% sub-regional demand		26.3	12.5	4.9	14.4	41.9	23.5
São Francisco Basin	1 077	35.3	8.7	7.8	12.9	138.2	203.0
% sub-regional demand		17.4	4.3	3.8	6.4	68.1	18.8

(Source: PRNH 2003)

Table 11 Water demand/water availability ratio in basins of the Brazil Current region where water demand (D) is higher than available water (Q).

Basin	Area (km^2)	P[1] (mm)	E[2] (mm)	Q[3] (m^3/s)	q[4] ($l/s/km^2$)	D/Q (%)
Itapicuru & Vaza-barris basin	67 761	950	915	75	1.1	144.3
Paraguaçu River basin	71 134	1 073	974	224	3.1	182.1
Rio de Janeiro Littoral basin	19 698	1 344	699	403	20.5	109.3
São Paulo Littoral basin	4 893	1 823	1 217	94	19.2	102.1
Rio Grande do Sul Littoral basin	56 654	1 381	731	1 168	20.6	231.3

Note: [1]P=Precipitation, [2]E=Evapotranspiration, [3]Q=Mean flow over a longer period, [4]q=Specific flow. (Source: PNRH 2003)

In some basins of the South/Southeast Atlantic and East Atlantic Basins, water demand exceeds the available water resources (Table 11). This situation requires special management policies such as flow regulation, preservation of springs, groundwater exploitation and transfer of water from other basins or, in the last resort, rationing (PNRH 2003). Nevertheless, considering South/Southeast Atlantic and East Atlantic Basins together, the demand is comfortably below the average available water.

In South/Southeast Atlantic and East Atlantic Basins water quality is more important than water quantity from the environmental viewpoint. In São Francisco Basin, quantity is the main concern and changes in the stream flow due to damming have severely affected the ecosystems and the aquatic diversity, as well as the sediment transport to the coast.

Environmental impacts

Modification of stream flow

Modification of stream flow produces moderate environmental impact in the South/Southeast Atlantic and East Atlantic Basins, but produces severe environmental impacts in São Francisco River Basin. Stream flow monitoring has been carried out in many rivers in Brazil. In 2002, the monitoring network in Brazil had 8 144 stream flow monitoring stations monitored by different institutions, among them, 948 stations which also monitor water quality (PNRH 2003). However, in some cases the quality of the data needs to be improved. One methodological constraint highlighted in Clark & Dias (2003) is that stream flow versus water level function adjustments are required when erosion takes place, yet collecting the necessary data is constrained by the fact that many of the stations are remote and difficult to access. There are indications of modification of stream flow in many rivers in the Brazil Current. Few studies have addressed this issue in a scientific long-term perspective, which would be necessary to address more precisely the causes of flow modification. Some illustrations of stream flow modification leading to both freshwater scarcity and flooding are described below.

Modification of stream flow is observed in several rivers in South/Southeast Atlantic Basins, not always related to freshwater shortage. In some basins, the impacts can be considered as severe. One example occurs in Santa Catarina state. Intensive deforestation has caused erosion, reduction of water infiltration and siltation of riverbeds, which in turn is associated to increased flooding in the Valley of Itajaí River (basin 83 in Figure 2). Associated to climatic conditions, changes in land cover have caused water scarcity and flooding in this area. In the upper Itajaí River basin, deforestation of the hillsides and degradation of riparian vegetation lead to impacts on watercourses, which dry up due to silting (Frank 1995). Deforestation has reduced the soil capacity for rainwater storage and has affected the stream flow. Increased human activity in urban and rural regions has reduced the areas not subject to flooding (Frank 1995). During the drought periods, freshwater availability for human consumption and irrigation in the higher parts of the Itajaí Valley has decreased. However, the most severe socio-economic impacts are due to flooding in the lower parts. The floods have been a long-term problem for Itajaí Valley and since 1850, 67 floods have been recorded in the city of Blumenau. However, since the 1920s, when occupation of the upper part of Itajaí Valley expanded, the frequency of smaller floods has increased (Figure 22).

Freshwater shortage in the East Atlantic Basins is a result of the combination of regional and local weather conditions and anthropogenic causes. The region is characterised by a sharp gradient of climate. For natural reasons, freshwater shortage in the East Atlantic

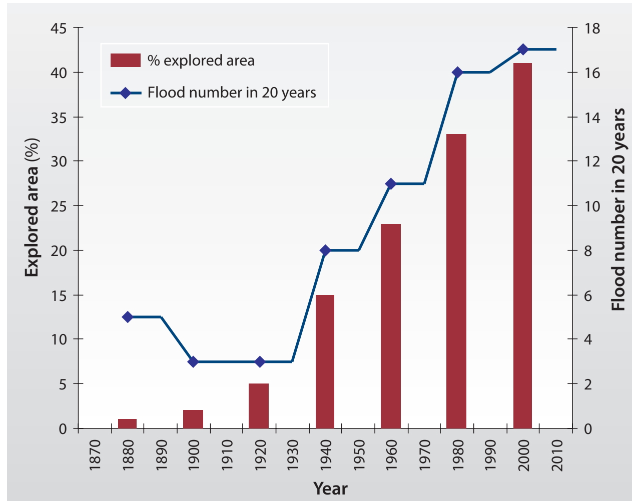

Figure 22 Explored areas in the Itajaí River basin and the occurrence of flood events per year in Blumenau city in 20 year intervals (1850-1990).
(Source: IPA/FURB in Comitê do Itajaí 2002)

Basins decreases from north to south because of the climate gradient, which varies from semi-arid in the north to humid in the south. This is also seen in the seasonal variations of river flows, where the northern flows are intermittent and the southern are perennial. The area with the worst freshwater shortage is therefore the northern coastal area. In addition to climate, the construction of dams and use of the water for multiple purposes (e.g. drinking water and irrigation) on many rivers has changed the water balance in the region. Even excluding the atypical low levels of rainfall during 2000-2001, there is a clear decrease in water flow compared to historical values in tributaries of medium-sized basins in the East Atlantic Basins, including the transboundary basins of Contas, Jequetinhonha, Mucuri, Doce and Paraíba do Sul rivers. In order to investigate flow changes and statistical significance of these, in the Paraíba do Sul River, stream flow time series data taken from one monitoring station (Guaratingetá) were analysed from the beginning of the 20th century (Marengo et al. 1998), using the Mann-Kendall statistical method. A significant trend towards flow reduction (negative trend) was observed in this important water supply body. The same statistical modelling applied to the rainfall data taken from the upper and middle portions of the basin showed no significant changes (Marengo et al. 1998). The reduction observed in the stream flow was therefore imputed to anthropogenic activities in the basin.

The Doce River basin (56 in Figure 2) has an area of 83 500 km^2, 86% located in Minas Gerais state and 14% in Espírito Santo state. During the last decades, the River has suffered from progressive land degradation. Progressive erosion contributes to the pollution with suspended solids and siltation of riverbeds. Pasture with an excessive number of animals per hectare (overgrazing) and deforestation of steep slopes have been the main cause of erosion, followed by the type of grass in the pasture areas, and annual burning as a routine agriculture practice. These practices reduced the productivity in the region with a tendency to replacement of pasture by Eucalyptus trees, which resist to low fertility and high acidity of the soil. In the Doce River basin, the sub-basins specific flows vary from 5-10 to 30-35 $l/s/km^2$, and there is a significant stormwater run-off due to silting (suspended solids issue) and low infiltration rate, causing a shortage of water for vegetation, groundwater recharge and consequently more erosion and stream flow modification. The consequence is drought or flooding, depending on the climatic conditions.

Although the severity of environmental impacts due to freshwater shortage in the Brazil Current as a whole was moderate, specifically in São Francisco Basin the issue modification of stream flow has caused severe environmental impacts according to the criteria: significant increased silting or erosion due to changing in flow regime. As previously mentioned, this basin is partially located in the Brazilian semi-arid region (The Drought Polygon). Although rainfall rates in excess of 1 300 mm per year prevail in the upper São Francisco area, as one travels downstream, the climate changes and becomes gradually drier, changing from a humid tropical climate in the upper part, to sub-humid, semi-arid, and then returning to sub-humid near the coast (Figure 23). There is clear evidence of declining flow rates of São Francisco River streams, particularly those located in the semi-arid region. Similarly to the investigation carried out for Paraíba do Sul River (Marengo et al. 1998), time series analysis for São Francisco River stream flow (Juazeiro station) were carried out from the beginning of the 1900s (Marengo et al. 1998). Using the Mann-Kendall statistic method, significant trends towards flow reduction (negative trend) were observed. Rainfall time series analysis for the region did not show any negative trend. Therefore, the stream flow reduction was again imputed to anthropogenic activities in the basin. Irrigation is an activity of little significance restricted to the driest months in the upper São Francisco River but becomes essential and is intensively practiced in the middle and lower São Francisco.

Above all, the construction of a cascade of dams along São Francisco River has resulted in flow regulation and reduction of the peak flows as well as an increase in evaporation of the order of 10-12% from the constructed reservoirs (ANA 2002b). As a consequence, during the last years, a significant reduction in sediment transport has occurred, particularly after the construction of Xingó Dam. Severe impacts such as coastal erosion and reduction of primary productivity are noticed (Machmann de Oliveira 2003).

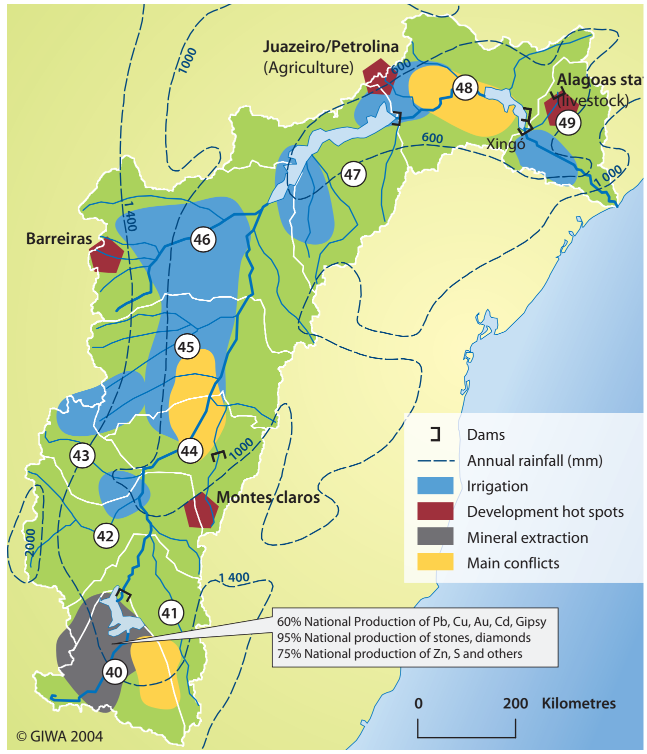

Figure 23 São Francisco River Basin.
(Source: PNRH 2003)

Pollution of existing supplies

The issue pollution of existing supplies as part of the concern Freshwater shortage is assessed in more details under the concern Pollution, where different issues related to pollution of freshwater and coastal/marine water are investigated. Here, pollution will be briefly addressed and the emphasis will be put instead on water scarcity aspects due to pollution. Since in a causal chain analysis perspective, if pollution is the cause of water scarcity, the policy options and initiatives to be proposed will focus on pollution. Pollution of existing supplies was assessed as causing moderate environmental impacts in South/Southeast Atlantic and East Atlantic Basins and slight environmental impacts in São Francisco River Basin. The majority of the Brazilian rivers which are monitored for water quality (surface, sediments and groundwater) have incomplete time series and monitoring methodological problems. Therefore, pollution severity in water supplies at regional level might be underestimated due to insufficient available information. In 2001, the Brazilian National Agency of Water (ANA) estimated, based on monitoring programmes and data, that about 70% of all rivers included in the South/Southeast Atlantic and East Atlantic Basins of the Brazil Current and the contiguous GIWA region 40a Brazilian Northeast, were polluted as a consequence of human activities. ANA concluded that these rivers are contaminated by pesticides, fertilisers, industrial effluents, domestic sewage due to inappropriate land use and occupation and the by-products of mining and deforestation. The southeastern Brazilian coast is the most industrialised and urbanised part of the South American coast and has the largest industrial parks and ports of the sub-continent (Lacerda et al. 2002). Insufficient or lack of treatment for both domestic as well as industrial sewage represents a serious threat to the freshwater supplies. In the whole Brazil Current, the most common widespread type of pollution is the organic load/nutrients discharged into rivers, mainly from untreated domestic sewage, which is in part naturally mitigated. Other important types of pollution of water supply bodies (e.g. chemical, suspended solids and spills) are more site-specific and depend on the sector activities in each basin. Chemical pollution comes mostly from industries and agriculture along river catchments and pollution by heavy metals (mostly in sediments) has been the most frequently studied. Due to recent episodes in both South/Southeast Atlantic and East Atlantic Basins, pollution by toxins released during algal blooms in reservoirs and lagoons is gaining importance in the environmental debate (for details, see section on Pollution and Annex III).

In some parts of the coast of São Paulo, for instance, sewage is pumped straight into rivers or the sea, although thanks to the efforts of the local and the state government during the last decade, the problem has been reduced (Municipality of Santos 1997). Rivers contaminated with heavy metals and other hazardous substances is found in the Ribeira Valley, in the São Paulo portion included in South/Southeast Atlantic Basins. Among the most severe cases of water pollution in the South/ Southeast Atlantic Basins, the Valley of Itajaí (83 in Figure 2) and the Guaíba Lake (87 in Figure 2) should be mentioned. In the Guaiba Lake, the main pollution sources are the domestic sewage, metal industry, food and textile industry and sand extraction. In the Itajaí Valley the main sources are sugar cane and alcohol production.

Although the environmental impacts in the East Atlantic Basins resulting from contamination of existing water bodies were considered moderate, there are basins that suffer from severe impacts, such as some tributaries of the transboundary rivers in the Brazil Current: Paraíba do Sul, Doce, Jequitinhonha and Pardo. Pollution of these water supplies has transboundary implications and has caused periods of water scarcity/rationing. Economic activities in the upstream state such as mining, agriculture, urbanisation and industry are polluting the water that supplies the downstream state. These implications are now addressed by the states sharing the drainage basins through interstate basin Committees, recently created, according to the Brazilian Federal Water Law No. 9 433, 8th January, 1997. Two recent episodes involving Paraíba do Sul River illustrate the severity of this transboundary issue and the risk of water scarcity downstream: (i) an event of algal bloom in the Funil Reservoir in Rio de Janeiro due to pollution transported from the upstream São Paulo state (Diário do Vale 2001, O Globo 2001); and (ii) an accident with the Cataguazes paper-pulp plant, located in the upstream Minas Gerais state, causing contamination downstream in the north of Rio de Janeiro state, resulting in increased mortality among domestic animals and interruption of domestic supply (FEEMA 2003a, FEEMA 2003b) (for details, see Annex III). Due to their importance as water supply bodies and the transboundary management complexities, the basins of Paraíba do Sul River and Doce River are priority candidates for governmental actions.

The main sources of pollution in São Francisco Basin are domestic sewage, industrial wastewater, and diffuse pollution by pesticides and fertilisers from agricultural areas. Although freshwater shortage is the first priority concern in São Francisco Basin, pollution is not the main cause (see Modification of stream flow in São Francisco Basin). Excluding the upper São Francisco Basin (Belo Horizonte Metropolitan area), pollution was considered as having moderate impact on freshwater shortage. The Belo Horizonte Metropolitan area in the upper São Francisco is alone responsible for 54% of the domestic organic load discharged in the whole basin. Besides domestic and industrial sewage, mining and mineral processing industry is also an important source of pollution in the upper São Francisco Basin. The sugar cane alcohol industry still discharges large amounts of wastewater into the upper São Francisco, although some improvement has been noticed since the start of the practice of using waste from transformation of alcohol to irrigate agriculture.

In Uruguay East region, the impacts of increasing activities such as agriculture, livestock and tourism on the water quality have not been fully addressed. In this region, many cities with 10 000 to 20 000 inhabitants are found in the heart of agricultural areas. In some of these cities and their surroundings, levels of nitrates higher than the threshold limits have been found in wells used for human supply and other uses. This pollution seems to be limited to local aquifers and the pollutant transport parameters vary from area to area (JICA 1994). In many cases, groundwater pollution is related to bad construction of wells, inefficient wastewater management and lack of protection of the wells and the recharge areas (Anido 2003).

Changes in the water table

For South/Southeast Atlantic and East Atlantic Basins the environmental impacts due to changes in the water table were considered slight. However, São Francisco Basin suffers from moderate environmental impact. In Brazil, the volume of groundwater has been estimated at 112 000 km^3 and there are approximately 300 000 wells being used and over 10 000 new wells are bored every year (PNRH 2003). In contrast to the monitoring of surface water, groundwater monitoring in Brazil is much more fragmented, being the responsibility of the state, instead of the federal government (Clark & Dias 2003). The state Company of Mineral Resources Research (CPRM) has been organising a databank (SIAGAS) for groundwater quality that hopefully will help to improve the information available. The use of groundwater for supply purposes varies from basin to basin. In the sub-basin of Taquari-Antas in Rio Grande do Sul state (South/Southeast Atlantic Basins), for instance, 74 out of 111 municipalities are totally dependent on groundwater for human consumption. In Paraíba do Sul River basin (58 in Figure 2) groundwater is mostly used by the industries that need higher quality of water and such use is more relevant in the state of São Paulo (Taubaté). In the Brazil Current region, a high number of wells have been abandoned or deactivated due to salinisation of the water. Among groundwater contaminants in Brazil, the most important is nitrogen (ammonium (NH_4), nitrite (NO_2) and nitrate (NO_3)) as a consequence of the low percentage of sewage collection and treatment. Irrigated agriculture also contributes to elevated levels of nitrate in the groundwater. As a consequence of growing industrialisation and agriculture with irrigation and intensive use of fertilisers, other pollutants that have become important are phosphate, sulphur, selenium, mercury, cadmium, lead and zinc.

Groundwater pollution has been detected in São Francisco Basin, where the dependency on this supply of water is greater than in the rest of the Brazil Current region. Two geological formations coexist in São Francisco Basin. The potential of crystalline rocks and their overlying soils as water resources is limited due to lack of permeable aquifer volume, rendering such resource insufficient for human consumption. The largest reserves of groundwater are located in sedimentary rocks and their associated soils. Some areas intended for agriculture have been impaired by salinisation, resulting in a loss of cultivation capacity in those areas. In northern Bahia state, the use of groundwater for domestic, agricultural and industrial purposes is considerably higher than in southern Bahia, where it is used mostly for industrial purposes. During periods of drought in São Francisco Basin, the use of groundwater compensates for the water scarcity in non-perennial rivers. The drainage area bound to the north by the São Francisco Basin and to the south by the Todos os Santos Bay in Bahia state (50 in Figure 2) shows regional scale of salinisation, and perennial waterways are drying up. In the basins of Vaza-Barris, Sergipe and Piauí-Fundo-Real, for instance (50 in Figure 2) the salinisation of wells is documented in areas of extensive cattle farming and non-irrigated agriculture.

Socio-economic impacts

Economic impacts

The economic impacts due to anthropogenic activities arising from freshwater shortage in the Brazil Current were considered moderate in all sub-regions at present but with a clear tendency to be aggravated in the future. In South/Southeast Atlantic and East Atlantic Basins during the 1990s, due to the low economic growth rate, the federal and the state governments made limited investments to avoid water scarcity. Diversion of river course for water transfer are costly and environmentally questionable. The project proposed for São Francisco River to transfer water to the semi-arid portion of the basin has been exhaustively discussed during decades, with no clear conclusion about its convenience. Water policy is becoming more and more restrictive. According to the Federal Law of Water No. 9 433 8th January 1997, plans for any new sectorial activity dependent on water supply must be submitted to the basin committees formed by local/state government authorities, water users and representatives of stakeholders in order to obtain a permission to use a set quantity of water. Loss of opportunities for investments by economic sectors is likely to occur in those basins where such authorisation will be limited by the availability of water. In São Francisco Basin, where water scarcity is associated to quantity and climate conditions more than quality, economic impacts due to freshwater shortage are likely to turn from moderate to severe during the coming 20 years due to the worsening of the following: (i) limitation in agricultural productivity; in the municipalities of Petrolina, Juazeiro and Pilão, hundreds of fruit fields are dependent on irrigation, although energy generation has been a priority in this basin; (ii) limitation in future development of water-dependent activities; in upper São Francisco, the Três Marias hydropower plant restricts water consumption upstream of the dam, which impairs hydropower generation; and (iii) limitation due to low quality of the water; in the Rio das Velhas tributary, the uses of water for agricultural purposes, as well as for public supplies are restricted due to very low quality of the water. Other sectors affected by the low water quality are fishing, aquaculture and tourism.

Health impacts

In South/Southeast Atlantic and East Atlantic Basins as a consequence of the investments in water treatment and supply made by the state and municipal governments, health impacts due to freshwater shortage is considered to be slight at present. However, many coastal cities with a fast-growing tourism industry will require significant additional investments to fulfil the demands. Rationing due to water quality has been the strategy used when the treatment required to make potable water demands longer residence time in treatment stations, or more sophisticated procedures than usual. This has been the case in the water treatment facilities of Guandu that supplies 8 million inhabitants of the Rio de Janeiro Metropolitan area. In March 2003, the previously mentioned accidental release of a large volume of toxic waste water from the Cataguazes paper-pulp plant caused severe pollution and health impacts were only avoided by interruption of water supply to 600 000 people living in the Lower Paraíba do Sul in Rio de Janeiro state. However, the pollution did kill all the fish and mortality among domestic animals were registered. In São Francisco River Basin, the health impacts due to water scarcity were deemed as moderate with tendency to severe, particularly in the semi-arid portion of the Basin, due to the great number of people affected, and the duration, since the impacts are suffered frequently.

Other social and community impacts

Social impacts occur due to floods in the South/Southeast Atlantic and East Atlantic Basins caused by the set of events: deforestation - erosion - reduction of infiltration - siltation of rivers - modification of stream flow - increased flooding. Damage to houses built in the hills during intensive rainfalls in the rainy season (summer) are registered in many cities. There is also an increasing consumption of mineral water among middle-class citizens as a consequence of the public perception that the water quality in the rivers is low, regardless the fact that the water in the distribution system is treated and therefore potable. The social impacts where considered moderate in the South/Southeast Atlantic and East Atlantic Basins. In the lower-middle and lower São Francisco Basin, severe social and other community impacts are described as a consequence of freshwater shortage; migration of populations (about 20%) occurs between not too distant locations (Machmann de Oliveira, pers. comm.). Other social impacts worth mentioning are changes in the family structure due to replacement of fishing by other economic activities caused by the depletion of fish stock, as a consequence of damming and changes in the stream flow, and reduction of fish as a protein source. Significant morphological changes observed in the lower São Francisco River, due to stream flow regulation, are causing cultural changes. As a consequence of a large number of sandbanks along the waterway, navigation, a traditional activity on São Francisco River, is now very difficult and only possible for small boats. In the Atlantic Basin of Uruguay (89 in Figure 2) assessed independently from the Brazil Current region, although the water scarcity is currently considered as producing slight environmental and socio-economic impacts, these impacts are expected to increase due to the seasonal population increases associated with the development of the tourism sector and the urbanisation of the Atlantic coast of Uruguay during the coming decades.

Conclusions and future outlook

According to the water availability indicator mean discharge per capita (m^3/year/inhabitant), currently, the Brazil Current region encompasses basins that fit mostly in three categories: rich, sufficient and regular, which indicate that based on the quantity assessment, freshwater shortage is assessed as having moderate impact in the Brazil Current region. However, such an indicator does not take into consideration different degrees of economic development inside the Brazil Current region, population vulnerability, the anthropogenic pressures and the quality aspects of the water supply. The environmental impacts due to freshwater shortage are likely to increase moderately during the next two decades as a result of slow economic and population growth, aggravated by the littoralisation trend that will probably slow down during the coming decades. However, the most remarkable increase foreseen, in terms of severity of the impacts, will be the economic ones. In order to face the increasing demand for water and mitigate the pollution of existing supplies and reduce or, at least keep the impacts on human health and other social impacts under control, significant response from the society, in terms of investments and raised operational costs will be required.

Pollution

IMPACT **South/Southeast Atlantic Basins** IMPACT **East Atlantic Basins** IMPACT **São Francisco River Basin**

Aquatic pollution can be defined as the introduction of man-made substances into the aquatic environment which are harmful to life and to human or animal health (e.g. pesticides, hydrocarbons, PCBs) and the increase to harmful levels of naturally occurring elements (e.g. heavy metals, suspended solids, organic nutrients). According to the criteria of the GIWA assessment, the concern Pollution was assessed as moderate in South/Southeast Atlantic Basins and São Francisco River Basin, and severe in East Atlantic Basins. The concern was ranked as the priority in the South/Southeast Atlantic and East Atlantic Basins and the third priority in São Francisco River Basin (see Annex II). The same impact score but diverging priorities are due to the relative position the concern received inside each region. For the whole of the Brazil Current region, Pollution was assessed as having the highest priority. Evidence and indications that back this decision are presented below and in Annex III.

The pollution issues of great importance for the Brazil Current are microbiological pollution, eutrophication, chemical pollution and spills. In the Brazil Current region, these issues are usually associated to the process of littoralisation observed in Latin America (Hinrichsen 1998) and are likely to cause moderate to severe environmental impacts, particularly downstream of areas of high urban/industrial density. The severity of socio-economic impacts will depend on the

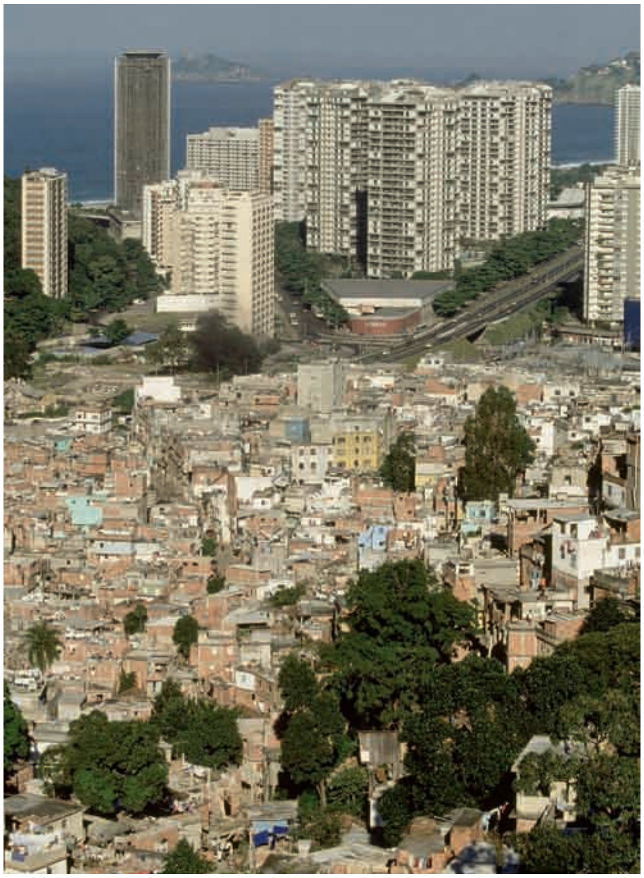

Figure 24 Aerial view of Rio de Janeiro. The Rocinha slum spreading down and out to meet the wealthy area. *(Photo: Corbis)*

society's response to the problem on a local and regional scale. Large cities and metropolitan areas in the Brazil Current, from north to south (metropolitan area/state) are: Salvador/BA, Vitória/ES, Rio de Janeiro/RJ (Figure 24), Santos/SP, Joinville/SC, Florianópolis/SC, Tubarão/SC, Porto Alegre/RS and Pelotas/RS. In these areas, the transport, dilution and assimilation capacity of receiving waters may be exceeded.

For the case where pollution associated to the sub-regional water availability is such that the supply is impacted, this impact was considered in the previous section Freshwater shortage. However, it was advisable to assess pollution of freshwater sources in the present section, regardless of whether it causes freshwater shortage or not.

Environmental impacts

Microbiological

Environmental impacts due to microbiological pollution were assessed as moderate in the South/Southeast Atlantic and East Atlantic Basins and slight in São Francisco River Basin according to the following.

Those river basins in the Brazil Current densely occupied with settlements have shown values of faecal coliforms above the threshold limit established by the Brazilian National Council of Environment (CONAMA) Resolution No. 020/1986 for waters in Class 2 (can be used for water supply after conventional treatment and for direct contact recreation activities such as swimming). Annex III includes information and references about average faecal coliforms concentration values found in Paraíba do Sul River and Doce River (East Atlantic Basins) as well as in São Francisco River. Only in the upper São Francisco does microbiological pollution produce significant impact due to the sewage discharge without treatment from the Metropolitan region of Belo Horizonte, that hosts 2 million inhabitants (IGAM 2001).

According to the Brazilian Law (CONAMA Resolution No. 274/2000) a segment of coastline (beach) is considered proper for bathing (meaning direct contact and recreational uses) if 80% or more of water samples during a 5 week-period do not exceed the threshold limit of 1 000 MPN (Most Probable Number) faecal coliforms per 100 ml of water. Otherwise it is considered inappropriate for bathing and the community is informed via media. Monitoring programmes for thousand sampling points on the Brazil Current coast using faecal coliforms as indicator are carried out by local governments. Based on periodic results, the authorities have recommended restrictions for recreational uses to several beaches located downstream urban centres in basically all coastal municipalities. Similarly to what occurs with rivers, beaches located downstream densely populated urban centres or metropolitan areas are more likely to be contaminated by faecal coliforms in concentrations above the threshold limit, in the littoral of all the states which make up the coastline of the Brazil Current. Rainfall regime has an important influence on the quality of the coastal waters. Intense/long rainfalls increase the stream flows and after these events the beaches receive the most contaminated discharges. It should be highlighted that the majority of beaches in the Brazil Current littoral are considered proper for bathing all year around but they are located outside urban centres and fortunately represent the major extent of the Brazil Current littoral. The efforts spent recently by state and municipal governments with increasing investments in sewage collection and treatment are likely to produce gradual improvements, as the case of São Paulo state in the South/Southeast Atlantic Basins (Municipality of Santos 1997, São Paulo 2002). In Annex III, average values of faecal coliforms, mostly in bays and lagoons in both South/Southeast and East Atlantic Basins are shown.

Eutrophication

The remaining organic load (organic load as BOD_5/day discharged in recipient waters, including treated and untreated effluents) discharged in the Brazil Current region is shown in Table 12 (PNRH 2003). The

Table 12 Remaining domestic organic load, based on estimated values.

Sub-region	Domestic organic load (tonnes of BOD_5/day)	% in the country
South/Southeast Atlantic Basins	1 042	16.4
East Atlantic Basins	1 258	19.8
São Francisco River Basin	498	7.8

(Source: PNRH 2003)

higher value observed for East Atlantic Basins when compared to the others is due to the basins in the littoral of Rio de Janeiro state (59 in Figure 2), which alone contributes with 469 tonnes per day (Figure 25). Paraíba do Sul River basin (58 in Figure 2) contributes with 235 tonnes BOD_5 per day (PNRH 2003). In addition, domestic sewage, run-off from agricultural areas and industrial effluents can be added. Owing to the natural attenuation capacity of the waterways, the impacts caused by the organic load in water supply bodies are mostly observed at lagoons, bays and constructed reservoirs, the last of which usually have two functions: electricity generation and water supply.

Annex III includes examples of rivers in the Brazil Current region, which are important water supply bodies and due to the low quality found in some monitoring stations they are classified as Classes 3 or 4, according to Brazilian standards (CONAMA Resolution No. 020/86). The quality parameters considered, among others, are: BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), nutrients, faecal coliforms and heavy metals. Rivers that serve the purpose of human supply after conventional treatment and primary contact (e.g. swimming) have been initially placed as Class 2 or, in the worse case, as Class 3, but should never be of lower quality than that.

Although eutrophication is not widespread in the coast and rivers (the reason environment impacts are assessed as moderate), in those areas where it occurs, the environmental impacts as well as the socio-economic impacts are certainly severe. The assessment of eutrophication divides the Brazil Current in two categories:

- South/Southeast Atlantic and East Atlantic Basins that show moderate environmental impacts due to eutrophication observed in lagoons, bays, affecting coral reefs and constructed reservoirs (with episodes of fish kills) and;
- São Francisco Basin where the environmental impact observed is due to the reverse problem: low concentration of nutrients mostly in the middle-lower and lower São Francisco River, as a consequence of the trapping of sediments/nutrients in dams, which has caused a decrease in primary productivity (see Annex III) (Machmann de Oliveira 2003). The environmental impact was not

Figure 25 Rodrigo de Freitas Lagoon, Rio de Janeiro (East Atlantic Basins). Death of tonnes of fish during summer due to oxygen depletion, as a consequence of the increasing organic load and temperature rise.
(Photo: JOAO P. NGELBRECHT/UNEP/Still Pictures)

assessed as unknown or absent, but as slight impact due to the eutrophication process and blooms of toxic algae recorded in some reservoirs such as Paulo Afonso and Itaparica (Braga et al. 1999).

Several bays, estuaries, lakes and lagoons downstream from urban centres show different degrees of eutrophication, Guanabara Bay in Rio de Janeiro state (59 in Figure 2), being the most severe case. Anoxia or low oxygen levels (<3 mg/l) occur in lowland watersheds, estuaries and coastal lagoons and significantly affect coastal embayments (Lacerda et al. 2002). Fish kills due to low concentration of dissolved oxygen associated with the proliferation of algae or algal toxins are not uncommon events in Conceição Lagoon (Sierra de Ledo & Soriano-Serra 1999) in Santa Catarina state and Patos Lagoon estuary in Rio Grande do Sul state. According to the Standard Trophic State Indexes (Nixon et al. 1986, Rast et al. 1989), used to classify the trophic level of a water body and that take into consideration particulate organic carbon, nitrogen and phosphorus concentration, dissolved oxygen and chlorophyll a, the following systems have eutrophic to hypertrophic conditions (for details and references see Annex III):

- Guanabara Bay, Sepetiba Bay and Coastal Lagoons of Rio de Janeiro state;
- Ribeira do Iguape River, Santos Bay, Cananeia Lagoon in São Paulo state;
- Coastal Lagoons in Santa Catarina state;
- Patos Lagoon in Rio Grande do Sul state.

In the north of Bahia littoral (East Atlantic Basins), signs of eutrophication processes impacting the coral reefs distributed along a small strip of discontinuous carbonate build-ups have been described (Costa et al. 2000). Coral reefs extend for 20 km along the northern coast of the state. Over the last 15 years, this region has experienced an acceleration of generally unplanned urbanisation, with the irregular and indiscriminate use of septic tanks in urban centres contaminating the groundwater. High densities of macroalgae and heterotrophic organisms were found impacting Guarajuba coral reefs (downstream of a densely urbanised area) when compared to Papa Gente reefs (downstream an underdeveloped area). A model of nutrient enrichment via groundwater seepage, according to Costa et al. (2000) is a plausible mechanism to explain the eutrophication occurring in Guarajuba coral reefs. Costa et al. (2000) suggest that the infiltration of nutrients and pathogens is facilitated by both the soil permeability and an accentuated hydraulic head, which eventually leads to the percolation of nutrient-rich groundwater seaward to the reefs. Higher availability of nutrients in Guarajuba coral reefs is affecting the trophic structure in the study area, especially in Guarajuba, with increased macroalgal growth, reducing light penetration to the coral colonies, competing with the corals for space and inhibiting the settlement of new coral larvae.

Eutrophication in reservoirs constructed for energy generation and water supply, as well as in aquaculture tanks is a matter of great concern. Eutrophic conditions have been described in reservoirs located in all three sub-regions in the following states: Pernambuco, Sergipe, Bahia, Minas Gerais, Rio de Janeiro, São Paulo and Paraná, Santa Catarina, Rio Grande do Sul (for references, see Annex III). Algal blooms episodes in bays, lagoons and in constructed reservoirs in South/Southeast Atlantic and East Atlantic Basins include species like: *Microcystis aeruginosa, Microcystis flos-aquae, Anabaena* spp., *Lyngbya confervoides, Sinychocystis aquatilis* (f. salina), *Phormidium* spp., *Cylindrospermopsis raciborskii* and *Coelosphaerium naegelianum*. Fish kills are recorded in some aquatic systems (for references, see Annex III).

Chemical pollution

In South/Southeast Atlantic Basins, chemical pollution is causing moderate impacts (for references, see Annex III). The industrial park of Cubatão on the coast of São Paulo state are responsible for pollution along the coastline. Analyses of Santos estuary sediments demonstrated that the coast has received effluents with high concentrations, above threshold limits, of heavy metals, such as zinc, mercury, chromium, copper and lead, mainly released by the factories in Cubatão and now concentrated in the marine sediments. In Santa Catarina state, the use of pesticides in rice plantations and fruit farms in the Itajaí River basin, in addition to intense industrial activity in the city of Joinville is responsible for coastal chemical pollution. Concentrations of cadmium and nickel have been detected in biotic components of mangroves in Santa Catarina state.

In Rio Grande do Sul state, the use of pesticides and agricultural run-off, mostly from rice plantation in the catchment area of Patos-Mirim Lagoon system, are the main causes of pollution, followed by industrial wastewater discharges and titanium mining. Heavy metals have also been found in high concentrations in the water column of Patos Lagoon in Rio Grande do Sul. High concentrations of heavy metals in the estuarine sediments of Rio Grande do Sul have been associated to industrial activities such as petrochemical, metallurgical, pulp-paper and refineries. BHC (benzene hexachloride), chlordane, DDT and PCBs have been detected in mussels on the coast of Brazil Current (see Annex III). Organochlorine compounds in the mollusc's tissues were detected in the coastal zone of Rio de Janeiro state (Cabo Frio, Guanabara Bay), Sao Paulo state (Santos Bay), Paraná state (Paranaguá Bay) and Rio Grande do Sul state (Patos Lagoon). Pyrite waste (iron sulphide) generated by mining activities in carboniferous reserves in south of

Santa Catarina state has been contaminating the water bodies (PNRH 2003). In the Itajaí Valley, the combination of textile industry, irrigated rice and pig raising represents a source of chemical pollution.

In East Atlantic Basins, chemical pollution is responsible for moderate environmental impacts (for references, see Annex III). The coast of Rio de Janeiro state (mostly bays such as: Guaratiba, Sepetiba, Mangaratiba, Angra dos Reis and Guanabara Bay) has suffered environmental impacts over the past decades due to chemical pollution, mostly from industry; heavy metals are found in sediments above threshold limits, which together with urban effluents are responsible for a reduction in marine/estuarine life. One of the largest natural fish breeding grounds, Sepetiba Bay, has been under severe impacts due to silting, pollution and mangrove destruction. The construction of Sepetiba Port and the activity of dredging to deepen the shipping channel have caused impacts on the Bay due to resuspension of heavy metals accumulated in the sediments. Heavy metals such as cadmium, zinc, lead and chromium have been found on the Rio de Janeiro coast in the suspended material, sediments and in the biota (mussels, oyster, macroalgae) of bays in Rio de Janeiro state (Sepetiba Bay and Guanabara Bay). Evidences from the Paraíba do Sul River, Doce River and Jequitinhonha River reveals heavy metals concentrations in the sediments above threshold limits. Abrupt changes in the river flows can make these metals available to the food chain. Increasing suspended solids discharge due to deforestation for urbanisation, agriculture and timber exploitation has caused severe economic impacts in important reservoirs such as Funil on the Paraíba do Sul River. Deterioration of water quality in rivers and reservoirs due to pollution and groundwater salinisation by irrigated land contribute to the limited availability of freshwater in the Basins. In Sergipe state, hydrocarbons contamination is related to discharge of oil production water. Occurrence of fish and mussel kills related to washing out of textile/organic effluents has been described. In Bahia state (Todos os Santos Bay) mercury is found 2 to 5 times higher than the baseline levels in hot spots (Lacerda et al. 2002). Mucuri River is the best example of a river affected by *Eucalyptus* spp. plantation and the associated paper industry.

Doce River Basin (Minas Gerais and Bahia states) is one hot spot for pollution and has as the main chemical polluting sources mining and industry, mostly steel industry. The results of monitoring data obtained during the period 1993-1996, compared to 1985-1990 (Gerenciamento Integrado da Bacia do Rio Doce 2003), revealed that in general terms an improvement of water quality occurred in 33% of all sampling points, a worsening was observed in 21% sampling points, while 46% remained at the same level of pollution. Based on water quality parameters, the quality of Doce River in many monitoring stations was classified as Class 3, the lowest quality permitted for supply purposes after receiving conventional water treatment. A total of 649 samples were analysed for 25 parameters. Currently, 59 monitoring stations are operating (Gerenciamento Integrado da Bacia do Rio Doce 2003).

Jequitinhonha River Basin (54 in Figure 2) is environmentally impacted mostly by mining and agriculture. Historically, the River has been intensively exploited for precious stones, gold and other ores. Paraíba do Sul River Basin (São Paulo, Minas Gerais and Rio de Janeiro states) is also considered one of the hot spots, in terms of chemical pollution, due to the heavy industrial park, mining and agriculture developed in the Basin. There are several publications reporting heavy metals concentrations above the threshold limits for chromium, cadmium, nickel, copper, arsenic and mercury in river sediments and suspended solids (see Annex III). High concentrations of phenols were detected at several sampling points of the Paraíba do Sul. Transport of mercury from inland to the coastal zone has been described (Lacerda et al. 1993b, Veiga 1997, Lacerda & Salomons 1998).

In São Francisco Basin, chemical pollution, particularly due to heavy metals are expected to occur, particularly in the Belo Horizonte Metropolitan area in the upper São Francisco, where industrial activities and mining areas have been significant (PNRH 2003) (see also the case study Mining in São Francisco Basin). The environmental impacts due to chemical pollution in São Francisco Basin were assessed as moderate.

Suspended solids

The impacts of suspended solids are severe in many areas of the Brazil Current region. Deforestation of large areas, hillsides, and removal of riparian vegetation along tributaries facilitating soil erosion, has resulted in increasing siltation of riverbeds and/or coastal zones. Diversions and damming of waterways are also seriously affecting the erosion-accretion equilibrium of the riverbeds and the coastline. The impacts associated to suspended solids are either due to the excess of suspended solids (turbidity, siltation, etc.) or due to reduction of sediment yield (coastal erosion, primary productivity decrease). The same river may have both impacts, in different locations.

The specific discharges of rivers in the eastern Brazil are naturally low and the construction of dams has increased the retention of suspended solids in the basins. Erosion along the river basin is an important factor in deteriorating the quality of the water in most rivers in the east, also provoking silt deposition along riverbeds and flooding. This increases during rainy seasons because of erosion of unprotected margins. Engineering works for transfer of water for supply purposes also means transfer of solid matter across catchment basins. In Sepetiba Bay (Rio de Janeiro littoral), for instance, diversion of the adjacent Paraíba do Sul River basin (both in the East Atlantic Basins) to supply the Rio Janeiro Metropolitan area, starting in the 1950s has resulted in a ten-fold increase in the freshwater discharge to that bay and increased sedimentation from about 60 mg/cm^2/year in the early 1970 to >320 mg/cm^2/year in the 1990s (Forte 1996, Barcellos & Lacerda 1994, Barcellos et al. 1997). On the other hand, at the mouth of the Paraíba do Sul River, on the north coast of Rio de Janeiro state and about 300 km from Sepetiba Bay, extensive erosion of the coastline is destroying fringes of mangrove forests, dunes and small villages in the area, due to lack of sediment transport (Dias & Silva 1984). In this example, suspended solids transport/sedimentation dynamics that cause pollution problems in one basin is indirectly causing habitat and community modification in another basin.

Brazil is the one of the world's largest iron ore producers and exporters. Iron has traditionally been the country's largest export product, accounting for 5% of the total value of mineral exports. Production in 2000 was 200 million tonnes, of which 158 million tonnes was exported. Japan, Germany, China and South Korea were the main importers. One of the most productive areas is the Iron Quadrangle of the state of Minas Gerais (East Atlantic Basins). Important metallurgical industrial activities, such as the giant Compania do Vale do Rio Doce are located in the Minas Gerais state, where reserves have been estimated at 1.3 billion tonnes of high iron grade hematite and 4.3 billion tonnes of rich itabirites. Mining is one of the activities responsible for soil erosion/pollution in the region.

Diversion and damming of São Francisco River are seriously affecting the erosion-accretion equilibrium of its estuary. These effects are most apparent where water resources are scarce, as the case of middle-lower and lower São Francisco River Basin. The total discharge of sediments in the São Francisco River estuary that in 1983 was 6 million tonnes per year was in 2000 reduced to 410 000 tonnes per year. This residual transported sediment is likely to be material generated in the lower São Francisco, since the sediments generated upstream are trapped in the cascade of reservoirs (Machmann de Oliveira 2003).

Solid waste

In the Brazil Current region, major efforts have been made by city authorities in an attempt to reduce litter as much as possible, and keep clean the urban centres and beaches with the greatest influx of tourists, since this is a considerable source of income. Educational campaigns have had positive results in changing citizens' behaviour. Collection of municipal solid waste in the states entirely or partially included in the Brazil Current varies from 98.8% in São Paulo (in South/Southeast Atlantic Basins) down to 84.7% in Pernambuco (in East Atlantic Basins) (Table 13) (IBGE 2002). The poorest coverage is found in the shanty towns and the periphery of metropolitan regions and in the northeast portion of the Brazil Current region where the percentage collected is below the national average value.

Table 13 Collection and final disposal of municipal solid waste in Brazil Current.

State[1]	Collection (%)	Final disposal	
		Adequate (%)	**Inadequate** (%)
Pernambuco	84.7	38.0	62.0
Alagoas	91.0	6.50	93.5
Sergipe	89.6	2.20	97.8
Bahia	85.0	39.6	60.4
Minas Gerais	91.9	38.0	62.0
Espírito Santo	91.8	49.4	50.5
Rio de Janeiro	94.3	45.9	54.1
São Paulo	98.8	42.4	57.6
Paraná	97.0	39.0	61.0
Santa Catarina	96.8	53.7	46.3
Rio Grande do Sul	97.3	49.6	50.4
Brazilian average (for urban areas)	91.2	40.5	59.5

Note: [1]Brazilian states entirely or partially included in Brazil Current. Figures in red indicate values below the national average for collection/adequate final disposal. (Source: IBGE 2002)

When it comes to final disposal, the scenario is much worse; open dumps are still the most common final disposal option in many municipalities. The range varies from the best case: 53.7% of the municipal solid waste with appropriate final disposal in Santa Catarina (in South/Southeast Atlantic Basins) to the worst case: 22% in Sergipe state (in East Atlantic Basins).

Thermal

More research is needed to investigate the extension and the effects of thermal pollution in Brazil Current. Based on the current knowledge, there is no large-scale or significant output of effluents exceeding temperatures in receiving bodies in the Brazil Current region. The environmental impacts in South/Southeast and East Atlantic Basins were assessed as slight and unknown in São Francisco River Basin. The expansion of the number of thermal power plants in the region, as a result of the energy sector policy, will probably increase the impacts of thermal pollution.

Radionuclides

There is a potential risk for accidents in the region of Angra dos Reis in Rio de Janeiro, because of the nuclear power plants Angra I, II and III (South/Southeast Atlantic Basins). However, as regards these plants, the operation, maintenance and the radioactive waste deposits are considered adequately monitored and well controlled.

Spills

Several small-, medium- and large-scale spill events involving oil, grease and a number of chemical/hazardous substances have been registered in the marine, coastal and freshwater bodies of the Brazil Current region, particularly in South/Southeast and East Atlantic Basins. In few cases, recovery of habitats and species after the accidents has been described. In recent years, legal actions and high penalties have been applied.

In South/Southeast Atlantic Basins spills have been registered in São Paulo littoral (São Sebastião Channel), Santa Catarina littoral (e.g. Paranaguá Bay), Paraná state and Rio Grande do Sul littoral. Port activities, mainly in São Paulo and Paraná states, contribute to frequent small to medium-sized spills. According to the Environmental Accident Record (CADAC) of the Environmental Protection Agency of the state of São Paulo (CETESB), during the period from January 1980 to February 1990, there were 71 accidents involving oil and derivatives along the São Paulo coast, causing serious damage to estuary communities. The Centre South Ducts and Terminals (TEBAR-DTCS) on the São Paulo coast is the country's main sea terminal, accounting for around 55% of all oil transported in Brazil. A large number of accidents, including leaks and accidental oil spills have been recorded during routine operations: 191 accidents between 1974 and 1994 (Poffo et al. 1996) and 18 between 1995 and 1998, contributed to chronic pollution in nearby areas. As a result of these spills, rocky coast and sand beach ecosystems have been systematically affected. The coastal environment which is most frequently affected are the coastal areas and beaches located in São Sebastião and Bela Island, mainly inside the channel, because of their proximity to the sources of pollution. However, coasts and beaches all along the São Paulo coast have been affected to a lesser extent by oil and derivatives (Poffo et al. 1996). Every year, around 3.5 million m^3 of sediments are removed from the estuary to provide passage for large ships. This activity, apart from the impact on several benthonic animals, promoted the re-suspension of toxic substances which are deposited in the sediment on the riverbed, increasing the spectrum of action and the impact of this activity, which can stretch into areas adjacent to the Santos Bay and have a transboundary effect.

Frequent spills of smaller proportion are common in Todos os Santos Bay/BA, Vitória/ES and Guanabara and and Sepetiba bays/RJ (East Atlantic Basins). However, episodes of more serious proportions have been described as, for instance, 1 500 litres of oil spilled from a Cypriot company that was docked at Tubarão Port, Vitória/state of Espírito Santo (Ministério Público Federal 1999). Two large-scale accidents occurred during the period 2000-2001 involving the Company Petrobrás: (i) in January 2001, 1.3 million litres of oil spilled into Guanabara Bay (part of 59, Figure 2), Rio de Janeiro state, after the pipe that connected Duque de Caxias refinery to the Ilha d'Água Terminal was broken (IBAMA 2002); and (ii) an accident with the P-36 platform in Campos, also in the state of Rio de Janeiro, that sunk after an explosion. During these accidents, millions of litres of oil leaked into the water bodies, resulting in serious impacts on the regional ecosystems. These accidents bring a question mark to the effectiveness of environmental quality certificates, such as ISO 9 000 and ISO 14 000, given out to the companies responsible. More examples of spills are presented in Annex III.

In São Francisco Basin the environmental impacts due to spills were assessed as slight.

Socio-economic impacts

Economic impacts

Basically, there are two categories of economic impacts resulting from pollution. First those associated to loss of opportunities or loss of the economic value of goods due to the low quality of the water resources/water environment, reduced options for water uses; and second increasing water treatment and surveillance costs and costs associated to recovery of degraded areas and penalties. In the Brazil Current region, in the first category, impacts of pollution on tourism and fishing, loss of property value, and exploitation of more expensive alternative sources (e.g. groundwater, instead of surface water) are found. The second category also found in Brazil Current includes costs of construction, operation, maintenance of water treatment plants, costs for recovering/remediation of polluted areas and penalties against companies responsible for accidents (e.g. major spills events). Taking into account all these aspects, the economic impacts due to pollution in the Brazil Current were considered severe. Investments for treatment of water bodies and remediation due to accidents and spills in the marine environment are already high, with a tendency to worsen in the near future as the economic development expands.

Eutrophication alone is already responsible for severe economic impacts in reservoirs in South/Southeast Atlantic Basins (COPPE/UFRJ 2002). Significant investments for pollution abatement and/or maintenance costs associated to pollution in the South/Southeast and East Atlantic Basins are found in Marques (1995), MPO et al. (1999), Lamardo et al. (2000), CETESB (2001), COPPE & UFRJ (2002), COPPE/UFRJ (2002) and Sistema de Gestão Integrado da Bacia do Rio Paraíba do Sul (2003). Gradual improvement of the awareness among citizens and more efficient legal instruments are likely to promote enforcement. More efficient enforcement will probably lift the insurance costs. Examples of recent penalties applied due to spills are found in Ministério Público Federal (1999), Luiz & Monteiro (2000), IBAMA (2002), O Globo (2002a) and O Globo (2002b) (see also Annex III). Some densely populated

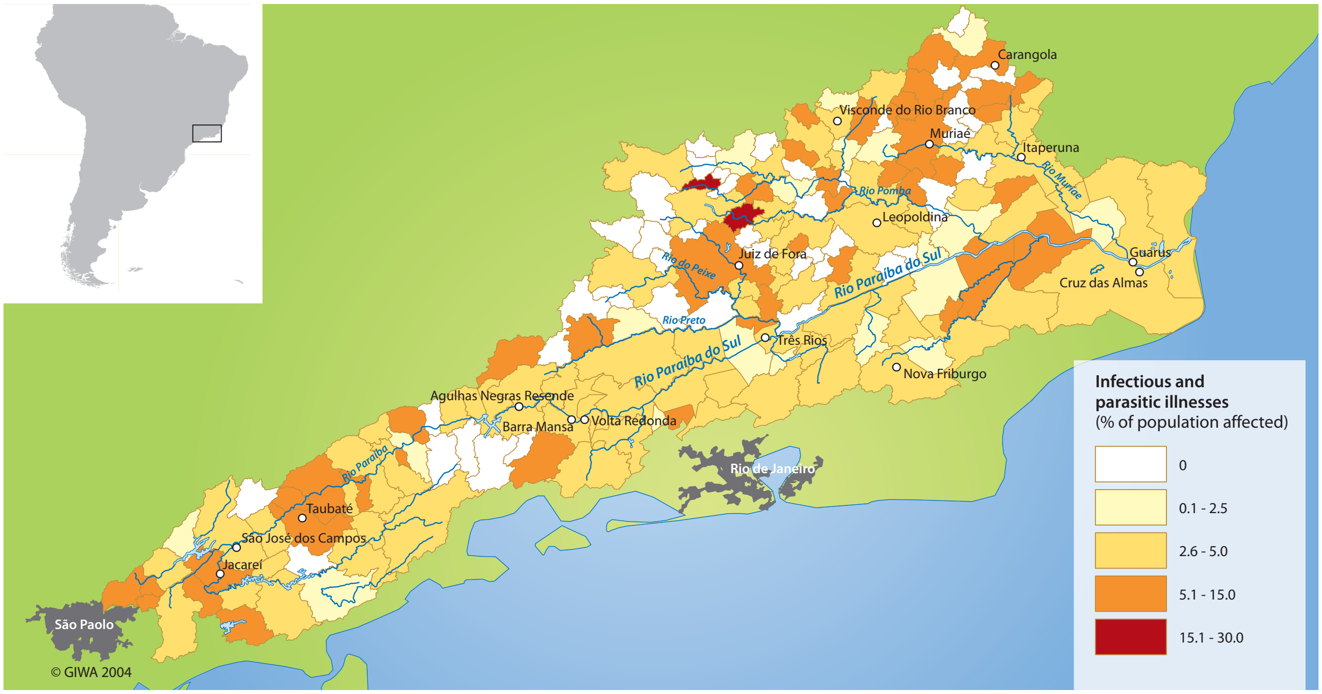

Figure 26 Infections and parasitic diseases (% of population affected) in municipalities of Paraíba do Sul River Basin (Minas Gerais, São Paulo and Rio de Janeiro states).
(Source: Based on data from IBGE 2001)

areas of the Brazil Current littoral have already experienced economic losses, mostly in tourism, which is a natural vocation for the region and employs a large contingent of people. In the significant reduction of fish stocks due to changes in suspended solids/nutrients transport dynamics is responsible for moderate to severe economic impacts in the fisheries sector. Siltation in the upper and middle São Francisco is causing an economic impact on fluvial navigation, an important means of transportation within the basin.

Health impacts

Health impacts due to water pollution is mostly associated to the absence of sewerage system and therefore, to the low-income areas. Health impacts due to eutrophication in water supply reservoirs and aquaculture tanks have recently become an issue of concern in South/Southeast Atlantic Basins as well as in East Atlantic Basins. At least two episodes of severe health impacts, with hundreds of cases of intoxication followed by death due the presence of hepatotoxins released in the water supply after algae blooms have been recorded (Azevedo 1996, Costa & Azevedo 1994, Teixeira et al. 1993, Proença et al. 1996). More frequent is the association between water pollution and health impacts related to water-borne diseases such as microbiological and parasites diseases (Governo do Estado de São Paulo 2002). Increasing gastrointestinal symptoms related to the time of exposure to polluted beaches was described by CETESB in Governo do Estado de São Paulo (1999). In the Paraíba do Sul River Basin (East Atlantic Basins) the incidence of microbiological infection and parasitic diseases varies among municipalities from 0%-30% (Figure 26 and Figure 27) (IBGE 2001). For more details see Annex III.

Regarding risks to human health in São Francisco Basin, cases of schistosomiasis have been registered all over the Basin. In the upper São Francisco there are health problems resulting from microbiological contamination and the suspicion of problems resulting from chemical pollution, which are not confirmed, due to lack of proper investigation. While the percentage of the population affected is small, the degree of severity is high, due to the poverty level of those affected, among whom the frequency of occurrence of this problem is high.

Other social and community impacts

Among the social and other community impacts due to pollution, the loss of recreational and aesthetic values of many beaches can be mentioned. This occurs from northeast down to south of the Brazil Current region, in the coastal area and bays downstream densely urbanised centres. Another example is the impacts on Environmental Protection Areas (APAs) occurring after large-sized spills, such as those which occurred in Guanabara Bay (East Atlantic Basins), affecting the APA of Guapimirim. This area represents the largest mangrove area on the Rio de Janeiro coast. Fluvial transportation is limited in those

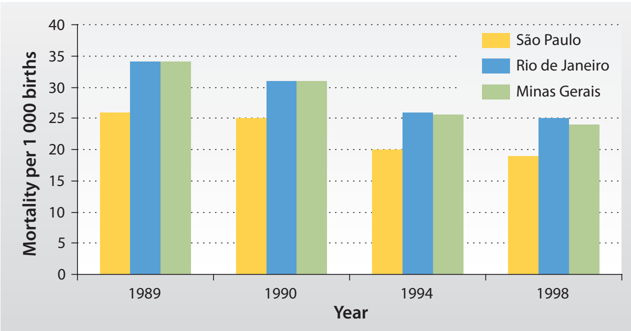

Figure 27 Estimated child mortality (<1 year old) per 1 000 births in the municipalities inside each state included in Paraíba do Sul River basin.
(Source: Based on data from IBGE 2001)

waterways that have suffered most by siltation, where there are also social impacts due to flooding. Below, five case studies of pollution associated to different sectors are briefly presented. Pollution has also been considered one of the causes of reduction of fish stocks, which causes social impacts in hundreds of communities of fishermen along the coast of the Brazil Current region.

Case 1: Mining activities in Jequitinhonha River basin (East Atlantic Basins)

Jequitinhonha River basin is a transboundary system that encompasses 53 municipalities, has a total area of 69 997 km^2, 65 517 km^2 (93.6%) of which in Minas Gerais state and 4 480 km^2 (6.4%) in Bahia state, and a population of 900 000. Gold, diamonds and other precious stones are the main natural resources explored. Although rich in mineral resources, the Jequitinhonha Valley (named by the UN the "Valley of Misery" in 1974) hosts one of the poorest populations in Brazil. Mining is the activity with the heaviest impact on the water resources in the region. Intensive dredging practices during many decades have changed the watercourse and caused pollution by mercury. Mining has also caused losses of riparian vegetation, ecosystems modification, erosion and silting. Some of the impacts due to mining during the last decades are considered irreversible. Besides mining, other activities that pollute the River are the use of pesticides and discharge of untreated sewage. Forest destruction has also contributed to erosion. Contamination by microorganisms and turbidity (suspended solids) are the most common parameters along the River which do not comply with standards. The socio-economic impacts include e.g. loss of transportation, which is no longer possible in the River. Sandbanks are seen in many portions of the River.

Case 2: Industry and urbanisation in Guanabara Bay basin (East Atlantic Basins)

The Rio de Janeiro littoral includes the City of Rio de Janeiro and the bays of Guanabara (Figure 28) and Sepetiba. Among the major

Figure 28 True-colour French SPOT-3 satellite image of Rio de Janeiro.
North is at top. Rio de Janeiro (light blue, at centre right) is just to the north of the mountainous Tijuca Forest (green, lower frame). At upper right is Guanabara Bay. The Atlantic Ocean is in the lower frame.
(Photo: Earth Satellite Corporation/Science Photo, Library)

stresses affecting these systems is discharge of domestic effluents and the petrochemical industry, emissions of trace elements, changes in sediment loading generated by river basin activities and other impacts by port activities.

Guanabara Bay (23°45´S, 44°45´W) represents an example of one of the most severely impacted systems of the Brazil Current region. The bay (384 km^2) measures 28 km from west to east and 30 km from north to south, has a 131 km perimeter, and a mean water volume of 1.87 billion m^3. The residence time is about 22 days and the average annual fresh water input from 35 small rivers is 125 m^3/s and peaks in January/summer. Tides are mixed and mainly semi-diurnal with a range of 0.7 m. The salinity varies from 21 to 34.5 ‰ with weak vertical salinity stratification. The bay is located in a Tertiary depression, named the Guanabara rift. There are many out-crops of Precambrian origin abound the Guanabara Bay basin, such as is the case of the 400 m high Sugar Loaf. Elevated paleo-beaches and marine terraces from the Late Quaternary are common around the bay. The climate is "Aw" according to the Köppen classification with an average annual rainfall of 1 173 mm, and highest rainfall in summer.

The bay is one of the most polluted and eutrophic bays of Brazil. The overall mean of chlorophyll a in the bay is 57 mg/m^3, the inner section 130 mg/m^3 and primary production lies in the order of 400 gC/m^2/ year. The water quality is indicated by average faecal coliform counts of the order of 1 000 MPN/100 ml (Most Probable Number/ml), but may attain one to two magnitudes higher in some restricted areas with sewage outfall. The urban population of Rio de Janeiro and 12 other surrounding cities is 11 million. The domestic run-off of the 8 million population which live directly within the catchment is still largely untreated and there are more than 12 000 industries in the basin. Two oil refineries process 17% of the national oil and the bay suffers from chronic oil pollution and sporadic spills. About 18 tonnes of petroleum hydrocarbons enter the bay daily, 85% via urban run-off. Suspended solids with heavy metals accumulate at the bottom. At least 2 000 ships dock in the port of Rio de Janeiro, in Brazil second only to Santos port. Dredging takes place continuously to a depth of 17 m. Besides urban and industrial areas, the basin consists of agricultural fields and cattle grazing lands. The Atlantic Rainforest still extends to the shoreline in a few places and is only intact on the steep slopes of the Atlantic Range. The interior of the bay is fringed by 90 km^2 of mangroves, threatened by oil and firewood cutting. Landfills located in the Guanabara Bay basin around the bay receive 10 000 tonnes of solid wastes daily. A number of open dumps are also found in the basin. Spills have destroyed fishing grounds, fouled rivers and estuaries, polluted mangrove swamps, and killed seabirds, fish and crustaceans. Out of 6 000 industries, 52 are responsible for 80% of the industrial pollution discharged in the bay. Navigation in the inner part of the bay is no longer possible.

There is no marine life as such, in many parts of the bay. Fishing has decreased by 90% during the last 20 years and the mangrove areas have been reduced to 50% their original size and the 53 beaches are not recommended for swimming due to pollution. Notwithstanding the accentuated degradation, the bay is still important for fisheries, supporting 6 000 families. The annual catch measures 3 000 tonnes (2 700 of fish, 200 of mussels, 100 of shrimp). About 30 species of birds are resident and dolphins used to be abundant. The sediment accumulation rate is estimated to be 1 cm/year although in some regions it increases to 4 cm/year. Since 1994, with a loan obtained from Inter-American Development Bank (IDB) and the Overseas Economic Cooperation Fund (OECF) the state government is investing in water supply, sewage collection and treatment, drainage and solid waste projects.

Case 3: Mining in São Francisco Basin

Ore mining activities (now declining) have been highly damaging, as the effluents of such activity usually contain heavy metals and can contain cyanides. There has been intensive mining activity over centuries in the upper reaches of the basin of São Francisco's tributary, Rio das Velhas, which has an area of 2 000 km^2. Coincidentally, this basin is inscribed in the geological context of the well-known Iron Quadrilateral in the state of Minas Gerais. Iron ore mining, followed by gold and gems has been undoubtedly the most important mining activity of the region, both for its economic importance and that of associated infrastructure, and the magnitude of its pits and waste and tailings deposits. The following figures illustrate the importance of this activity: the annual tonnage of iron mined is 56 million tonnes per year; 55 million tonnes per year of waste material are removed and disposed of in heaps alongside the excavations; 17 million tonnes per year of tailings are deposited in tailing dams or ponds.

As a result of the removal of waste and the exploitation of ore, voids are formed due to mining excavations at a rate of more than 40 000 m^3/year. The deepening of these pits nearly always requires lowering the water level of the aquifers. The iron formations in which the iron ore deposits are inserted, are the geological formations having the greatest potential for water in the area. These iron formations together with other geological formations with different groundwater potential, comprise a synclinal geological structure systems of great size, forming large groundwater basins, known geologically as the Moeda and Dom Bosco Aquifer systems, associated to the synclinals of the same name. These two large aquifer systems, apart from their large potential for water storage and availability, are responsible for the greater share of water supply to the surface springs in the Upper Rio das Velhas basin. In turn, this basin, through catchment of the Rio das Velhas and Morro Redondo Systems, with respective water flows of 5.20 m^3/s and 0.60 m^3/s, supplies nearly 50% of the requirements of the Belo Horizonte Metropolitan region. The most critical situation in the basin occurs in the Água Suja (Dirty Water) stream and on the stretch of River das Velhas downstream from the point at which these two watercourses meet. Its waters contain high values for organic load, turbidity related to domestic sewers and effluents from small industries, as well as from other sources such as rainwater drainage in both urban and rural areas and by mining liabilities.

Chemical pollution has been detected, e.g. high concentrations of arsenic which are found, show averages well above the threshold value define by the resolution CONAMA No. 020/86, and which may be the consequence of the former gold mining activities in the region and the geochemical characteristics of the local terrain, and the genesis of which is caused through the decomposition of rocks mineralised with gold bearing sulphides. The most serious problem appearing in the Itabirito River is its load of suspended solids, caused by iron ore mining operations. The River's organic load is still kept within limits, allowing its natural oxidation, along the course of the River. The morphology of the riverbeds of the water courses in the region show an excellent capacity for physical aeration being fully oxygenated at the majority of observation points. There are signs though, that future increased organic load may change this situation. Downstream, upon mixing with the main stream of the São Francisco, the pollution in the waters of the tributary of the Velhas River is diluted and quality improves, with reductions in the concentration of faecal coliforms and chemical pollutants. Poor management of municipal and industrial solid wastes occurs, but this problem causes no major identifiable impact other than aesthetic ones. There is no proper collection, transportation or final disposal of these wastes. In the São Francisco catchment area, a very small proportion of the population is supplied with treated water.

Case 4: Suspended solids in São Francisco Basin

Between the middle and lower São Francisco River Basin a cascade of reservoirs, such as Xingó have been constructed for power generation. These reservoirs trap most of the suspended solids (FUNDEPES 2001) and reduces the nutrients in the water. When the water loses gradient and flows slowly along the last 200 km until reaching the estuary, the River starts meandering, with consequent formation of sand banks and very low concentration of suspended solids. Inadequate agricultural practices represent another environmental problem in this basin. Irrigation projects have caused soil salinisation in some parts of the Basin.

Siltation is a serious problem over wide/ecologically significant areas and has resulted in markedly changed biodiversity and mortality of benthic species with concomitant changes in the nature of deposited sediments. In the upper and middle São Francisco River solid particles originating from mining, farming and livestock activities and from urban plotting areas form sandbanks along the river channel. Silt transportation occurs mainly as bottom load and very little in suspension. In the sub-basin of the Pará River, in the upper São Francisco, mining of clay, sands, granite, coal and, in the past, gold occur. Gypsum mining occurs in the Brígida River sub-basin. The Paraopeba River sub-basin witnesses an increase in sand exploitation and iron ore mining to meet the expansion of the civil construction and export. Other aggravating factors are connected with suspended solids from widely expanding agricultural and livestock activities. The problem of eutrophication in the São Francisco Basin occurs only in some reservoirs in the tributaries. In fact, there is a lack of nutrients in the main stream. A very low concentration of nutrients is noted in coastal areas as a result of a declining inflow of sediments and nutrients caused by the construction of dams. The smaller municipalities along the São Francisco Basin are not benefited by any sewage treatment, resulting in organic pollution of local water supplies.

Case 5: Pollution in the Uruguayan portion of Mirim Lagoon (South/Southeast Atlantic Basins)

The Uruguay East region is not a highly industrialised region and has a relatively low population density, particularly in the Mirim Lagoon basin (89 in Figure 2). According to the National Environmental Survey carried out by OPP et al. (1992), the main environmental problems in Uruguay at that time were related to: (i) internal causes (land use for agriculture, urban occupation of the coastal zones, deforestation, pollution of water supplies, highway and infrastructure development); (ii) transboundary causes, such as the pollution of the La Plata River (GIWA region 38, Patagonian Shelf) and pollution of the air due to the thermoelectric power plants in Brazil; and (iii) potential impacts due to international development projects (e.g. construction of regional waterways, bridges and highways). Since this national evaluation was made, livestock and rice production in the Mirim Lagoon basin and tourism in the Atlantic Basin of Uruguay have increased significantly. Pollution in the Atlantic Basin (89 in Figure 2) is assessed as producing slight environmental and socio-economic impacts, mostly related to the seasonality of the population during the summer. With the development of this economic sector, the impacts will probably become moderate, particularly the economic impacts due to the investments required to keep the environment clean and thus maintain the tourist flux.

Conclusions and future outlook

The overall impacts due to pollution was assessed as moderate in South/Southeast Atlantic Basins and São Francisco River Basin, and assessed as severe in East Atlantic Basins, based on a large amount of mostly proxy indicators. It is necessary to investigate more thoroughly the environmental effects these pollutants cause on the living resources. There is also a need for detailed epidemiological and economic studies to highlight the existing associations between pollution and economic-health impacts in the Brazil Current, where socio-economic activities associated to densely populated cities have imposed a heavy burden on water resources, expressed as pollution. Chronic as well as acute health impacts due to toxins released after algal blooms in reservoirs and aquaculture tanks must be carefully investigated and monitored. The information available indicates that for the next 20 years even a slow economic growth rate will generate economic impacts mostly associated to pollution abatement. Yet it is likely that costs for insurances and penalties for polluting will increase in the future, which hopefully will prevent the intensification of impacts on the environment and human health. A number of governmental initiatives, such as the Clean-up Programme of Hydrographic Basins (PRODES), created in March 2001 in Brazil under the responsibility of the National Agency of Water (ANA) is expected to contribute to the pollution abatement mostly the one associated to municipal sewage.

Habitat and community modification

IMPACT **South/Southeast Atlantic Basins** IMPACT **East Atlantic Basins** IMPACT **São Francisco River Basin**

The Brazil Current is composed of the drainage basin, the coastal and the shelf-oceanic compartments, all with a large number of habitats and ecosystems. The drainage basin contains the main biome Atlantic Rainforest; some portions of other biomes, such as Restingas (coastal sand spits), Caatinga (dry thornbush) and Cerrado (high plain bush); lakes and the man-made dams and reservoirs (see Regional definition). The coast includes various types of estuarine systems, like coastal lagoons, typical drowned river valley estuaries, bays, river-delta estuaries, wetlands (mainly mangroves), beach-ridges and dunes. The shelf-oceanic realm contains the nutrient poor (Brazil Current) and nutrient rich (upwelling) pelagic waters and the benthic organic- and carbonate-rich (calcareous algae and coral reefs) systems. The Atlantic Rainforest and the Brazil Current are common to the entire region. Several river basins are classified as extremely important regarding freshwater fish biodiversity (MMA 2000). The profile around estuaries, bays and coastal lakes is of fragile formations. Due to complex dynamics, formations and dimensions, when altered by natural or human pressures, these environments are irreversibly damaged. Land use has become a major driving force for both terrestrial and aquatic ecosystem modification and loss. Littoralisation has imposed a burden on habitats and communities. Information substantiating the assessment is briefly presented below.

Fishing in the Brazil Current region is dependent on species that spend a significant part of their life cycle in mangrove areas. Among these are crab species such as *Ucides cordatus, Callinectes danae* and *Cardisoma guanhumi*. The bivalves, *Mytella guyanensis, Macoma constricta, Anamalocardia brasiliana* and *Crassostraea rhizophorae,* which are an important source of income for populations living along the Brazilian coast, are also species dependent on mangrove forests. Species important to commercial fishing which are also dependent on mangroves for the completion of their life cycles are the fish species, *Mugil* sp., *Centropomus* sp., *Sardinella aurita*, *Brevoortia tyrannus*, *Dicentrarchus labrax* (sea bass), "Manjuba" *Curimatella lepidura* (similar to Whitebait), *Bagre marinus* (catfish) and the shrimp, *Penaeus* spp. Mangrove destruction in the Brazil Current region has therefore a direct impact on fisheries.

Moderate to severe environmental impacts are exerted on estuaries, bays, coastal lagoons, rocky foreshores, marshes and humid coastal regions in the Brazil Current. There is more information available for the South/Southeast Atlantic Basins than for the other sub-regions.

Environmental impacts

Loss of ecosystems or ecotones

This issue refers to the destruction of aquatic habitats. For the purpose of the GIWA assessment, recent loss will be measured as a loss of pre-defined habitats over the last two to three decades. In the Brazil Current loss of ecosystem has moderate environmental impact and applies mostly to parts of the coastline and river catchment areas with high population densities.

Littoralisation-urbanisation, tourism, petroleum exploitation, several existing large-sized ports, agriculture and more recently, aquaculture are the main sectors causing that generate severely impacted compartments in the Brazil Current from north to south: Todos os Santos Bay (BA), Vitória Bay (ES), Guanabara Bay, Sepetiba Bay and Grande Island Bay (RJ) in East Atlantic Basins; and Paranaguá Bay (PA) and Patos-Mirim Lagoon complex in South/Southeast Atlantic Basins. The expansion of tourism and land occupation along the littoral with fast construction of hotels, resorts and summerhouses has impacted important coastal ecosystems such as restingas and mangroves. Changes in the sediment transport dynamics due to land-based activities in the coast are considered one of the most serious environmental issues (IBAMA 2002).

There are several endemic species in the convergence region of the western South Atlantic and migration of decapod crustaceans (crabs, shrimp) and fishes, which use the estuaries as breeding grounds in the marshy areas (Rio Grande do Sul state), mangroves (e.g. Santa Catarina and Rio de Janeiro states), sea grass areas and shallow small bays. Peixe Lagoon (Lagoon of Fish), in Rio Grande do Sul, acts as an important resting and feeding area for migratory birds. The floral composition of the mangroves is very important for the associated fauna and the relatively low biodiversity and greater fragility in the South/Southeast Atlantic Basins emphasise the importance of its conservation. In the extreme southern Atlantic, rice-farming irrigation and application of pesticides and fertilisers followed by run-off into natural systems have destroyed marshes and have had a severe impact on lakes. In the estuary of Patos-Mirim Lagoon, Tramandaí and Laguna, overexploitation of fish has also impacted the habitats (BDT 2001). In Patos Lagoon estuary, 10% of marshland was lost during the last 40 years. The annual rate of loss of marsh area in this estuary is 0.25% (Seeliger & Costa 1997). The estuaries and bays located around the cities of Rio Grande, Tramandaí and Torres (Rio Grande do Sul state), Itajaí, Laguna and part of São Francisco do Sul (Santa Catarina state) have suffered impacts due to river discharge of organic pollutants and increasing oxygen demand. Two important environmental protected areas in Rio Grande do Sul are highlighted: (i) the Ecological Station of Taim and (ii) the National Park of Lagoa do Peixe-PARNA included in the UNESCO Network of Biosphere Reserves.

The Rio-São Paulo highway connects the most industrialised and populated areas of South America. The Rio-Santos highway throughout the coastal zone exerts direct pressure over the costal ecosystems. One of the greatest causes of biodiversity loss and reduction of fish stocks in Ilha Grande Bay, part of Rio de Janeiro littoral (East Atlantic Basins) has been the destruction of mangrove ecosystem that currently occupies an area of 2 000 ha, which represents 50% of the original formation. The intensive soil excavation and transport for construction of the Rio-São Paulo highway, the division of land into lots and urbanisation, associated to the regional rainfall regime, have caused intensive erosion and significant increase of suspended solids in coastal waters. The impacts include smothering of benthonic species, interference with the filtering species and fish respiration. Associated with this uncontrolled urbanisation, there are ports, oil terminals, aquaculture, introduction of alien species and run-off of fertilisers and pesticides (BDT 2001). The construction of decks, walls and land reclamation has destroyed the rocky foreshores and modified the beaches (IBAMA 1997). In Guanabara Bay, the mangrove ecosystem has been reduced, owing to: (i) the operation of the Gramacho metropolitan landfill that receives about 7 000 tonnes per day of solid waste; (ii) the illegal exploitation of mangrove wood for the brick industries in the environmental protection area of Guapimirim, which was created to preserve the mangrove; and (iii) occupation by low-income population.

Sepetiba Bay (Rio de Janeiro littoral) is a semi-enclosed water body located just before the Grande Island Bay in the direction Rio-Santos. It is connected to the sea in the east by a small shallow inlet with little water flow which crosses 40 km^2 of extensive mangrove forests (Lacerda et al. 2002). The sediment transport and sedimentation rates in the bay have changed dramatically, due to civil engineering work during the 1950s, with water transfer from another basin (River Paraíba do Sul) for the purpose of supplying the Rio de Janeiro Metropolitan area. The sedimentation rate increased from 30 mg/cm^2/year to over 250 mg/cm^2/year. The impacts on the bay's ecosystems have not been properly addressed.

The Brazilian salt marshes flora can be characterised as being of low biodiversity, when compared with other types of vegetation in Brazil. Considering the whole set of habitats which form salt marshes, the biodiversity found is high. However, when each individual ecosystem is considered on its own, the biodiversity is relatively low (BDT 2001). The salt marsh fauna has been little studied, requiring systemic information on the composition of fauna communities along different points of the coast, which could be provided by a larger number of inventories with reliable listings, including data on the relationship between them and the vegetation. The main anthropogenic pressures on the salt marshes in the Brazil Current can be distributed by region as follows (BDT 2001):

- Littoral of Espírito Santo and Rio de Janeiro states (East Atlantic Basins) and Sao Paulo (South/Southeast Atlantic Basins): industrialisation, uncontrolled urbanisation and illegal land occupation, land speculative business associated to tourism, mineral extraction, transport;
- Littoral of Paraná, Santa Catarina and Rio Grande do Sul states (South/Southeast Atlantic Basins): agriculture, irrigation projects, cattle farming, illegal land occupation, coal processing and introduction of alien species, pollution, deforestation and tourism.

The mangrove ecosystem along Bahia state littoral (East Atlantic Basins) presents higher biodiversity than mangroves in the South/Southeast Atlantic Basins. In the estuaries, endemic species of fish, crab fish and molluscs, as well as migratory species of turtles and birds have been identified. In Santa Cruz, Espírito Santo state littoral, the extraction of calcareous algae and muddy sands is impacting the landscape, the geological stability, the biodiversity and the genetic flux of fauna and flora. Deforestation and changes in the sedimentation-erosion equilibrium within the estuaries cause significant impacts on ecosystems. A decrease of approximately 5% of the total sediment flux has been considered the critical threshold (Lacerda et al. 2002), beyond which the coastal system has shown evidence of significant deterioration and coastal erosion. This level of change results in loss of mangrove areas, such as occurs in the River Paraíba do Sul delta (Salomão et al. 2001).

In Brazil, the coral reefs are found along 3 000 km from Maranhão as far as southern Bahia (East Atlantic Basins), making up the only reef systems in the South Atlantic. The main coral species on these reefs occur only in Brazilian waters, where they form structures unparalleled in other regions.

There are major gaps in knowledge, mainly in terms of mapping of biological communities and data on oceanographic physical and chemical parameters and biological interactions (BDT 2001). The coast of Bahia state has 20 km of coral reefs and over the last 15 years, this region has experienced an acceleration of generally unplanned urbanisation, with the irregular and indiscriminate use of septic tanks in urban centres contaminating the groundwater. High densities of macroalgal and heterotrophic organisms were found impacting Guarajuba coral reefs. A model of nutrient enrichment via groundwater seepage is the mechanism proposed to explain the eutrophication occurring in coral reef systems on the northern coast of Bahia (Costa et al. 2000). Data suggest that the great availability of nutrients is affecting the trophic structure in Guarajuba, with increased turf and macroalgal growth, reducing light penetration to the coral colonies, competing with them for space and inhibiting the settlement of new coral larvae (see Annex III).

Modification of ecosystems or ecotones

The state of Rio Grande do Sul (South/Southeast Atlantic Basins) and the 500 000 ha of lowlands in the departamentos of Rocha and Maldonado in Uruguay that form the "Bañados del Este" (eastern wetlands) host together a number of lagoons and wetlands with the highest importance in terms of biodiversity (Figure 11). In 1976, "Bañados del Este" (32° to 35° S; 53° to 55° W) in the departamento of Rocha, was declared as a "biosphere reserve". The eastern wetlands region comprises a remarkable complex of ecosystems of high biological diversity and very rich wild life (MAB 2003). Low hills on rocky substratum also occur on the ocean coast and several coastal lagoons are among the features of the region. Most of them are separated from the sea by a narrow sand bar, which regularly opens allowing the entrance of seawater. The biosphere reserve is the only area in Uruguay where Butia palms exist covering an area of almost 70 000 ha. At present, the palm is at risk of extinction, due to the ageing of the shoots and the lack of renovation of the buds that are eaten by the cattle. Cyperaceae, Juncaceae, Gramineae, and also *Monte psamofilo* and extensive stands of conifers are dominant in the herbaceous community. The indigenous fauna remains almost intact except that the marsh deer (*Lastocerus dichotomus*) is now locally extinct. The major ecosystem types are temperate grasslands and coastal wetlands. The major habitats and land cover types are: the coastal wetlands; Butia palm associations (*B. yatay*); herbaceous communities of Cyperaceae, Juncaceae, Gramineae (*Scirpus californicus*, *Typha* spp., *Zizaniopsis bonaerensis* etc.); and conifer woodland with *Pinus atlantica*. In 1997, 235 687 people lived in this biosphere reserve developing activities such rice plantation, cattle raising, hunting of fur and aquatic mammals (MAB 2003). Some 100 000 tourists visit the reserve annually. The ecosystem is threatened with serious changes as livestock raising gradually gives way to rice fields. Pesticides are now being used and there has been an attempt to dry the lake areas and alter the water levels in the flood zones. Sites of prehistoric archaeological interest also exists that need to be protected for their study and preservation defining their patrimonial value. The environmental and the socio-economic impacts were both assessed as severe at present, with a tendency of increase during the coming years, due to the tourism and the agriculture sectors. According to the MAB programme (MAB 2003), the biosphere reserve has developed several planning and territorial management activities, incorporating the environmental dimension in local economic and social systems, local participation and knowledge generation (MAB 2003).

Table 14 shows the main lagoons and wetlands in the region comprised by Rio Grande do Sul (South/Southeast Atlantic Basins), Uruguay East region and the main impact sources and threats against these habitat and ecosystems (Menegheti 1998). Noteworthy in Uruguay are: the Rocha Lagoon; "Laguna Negra y Bañados Santa Teresa" (Negra Lagoon and Santa Teresa marshes); Castillos Lagoon; Garzón and José Ignacio

Table 14 Lagoons and wetlands in the state of Rio Grande do Sul, Brazil and in the departamentos of Rocha and Maldonado, Uruguay: Main impact sources and threats to the habitat and ecosystems.

	Lagoon/wetland system	Urban land uses	Agriculture land uses	Tourism	Transport	Petroleum	Mining	Damming	Pollution	Habitat fragmentation	Stream flow modification	Overexploitation
Brazil	Group of lakes in north Tramandai	x	x									
	Group of lakes in Osorio		x	x					x	x		
	South of Tramandai	x	x	x					x			
	Banhado Grande system	x	x	x		x	x		x	x	x	
	Peixes Lagoon system	x	x			x	x		x	x	x	x
	Banhado do Taim system		x						x	x	x	x
	Patos Lagoon system	x	x	x		x	x		x	x	x	x
	Mirim Lagoon (Brazilian portion)	x	x					x	x	x	x	x
Uruguay	Mirim Lagoon and Bañados San Miguel-Los Indios	x	x	x	x					x	x	x
	Rocha Lagoon	x	x	x					x	x	x	x
	Garzon and Jose Ignacio Lagoon	x	x	x					x	x	x	x
	Negra Lagoon and Bañados de Santa Teresa		x	x				x		x	x	x
	Castillos Lagoon and Arroyo Valizas	x	x	x					x	x	x	x

(Source: based on information available in Menegethi 1998)

Lagoons; and "Bañados de San Miguel" (San Miguel marshes). Inside Brazil, the lakes north of Tramandaí; the Osorio Lakes; the lakes south of Tramandaí; "Banhado Grande" (marshes); Peixe Lagoon; "Banhado do Taim" (marshes); and Patos Lagoon stand out. Additionally, there is the Mirim ("Merín" in Spanish) Lagoon, which is an international water system, with the upstream portion in Uruguay and the downstream portion in Brazil. Inside the Brazilian territory, Mirim's waters drain into the Patos Lagoon through the Sao Sebastião channel (Wetlands International 2003). These lagoons and marshes have suffered due to extended development of rice fields, while the coasts in general are threatened by the disorganised encroachment of tourism and urban development. A project administered by PROBIDES (a local NGO), with the support of the Global Environment Facility (GEF), seeks innovative solutions for the management of the eastern Uruguay wetlands. These are the coastal lagoons of Veiana, Fundo, Paura and Pai João. This project includes the Brazilian Lagoon Peixe, which is connected to the sea via an ephemeral channel, making the lagoon function as an estuary.

The lacustrine system of Peixe, for instance, includes five lagoons with a medium depth ranging from 0.3 to 3 m. The National Park of Peixe Lagoon is located in the state of Rio Grande do Sul, 220 km south of Porto Alegre and has an area of 34 400 ha. It is a large lowland area situated in the middle section of the coastal plains of the Rio Grande do Sul. It includes representative samples of the ecosystems of the Rio Grande do Sul coastal zone such as salt marshes, coastal dunes and lagoons, woods, grassy marshes, beach strips and marine area. Dunes which run parallel to the shoreline are a distinct feature and are formed by wind-borne deposits of sandy quartz material. The unique environment of Peixe Lagoon is one of the most spectacular sanctuaries of migratory birds in all of South America. Important species include *Limosa haemastica* and *Calidris canutus*. This is the only place in Brazil where one can find flocks of *Phoenicopterus chilensis* all year round. In the far north of the region, which is mainly a refuge, thousands of waterfowl such as *Cygnus melanocoryphus*, *Coscoroba coscoroba*, and several wild ducks including *Dendrocygna viduata*, *D. bicolor*, *Anas georgica*, *A. flavirostris* and *Netta peposaca*, occur. The Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) owns 10% of the Park's land with the remainder either being private property or federal property. Land use consists of extensive herd breeding, rice and onion farming, shrimp and mullet fishing in the lagoon, and net fishing in the sea, fishing with trawlers (at a range of 3 nautical miles), hunting, tourism and swimming. Reforestation with *Pinus* and the logging of native woods also occurs.

In Brazil, Patos Lagoon covering 10 360 km^2, suffers pollution resulting from the discharge of untreated chemical and organic effluents (see Diegues 1999 and the Causal chain analysis for Patos-Mirim Lagoon). Among the most serious threats to the Patos Lagoon ecosystem are the drainage for rice culture, the fishing of shrimp (*Penaeus* sp.) and mullet (*Mugil* sp.) during the spawning season, hunting, and land speculation in the beach area (Diegues 1999). In the Uruguayan portion of Mirim Lagoon basin, for instance, there are wetland areas replaced by rice plantation while some wetland areas are still preserved. Those still preserved are extremely important sites of resting for species such as *Phimosus infuscatus* and *Plegadis chihi* (Threskiornitidae). Field surveys have identified 500 members of *Phoenicopterus chilensis*, 262 *Cygnus melanecoryphus* and 293 *Coscoroba coscoroba*, 1 563 *Anas georgica* and 1 804 *Dendrocygna bicolour* (Menegheti 1998). The priority in the Uruguayan portion of Mirim Lagoon basin, in terms of conservation are: wetland ecosystems; marginal forest; lagoon and wetland landscapes; aquatic plants, palms and riparian trees; turtles (tortuga de canaleta *Platenys spixii*); birds such as aguatero (*Nycticryphes semicollaris*), gallineta overa (*Rallus maculatus*), doradito copetón (*Pseudocolopteryx sclateri*), pato criollo (*Cairina moschata*), caracolero (*Rostrhamus sociabilis*), gaviotín lagunero (*Sterna trudeaui*), pajonalera pico curvo (*Limnornis curvirostris*), pajonalera pico recto (*Limnoctites rectirostris*), curutié ocráceo (*Cranioleuca sulphurea*), viudita (*Heteroxolmis dominicana*) and capuchino pecho blanco (*Sporophila palustris*); and historical and archaeological heritage.

Most of the Brazilian plants and animals currently on the list of endangered species are endemic to the Atlantic Rainforest (BDT 2001), which currently represents 7% of the original biome. Fragmentation of habitats leads to a gradual reduction of genetic diversity in the populations affected, leading to their disappearance over the medium or long-term. Such process has taken place for instance, in Paraíba do Sul River basin.

Regarding fish biodiversity, disturbances in sediment transport dynamics have been pointed out as the cause of extinction of several species of fish in the neartic region. There are 165 species of fish species at risk of extinction in Brazil, according to the official list of the Brazilian Institute for the Environment (IBAMA). The main causes are constructed dams, forest destruction and pollution of waterways (Bomfim 2003). The states of Goiás, Rio Grande do Sul and Bahia (the latter two included respectively in South/Southeast Atlantic and East Atlantic Basins) are the Brazilian states where 87% of these species are concentrated (Bomfim 2003). In the list of endangered species, some found in the Brazil Current region are presented below (Bomfim 2003):

- Small-sized fishes like cascudos, lambaris, peixe limpa-fundo, guarus, bagres found in small rivers of the Atlantic Rainforest might disappear as a consequence of deforestation;

- Vermelha *(Brycon vermelha)* in the River Mucuri (East Atlantic Basins) is threatened by deforestation, pollution and plans to construct hydropower plants in Minas Gerais and Bahia states;
- Surubim *(genus Steindachneridion)* in Jequitinhonha and Doce rivers (East Atlantic Basins) is threatened by pollution, deforestation and hydropower plants;
- Andirá *(Henochilus wheatlandii)* only found in a tributary of the Doce River (East Atlantic Basins) is threatened by overfishing and the plans to construct hydropower plants;
- Peracuca *(Kalyptodoras bahiensis)* in the Paraguaçu River that discharges into Todos os Santos Bay (Bahia state) has been wiped out by river silting;
- Pira-tamanduá *(Conorhynchos conirostris)* has economic importance in the São Francisco River where it can reach more than 10 kg. The main threats are the hydropower plants and pollution;
- Annual small-sized fishes (approximately 10 cm length) are highly endemic species living in marshes and swamps. In the Caatinga biome (see Regional definition) they are called cloud fishes by the locals because they appear and suddenly disappear, returning in the next rainy season. They have the highest importance as protein source for the local and poor communities. In Rio Grande do Sul (South/Southeast Atlantic Basins), the main threat is the rice plantation. Deforestation and urban development are the main threats in São Paulo and Rio de Janeiro littoral and Bahia littoral. 52 species of annual fishes are included in the list of 165 endangered species (Bomfim 2003).

Biodiversity of freshwater fishes in the River Paraíba do Sul (East Atlantic Basins), where endemism reaches the highest level due to the Atlantic Rainforest, is classified as extremely important (Figure 29) according to the classification of the Brazilian Ministry of Environment (MMA 2000). However, water quality deterioration of Paraíba do Sul tributaries has created barriers to genetic interchanges between different populations of ichthyofauna species. Genetic interchange is currently confined to tributaries where better water quality and environmental integrity are found.

Lack of information about ichthyofauna biodiversity before deforestation makes it impossible to evaluate the magnitude of the impacts of deforestation on local ichthyofauna during the last two to three decades. However, it can be inferred that changes act more on groups which depend on visual orientation for capturing their prey, affected by increased sediments/suspended solids in the waterways, as it seems to be the cause for a decline in the Brycon species. In some sections of the River Paraíba do Sul (between Resende and Volta Redonda and downstream Juiz de Fora), domestic and industrial pollution loads eliminated more sensitive fish species. Those sub-basins which still present good water quality are used as the last refuge for local species. In some sections of the Grande River, discharge of effluents is magnified by the relatively low stream flow and the impacts are deformities and lesions in *Hypostomus affinis* and *Rhamdia parahybae*. In the tributary, the Muriaé River, the increased microbiological pollution, and BOD and COD has caused the disappearance of fish species. In the Lower-Paraíba do Sul from São Fidélis to the river estuary, there are a large number of lenthic water bodies (swamps, lakes and pools) fed by flooding from the Paraíba do Sul. This section has a small slope with an average value of 0.22 m/km. Due to recent disappearance of flooding as a consequence of stream flow control by damming; these systems have been badly affected. A marked aspect along the Paraíba do Sul is the large number of aquaculture farms. This is more prevalent in the middle and upper reaches of the River and the species cultivated include snapper, tilapia (*Tilapia rendalli*), Characidae, Cichlydae, carp, tambacú and African catfish. Aquaculture imposes risk of accidental introduction of alien species into the Basin.

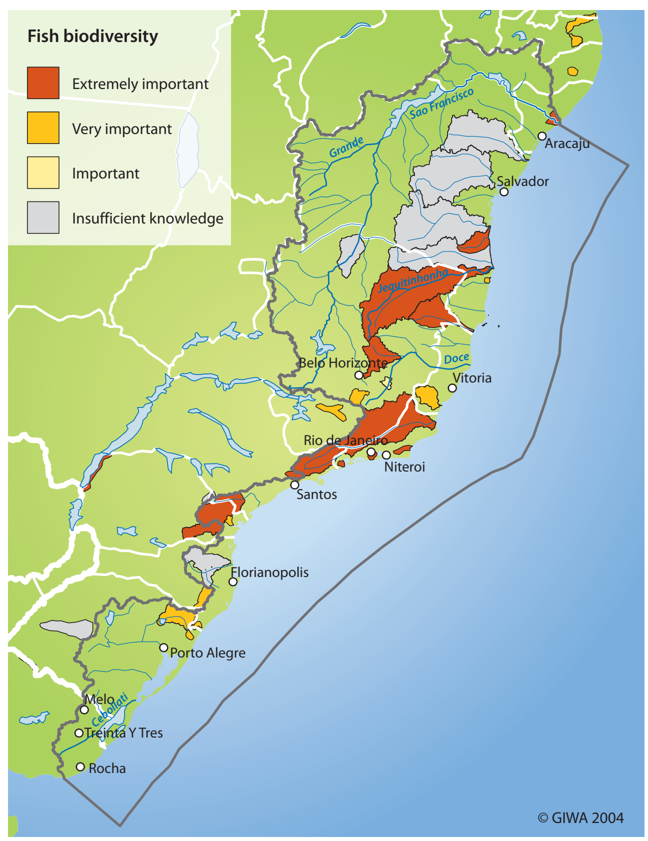

Figure 29 Priority basins in terms of freshwater fish biodiversity/endemism in the Atlantic Rainforest in Brazil Current.

Almost all areas extremely important regarding fish biodiversity are inside the Brazil Current region: among 35 freshwater bodies of importance for freshwater fish biodiversity marked on the map, 24 are inside the region. The area with the highest endemism of fishes is formed by a group of rivers in Rio de Janeiro state (e.g. Paraíba do Sul and São João Rivers).

(Source: MMA 2000)

The results obtained from a detailed study about anthropogenic impacts and aquatic biodiversity in the Doce River (Minas Gerais and Bahia states in East Atlantic Basins) showed that the biodiversity of ichthyofauna found in the basin is low and the ichthyofana is composed by species that show a wide geographical distribution and high tolerance to environmental changes and pollution (Barbosa et al. 2000). These results indicate that significant ichthyofauna biodiversity reduction has already occurred. Among the main economic activities are those associated to steel industry, mining, agriculture and monoculture with timber production (Eucalyptus). The causes behind biodiversity reduction is likely to be increasing turbidity, increased organic load and reduced oxygen content of the water, together with chemical pollution (de Paula et al. 1997).

The construction of dams and stream flow regulation in the São Francisco River Basin has caused the elimination of rapids, isolation of marginal lagoons and margin niches, sandy bottoms due to the reduction of terrigenous inflows and some fish species that need the currents to reach sexual maturity has therefore disappeared. The rice plantation and other water demanding crops in the Basin has been largely impacting the region and these very cultures have been subjected to the attacks of rodent epidemics. The elimination of riverine belts (riverine forests) has resulted in riverbank erosion. Such erosion has directly affected the presence of shoals and, therefore, the fishing activities, as the destruction of such ecosystems impacted the reproduction of several fish species. Fluvial navigation has been directly affected due to siltation and the formation of large sand banks. The introduction of alien fish and mollusc species has occurred over the years in the lower São Francisco region. It is planned an increase in the hydropower capacity of the cascade of reservoirs on the São Francisco, to meet the regional demand for energy. Considering the present level and flow of the River, which has no capacity to transport the sediments accumulated in many sandbanks, and for the sake of the environment, it has been proposed (Machmann de Oliveira 2003) that the new reservoirs should operate during some weeks every year at full discharge rate, in order to reproduce the natural flooding, which was suppressed by the cascade of reservoirs. During this "artificial high stream flow", the sediments deposited in sandbanks will be transported to the oceanic region, minimising erosion and biomass depletion due to lack of nutrients. The environmental benefits are clear but the direct and indirect costs of such operational procedure need to be defined in more details. The lower São Francisco River and its estuary, located at the coastal boundary of and shared by Alagoas and Sergipe states, has suffered significant morphological changes due to stream flow regulation as a consequence of the cascade of constructed dams. Significant reduction of sediment/nutrient transport has caused sediment deficit in coastal areas, erosion and modification of ecological niches. Figures 30, 31 and 32 show the trophic status of the pelagic ecosystems through measurement of biomass of phytoplankton, microplankton and macroplankton in the São Francisco River, the River's estuary and the contiguous sea (Machmann de Oliveira 2003).

In all seasons, the values of plankton biomass found in lower São Francisco River, estuary and contiguous sea were extremely low, close to the lowest limit expected for coastal zones, indicating that the River

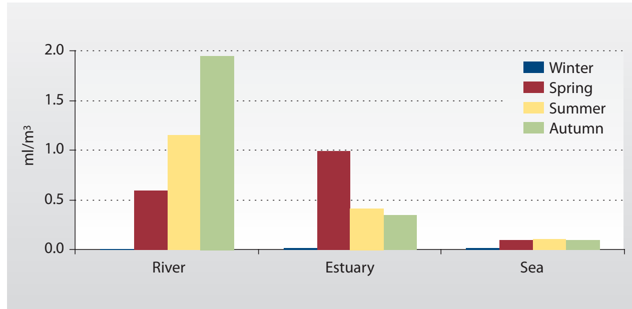

Figure 30 Biomass of phytoplankton in the river, estuary and the sea contiguous to the São Francisco River.
Note: Biomass measured as biovolume. (Source: Machmann de Oliveira 2003)

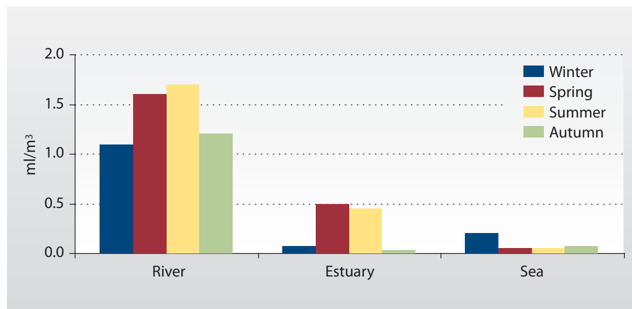

Figure 31 Biomass of microplankton in the river, estuary and the sea contiguous to the São Francisco River.
Note: Biomass measured as biovolume. (Source: Machmann de Oliveira 2003)

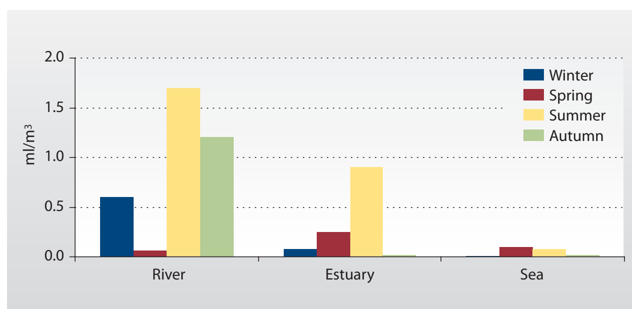

Figure 32 Biomass of macroplankton in the river, estuary and the sea contiguous to the São Francisco River.
Note: Biomass measured as biovolume. (Source: Machmann de Oliveira 2003)

contributes very little for the planktonic production in the coastal zone (Machmann de Oliveira 2003). This is likely to be the main cause of the low level of fish production recorded at the River's mouth (Figure 33) and some tributaries (Figure 34).

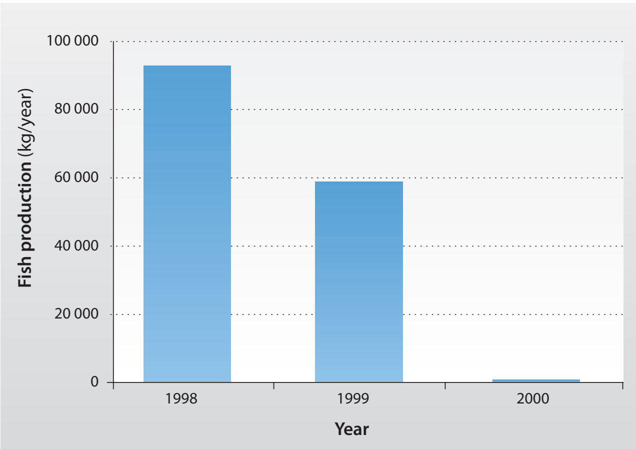

Figure 33 Fish production at the São Francisco River estuary.
(Source: Machmann de Oliveira 2003)

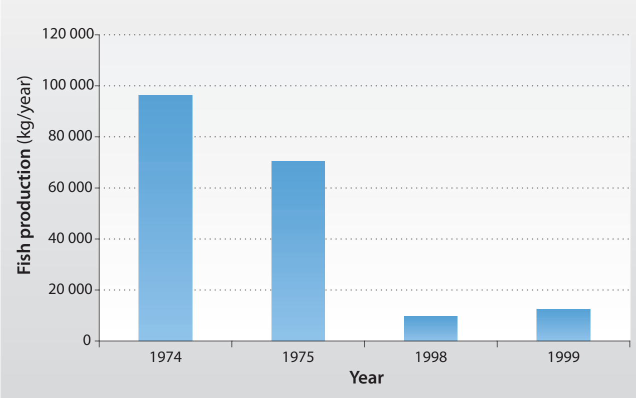

Figure 34 Fish production in the Itraipu River, tributary of São Francisco River basin.
(Source: Machmann de Oliveira 2003)

Socio-economic impacts

Economic impacts

The economic impacts due to habitat and community modification in the Brazil Current were considered moderate with tendency of worsening. Economic impacts include: loss of revenues from tourism; loss of property value; reduction of fisheries; increased costs for coastal areas maintenance due to higher vulnerability to erosion, lower stability of coastline, recovery costs after the occurrence of floods; costs with maintenance and recuperation of river banks; and control of alien species. Even with a short-medium term economic return obtained with the economic sectors, this compensation does not eliminate the aforementioned losses.

The size of economic and public sectors affected by the habitat and community modifications were considered large in South/Southeast and East Atlantic Basins, and small São Francisco River Basin. The frequency/duration of these impacts once they occur was considered continuous, since losses and significant modifications of habitats are hardly reversible.

Health impacts

Health impacts in the region due to habitat and community modification include major risks for humans from disease caused by habitat alteration, such as proliferation of disease agents. Low-income population is particularly exposed to these kinds of impacts.

Other social and community impacts

Social and community impacts in the region include: reduced capacity of local populations in meeting basic human needs, particularly in São Francisco River Basin where fish stocks have been drastically reduced; and changes in work opportunities, loss of aesthetic and recreational values, mostly in the coastal areas of region South/Southeast and East Atlantic Basins where loss of habitats have reduced the beach and the stability of the coastline. Loss and/or modification of ecosystems and ecotones have also created generational inequity, loss of scientific and cultural heritage since the disappearance of aquatic species is irreversible.

Socio-economic impacts associated to habitat and community modifications and sectorial activities are also addressed in other chapters of this report (e.g. the Causal chain analysis).

Conclusions and future outlook

After land settlement and water resources exploitation, modification of aquatic habitats is one of the first impacts observed. Particularly in high densely populated regions, such as the coastal zone of the Brazil Current region, not surprisingly, the impacts are severe. The expansion of tourism in both the Brazil Current coastal zone and the Atlantic Basin of Uruguay (Vertiente Atlantica 89 in Figure 2) represent a serious threat to those coastal ecosystems that are still preserved. This concern, together with pollution, was considered as a priority concern for the Brazil Current region. The common root causes and sector activities responsible for both pollution and habitat and community modification will be highlighted during the causal chain and policy options analyses performed for selected aquatic systems. Habitat and community modification as well as pollution is responsible for part of the observed depletion of fish stocks (which is also caused by unsustainable exploitation) and part of the changes in the hydrological cycles (which are also a result of the global changes). The precedence position of these two concerns in a causal chain connecting all concerns was also taken into consideration when establishing the priority concerns. Knowledge about the ecosystems in the Brazil Current region is limited and better assessments of the impacts of anthropogenic activities are dependent on better inventories.

Unsustainable exploitation of fish and other living resources

IMPACT **South/Southeast Atlantic Basins** IMPACT **East Atlantic Basins** IMPACT **São Francisco River Basin**

Based on global productivity estimates from SeaWiFS, the Brazil Current portion corresponding to the LME 15, Large Marine Ecosystem South Brazil Shelf (Figure 1), is considered Class II: Moderately high productive ecosystem (150-300 gC/m^2/year). This productivity is reduced as one moves northwards and the LME 16, East Brazil Shelf (Figure 1), is classified as Class III: Low productivity ecosystem (<150 gC/m^2/year). LME 16 has a more diverse food web but has the lowest productivity of Brazilian marine ecosystems.

Estimates of the potential annual fisheries yields of Brazil up to depths of 200 m made by Yesaki (1974) are 1 400 to 1 700 tonnes and 1 100 to 1 600 tonnes by demersal and pelagic fisheries respectively. The potential of the South/Southeast Atlantic Basins is about five times higher (950 tonnes) than the potential of the East Atlantic Basins (200 tonnes). The GIWA region 40a Brazilian Northeast has a mere 100 tonnes (Hempel 1971). The estimates are about two-fold higher than Brazils total annual fisheries catches (IBGE statistics for 1980-1994 in Paiva 1997), which fluctuated around 750 000 tonnes in the 1980s, declined towards about 600 000 tonnes in the early 1990s and recovered by about 10% thereafter (Matsuura 1998, Paiva 1997, Matsuura 1998, FAO 2000). The East Atlantic Basins and the GIWA region 40a Brazilian Northeast account for similar catches with 41 000 tonnes and 39 000 tonnes, respectively, and the South/Southeast Basins 425 000 tonnes (South=75 000 tonnes, Southeast=350 000 tonnes).

In the southeast, sardines (*Sardinella brasiliensis*) and mackerel (*Scomber japonicus*) are most important by weight, reflecting the pelagic oriented production in the area. In the south, demersal fish biomass is higher than in the southeast. The important fisheries species are the demersal hake (*Merluccius hubbsi*) and sciaenids (*Umbrina canosai*, *Micropogonias furnieri*), but also shrimps (*Xiphopenaeus kroyeri*, *Panaeus paulensis*, *Panaeus brasiliensis*), and pelagic anchovies (*Engraulis anchoita*) and sardines (*Sardinella brasiliensis*) (Paiva 1997).

In clear contrast to the South/Southeast, the oligotrophic character of the marine component of the East and Northeast is related to its diverse food web structure (Matsuura 1998, Ekau & Knoppers 1999). Common to both sectors, however, are the mesopelagic species of the Brazil Current, along and beyond the shelf edge. Their ichthyoplankton serve as food for higher trophic level carnivorous fish. A considerable fraction of the commercial fisheries of this oceanic realm is tuna, including *Thunnus albacares, Thunnus atlanticus, Thunnus thynnus thynnus* and *Katsumonus pelamis*. The catches of the northern sector of the East Atlantic Basins are similar to those of GIWA region 40a, being dominated by snappers, crabs (*Ucides cordata*), shrimps (*Penaeus schimitii*), lobsters (*Panulirus* sp.) and some mullet (*Mugil* sp.). On the Abrolhos Bank (Bahia state littoral), demersal species dominate the system. The food web at the Abrolhos Bank, with a high diversity in herbivorous fish, possibly relying on the primary production of benthic algae, is in sharp contrast to the South/Southeast where diversity is low at the herbivorous level (Matsuura 1998).

In the Atlantic Basin of Uruguay (89 in Figure 2, assessed separately from Brazil Current), fishing has different dynamics from those found in Brazil Current. The Patagonian Shelf LME 14 (highly productivity ecosystem) provides a favourable reproductive habitat for anchovies and sardines, when physical processes such as upwelling and mixing combine favourably in special configurations (Bakun 1993), so that fish larvae remain close to food sources. There are favourable reproductive habitats for small, pelagic-spawning clupeids (Bakun & Parrish 1991). Common hake is abundant on the northern shelf and off of Uruguay and southern Brazil. The Atlantic anchovy (*Engraulis anchoita*) is a key species in the trophic system (Bakun 1993). Only Argentina targets the Atlantic anchovy, and it is presently under-exploited. It inhabits an extended stretch of coastal habitat from Cabo Tres Puntas in south-central Argentina to Cabo Frio in Rio de Janeiro (upper limit of South/Southeast Atlantic Basins). It spawns in the southeastern Brazilian Bight from late winter to early summer, and is a temperate rather than a tropical species, occurring at depth or in upwelling plumes (Bakun 1993). Uruguay has an artisanal fishery of croakers and weakfishes. In Bañados del Este, the project PROBIDES financed by GEF stimulates the production of smoked fish in order to aggregate value to the product and reduce the pressure on the fish stocks exerted by the artisanal fishing colonies. Since this region receives tourists all year around, selling a more expensive product is not a problem.

Environmental impacts

Overexploitation

The severe impacts of overexploitation of fish applies to the marine component of the Brazil Current region as a whole, as follows:

The fluctuations of Brazils total catches may be attributed to manifold natural and cultural impacts, as exemplified for the sardine and anchovy fisheries of the South/Southeast Atlantic Basins (Bakun & Parrish 1991, Paiva 1997, Matsuura 1998). The sardine fishery recorded a maximum catch of 228 000 tonnes in 1973, followed by a declined in the following years up until 1986 when catches were down to 90 000-140 000 tonnes per year and has since suffered a near collapse. Major declines were due to recruitment failures in 1975 and 1987, attributed to oceanographic anomalies, such as less intense intrusions of the northward flowing colder nutrient rich South Atlantic Central Waters (SACW) onto the inner shelf and coastal regions. The process is controlled by atmospheric/oceanic conditions of regional scale. On the other hand, some fish stocks in South/Southeast Atlantic Basins have become either fully exploited or overexploited, raising doubts if the level of exploitation can be sustained without impairing the productivity and integrity of the ecosystems. A 90% reduction of the catches of viviparous shark occurred at the Patos Lagoon estuary and *Netuna* spp. has also been overexploited (Montu & Gloeden 1982, Haimovici et al. 1997). Fish stocks in Sepetiba Bay have declined 20% during the last decade (Lacerda et al. 2002). Dramatic declines due to overexploitation have been registered for the lobster fisheries in the northern sector of the East Atlantic Basins, including the estuary of São Francisco River and especially in another GIWA region 40a Brazilian Northeast. Examples of marine fish species whose exploitation exceeds the Maximum Sustainable Yield (MSY) in São Francisco River and estuary are: large prawns, catfish, sea shrimp. It is worth mentioning that a reduction in the production of some important species, particularly of shrimps (more details, see Habitat and community modification) in São Francisco River, has been the result of reduction of sediment/nutrients transport due to flow regulation by dam construction and the subsequent dramatic reduction in primary productivity, followed by a drop in the ichthyofauna production in the Basin and at the River mouth. Such impact on biodiversity dramatically reduced the stocks and limited even further the sustainability of fisheries in this basin.

The commercial fisheries statistics of Brazil continue to be a difficult issue. The socio-economic characteristics of the fishing industries are highly variable, due to the large geographical extension of the coast (8 400 km), local to regional differences of the productivity of coastal waters and cultural influences upon the industries. A particular problem for the gathering of reliable statistical data is the coexistence of artisanal and industrial fisheries. The former accounts for about 40% of Brazils total fisheries catches (Paiva 1997), operating with a fishing fleet of 23 000 small to medium-sized boats, in contrast to the industrial coastal fleet with 1 630 boats and the industrial oceanic fleet with 52 boats (FAO 2000). Its landings are local-scale at numerous small fishing ports and villages. The industrial statistics are sounder, because catches are restricted to a few major state ports. The relative importance of artisanal fisheries diminishes from north to south, supporting the argument that statistics of the South/Southeast Atlantic Basins are more reliable (Paiva 1997).

Artisanal fisheries practiced at the littoral of Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul (South/Southeast Atlantic Basins) have been about 22% of the total commercial catch (Paiva 1997). As artisanal fisheries capture have a much larger amount of species with lower biomass than industrial fisheries, they have a different impact upon biodiversity. Better statistics are thus particularly necessary for the tropical oligotrophic waters with high biodiversity of the East Atlantic Basins and the GIWA region 40a Brazilian Northeast (Paiva 1997). In Sepetiba Bay, state of Rio de Janeiro littoral, traditional fishing communities have almost disappeared and workers have moved to other activities.

In Barbitonga Bay, state of Santa Catarina (South/Southeast Atlantic Basins) overexploitation of crab, shrimp and mollusc in the mangrove areas can be observed. There is overexploitation of these groups in the mangroves of the South/Southeast Atlantic Basins: the Itajaí-Açú River estuary, the Camboriú River estuary and the Porto Belo Bay, state of Santa Catarina, which has severely affected the stocks. In the coast of the state of Rio Grande do Sul (South/Southeast Atlantic Basins) artificial lakes and reservoirs have been under much pressure from sport fishing, which is often carried out illegally, and no evaluation is made of its impact.

Artisanal landings for East Atlantic Basins and São Francisco River Basin (states of Espírito Santo, Bahia, Sergipe and Alagoas) have been estimated to account for up to 80% of the total commercial catches, which is even higher than for region 40a Brazilian Northeast with about 59%. Although most of the state of Alagoas belongs to Brazilian Northeast, its landings originate in large part from the area of the São Francisco river mouth and shelf.

The lagoon systems in the states of Rio Grande do Sul and in the Uruguayan East region hosts important lagoon systems in a total of 13, according to the Wetlands International. Eight lagoon systems are suffering overexploitation of fish: Peixe Lagoon system; Laguna Castillos and Arroyo Valizas do Taim; both Brazilian and Uruguayan portions of Mirim Lagoon; Patos Lagoon; Laguna de Rocha; Laguna Negra y Bañados de Santa Teresa; Laguna Garzón y Laguna José Ignacio; and Bañados San Miguel-Los Indios.

Excessive by-catch and discard

By-catch and discard is currently one of the main problems being faced in the coastal area outside the Paraná state coast section (South/Southeast Atlantic Basins), mainly in the areas between the cities of Ilha Comprida and Pontal do Sul. Trawlers have constantly acted illegally near the beaches, at depths of less than 2 m, and within the area forbidden under federal law. Apart from the capture of juvenile and adult fish during reproduction periods, these boats discard enormous quantities of small and valueless dead fish close to the beach, causing an impact due to organic build-up. An equally undesirable practice is that the city councils clean the beaches, removing sand along with the fish remains, which worsens the problem in the water. Commercial fish populations have shrunk and some of them are in critical condition in the lagoons of northern Rio Grande do Sul coast. Discards occur, even if in small quantities, inasmuch as accidental fishing is in large part used for human consumption. If species of little direct economic importance comprising accidental fishing are considered, the impact score might go up. Accidental fishing of juvenile fish jeopardises the MSY.

The excessive by-catch and discard in the mouth of the São Francisco River is severe. However, considering the São Francisco Basin as a whole, the impact was considered moderate. Maritime discards are traditionally high. Trawling of any one area of seabed is occurring 1 to 10 times per year. The introduction of tilapia species, tucunaré (Cichlydae) and tambaqui (Characidae) in some areas of the São Francisco Basin has threatened native species, due to food competition. Additionally, the tucunaré eats eggs and young forms of native species. In ocean fishing, 80% is by-catch (on the Sergipe and Alagoas coast this can reach 90%) with discards around 60%, the boats retaining only those species with the higher market value, due to their limited capacity.

Destructive fishing practices

There is the general practice of trawling, affecting all demersal species. Valuable species such as shrimp, line species such as Serranidae, pelagic species (sardine, tuna) and benthonic species (Portunidae, mussels, crab) are exploited above the MSY level. Many habitats are lost because of trawling. The use of bombs or poison is seen in most estuaries in the state of Sergipe (East Atlantic Basins). There are indications along the entire Bahia coast (East Atlantic Basins) of the use of explosives for fishing, destroying reefs and mangroves.

Decreased viability of fish stocks

There has been an increase in the number of disease occurrences and there is data on malformation, tumours, loss of scales and increases in mycoses. In some sub-basins, such as Muriaé River in the city of Muriaé, in the past few years some local species have disappeared, which until then were uniformly distributed. Discharge of domestic sewage in parts of the River with low circulation has dramatically increased faecal coliforms, BOD and COD.

Impact on biological and genetic diversity

There are several examples of species undergoing alterations of the biological diversity among native species on the Brazilian coast. For example, on the northern Rio Grande do Sul coast (South/Southeast Atlantic Basins) the porrudo (*Trachaelyopterus lucenai*) was introduced into the region, probably through irrigation systems for rice plantations. Fish farm activities are expanding, especially using alien species, such as carp (*Ciprinus* spp.), with potential for invasion of natural systems and the introduction of diseases and pathogens among native species. Changes have been seen in the composition and genetics of native fish species following the introduction of species in the dams of the state of Minas Gerais as well as shrimp farms in the state of Bahia (East Atlantic Basins). In more than one sub-basin of Sergipe, hybrids were seen and the local disappearance of some species of ichthyofauna is suspected to be a result of the introduction of alien species. There is also a record of parasite species which came with the breeders to the farms. Among benthic organisms, the *Melanoides tuberculata* and some species of *Macrobrachium* spp. were accidentally introduced. The species *Melanoides tuberculata* has been responsible for the disappearance of native gastropods and for being home to some life cycles of trematodes which cause diseases in fish and man.

Socio-economic impacts

Economic impacts

Most species of fish, crustacean and molluscs in southern estuary regions are of great importance considering not only the formal but also the informal economy, sustaining a high number of traditional fishermen who have lived for generations off this activity. Fishing of shrimp, crab, mussels, oysters, catfish and other species are part of the tradition of fishing families in Rio Grande do Sul and Santa Catarina since the last century. In turn, line fishing for more valuable species such as verne, namorado, red porgy, and others (many for export) also shows signs of overfishing.

Industrial fishing in the state of Rio de Janeiro as well as the states of Bahia and Espírito Santo (East Atlantic Basins) has been hit hard over the years with falling sardine production, and the closure of many salting and canning companies. On the coast of the state of São Paulo (Santos and Guarujá), industrial fishing and fish food industry are important economic activities with processing factories for export. On the other hand, small and artisanal fishing is in freefall, due to overexploitation in coastal and near regions, and direct competition from large fleets.

On a sub-regional scale, the size of the economic sector affected by overexploitation of fish and other living resources is considered small in comparison with the whole economy of the South/Southeast Atlantic and East Atlantic Basins, where other sectors (e.g. industry, agriculture, energy, services, etc.) represent the largest component of the economy. In these sub-basins, the economic impact as regards the size of economic sectors affected by non-sustainable exploitation of fish resources was considered to be moderate. However, in São Francisco Basin, fisheries play a relatively more important role in the basin economy and the economic impact is moderate.

The degree of impact (cost, output changes, etc.), although limited to one economic sector (differently from freshwater shortage, which affects several sectors) is classified as moderate to severe. This means that the sector suffering the impact (fisheries, both industrial and artisanal) has suffered it severely. From the frequency point of view, the economic impacts varies from frequent to continuous, although some stocks might recover up to the previous level, depending on the management strategy.

As a consequence of the declining stocks and interruption of industrial activities (fish salting and canning) unemployment in the industrial sector associated to seafood processing increased. Some processing industries replaced the local raw material by imported material. *Sardinella brasiliensis*, for instance is still caught in Brazilian coastal waters, particularly from Cabo Frio and Angra dos Reis (Rio de Janeiro littoral), Santos (São Paulo littoral) and Itajaí (Santa Catarina littoral), all littorals of South/Southeast Atlantic Basins. However, *Sardina pilchardus* and *Sardinella aurita* are imported from Venezuela, among other sources (Silva & Batista 2003).

Health impacts

Health impacts associated to overexploitation of fish would occur if the protein originally obtained from fish could not be replaced by other sources of animal protein. This has not been the case of the majority of fishing communities in South/Southeast and East Atlantic Basins, where the labour force available due to reduction of fish stocks is usually occupied by the service sector in the coastal zone of the Brazil Current. However, given that this occupation does not absorb 100% of the labour force, the degree of impact might be considered at least slight. In São Francisco River Basin although poverty among the communities is worse than in the other sub-regions, health impacts were considered moderate.

Other social and community impacts

Several fishing colonies have been closed and the labour force has been diverted into services associated to tourism. Canoeing and fish (dourado) festival are tourism activities in the Paraíba do Sul River (in the East Atlantic Basins), mainly along the Minas Gerais section of the Paraibuna River for canoeing, and in Itaocara where the dourado festival attracts many fishermen from other areas. Professional fishermen in the Paraíba do Sul River basin, state of Rio de Janeiro portion, have been traditionally organised into four colonies. As reported by the Brazilian Institute for the Environment (IBAMA), these associations have gradually disintegrated and currently only two colonies remain. A similar trend has been observed all over the Brazil Current. It should be noted that fishing has the highest social significance, as a subsistence activity not accounted for in the formal economy. Traditional fishing is intrinsic to coastal communities, consolidating the importance of estuarine species as a social, cultural and economic element in the region.

In the São Francisco Basin, even though the size of economic sectors affected and the number of people's health affected are deemed small in comparison to the economy and population of the Basin, the degree and severity of impacts have been deemed high and permanent, taking into account that if the Basin's fish shoals are jeopardised, this would result in the end of subsistence activities.

Conclusions and future outlook

Severe environmental impact on fish species and other living resources in the Brazil Current is a consequence of overexploitation, use of destructive fishing practices, decreased viability due to pollution and destruction of coastal ecosystems such as mangroves, which are important for the reproductive cycle of several species. Regarding economic impacts, the fisheries sector has a peculiar condition in the Brazil Current, since it constitutes a relatively small portion of the GDP, to which other economic sectors such as industry, agriculture, urbanisation, tourism, energy, and services, provide a much bigger share. However, severe impacts are seen on the fisheries sector economy, affecting the population directly dependent on the sector (e.g. fishermen and their families, food industry).

In the Brazil Current, the development of aquaculture mostly in South/Southeast Atlantic Basins and São Francisco River Basin has been a clear trend during the last two decades. The state of Santa Catarina (South/Southeast Atlantic Basins) has been the states with the greatest growth. The environmental impacts of this growing activity should not be neglected and must be properly addressed to avoid the severe environmental destruction due to aquaculture observed in other parts of the world, such as Asia.

Global change

South/Southeast Atlantic Basins | **East Atlantic Basins** | **São Francisco River Basin**

Climate change can be seen as one of many pressures on the water resources. Freshwater shortage and pollution illustrate alterations in the hydrological systems of the Brazil Current region as a consequence of land use and land-management practices, which often lead to deterioration in the resource baseline. For rivers in semi-arid lands included in the Brazil Current region, significant negative trends of river flow have been detected, but these variations seem to be related to consumption by agriculture and damming, rather than climate-induced changes (INRENA 1994, Marengo 1995, Marengo et al. 1998). Global warming and sea level raise are likely to influence the hydrological cycle, agricultural yield and threaten human health and property security (IPCC 2001). The association between climate changes and the fluctuation of Brazilian sardine catches has been investigated (Rossi-Wongtschowski et al. 1996). However, complex climatic patterns, which result in part from interactions of atmospheric flow with topography, intermingled with land use and land-cover change, make it difficult to identify common patterns of vulnerability to climate change in a given region (IPCC 2001). Global warming and regional climate change resulting from land-cover change may be acting synergistically to exacerbate stress over the region's tropical ecosystems (IPCC 2001). In several cities in South/Southeast Brazil, studies on long-term time series for temperature, from the beginning of the 20th century, indicate warming tendencies (Sansigolo et al. 1992). This could be attributable to urbanisation effects or to systematic warming observed in the South Atlantic Ocean since the beginning of the 1950s (Venegas et al. 1996, Venegas et al. 1998).

Based on available information, Brazil Current sub-regions are differently impacted by some issues of the concern Global change, as briefly illustrated below. For the South/Southeast Atlantic Basins, there is more information substantiating the impacts than for the other sub-regions.

Environmental impacts

Changes in the hydrological cycle and ocean circulation

For South/Southeast Atlantic Basins and particularly for the semi-arid portion of the two other sub-regions, environmental impacts due to global changes were assessed as moderate. Based on that, the severity of environmental impacts for the whole of the Brazil Current was assumed to be moderate. The criterion was: "Extreme events such as flood or drought are increasing". Although there is no definitive evidence, for the South/Southeast Atlantic Basins, a second criterion supporting the moderate score that would also apply is: "Aquatic productivity has been altered as a result of global phenomena such as ENSO events."

Regardless the incomplete picture (Calder 1999) about the role played by forests in the regional hydrological cycle, if the extent of deforestation were to expand to substantially larger areas, rainfall is expected to be reduced in the centre-south region of Brazil (GIWA region 38 Patagonian Shelf), and south region of Brazil, as a consequence of reduction in evapotranspiration (Lean et al. 1996). According to the same principle, the large-scale deforestation of the Atlantic Rainforest in the Brazil Current during the 20th century (currently, only 7% of the original forest area remains, according to Fundação SOS Mata Atlântica & INPE 2002) has probably affected the hydrological cycle, resulting in increased surface temperatures, decreased evapotranspiration and reduced precipitation. However, there is insufficient data to substantiate this hypothesis.

As regards El Niño, there are evidences of changes in hydrological cycles and ocean currents as a result of the El Niño Southern Oscillation (ENSO). In the sub-tropical area of Brazil, precipitation exhibits a long-term change, with a sharp increase in the period 1956-1990 after a dry period during 1921-1955 (Barros et al. 1995). South Brazil is the region most impacted by these changes. The effects of El Niño and La Niña in Brazilian territory are presented in Table 15.

Table 15 Variability and impacts of El Niño and La Niña on different Brazilian and GIWA regions.

	Climatic/Hydrological variable	Brazilian region	Source	Observation period
El Niño[a]	Severe droughts	Northeast Brazil[c]	Silva Dias & Marengo 1999	1901-1997
	Decrease in precipitation during rainy season	Northern Amazon[d] Northeast Brazil	Aceituno 1988, Richey et al. 1989, Marengo 1992	1931-1998
	Negative large anomalies of rainfall during rainy season	Northeast Brazil	Silva Dias & Marengo 1999, Hastenrath & Greischar 1993	1930-1998 1912-1989 1849-1984
	High precipitation and flooding	Southern Brazil[e]	Rebello 1997	1982-1983
La Niña[b]	Increase in precipitation, higher run-off	Northern Amazon Northeast Brazil	Marengo et al. 1998, Meggers 1994	1970-1997 Paleoclimate
	Severe droughts	Southern Brazil[e]	Grimm et al. 1996 and 2000	1956-1992

Notes: [a]Extremes of the Southern Oscillation (SO) are responsible in part for a large portion of climate variability at inter-annual scales in Latin America. El Niño (ENSO) events represent the negative (low) phase of the SO. [b]La Niña is the positive (high) phase of the SO. [c]Includes GIWA region 40a Brazilian Northeast and the semi-arid portion of the São Francisco River Basin. [d]Part of GIWA region 40b Amazon. [e]Includes the south portion of GIWA sub-region39 South/Southeast Atlantic Basins and the upper Patagonian Shelf, GIWA region 38 .

El Niño/La Niña disrupts some of the "normal" climatic conditions described in the Regional definition. During El Niño, the polar frontal systems are blocked and diverted eastwards out to the Atlantic and trade winds are barred at the front. The blockage system extends from southern Peru to southern Brazil and its position oscillates in relation to the degree of enhancement of the sub-tropical jet stream and, of course, intensity of the El Niño phenomenon. This situation provokes an anomalously high rainfall in the blocking zone and drought northward, as well as modification of the wind patterns, and consequently of the wind-driven littoral dynamics. ENSO leads to floods in the southern portion of the South/Southeast Atlantic Basins (Rio Grande do Sul, Santa Catarina and Paraná states), in the Atlantic Basin of Uruguay (89 in Figure 2) and in the GIWA region 38 Patagonian Shelf, provoking the reverse effect in the rest of the Brazilian coastal regions. The upper São Francisco Basin follows the pattern of the southern portion of South/Southeast Atlantic Basins: the more El Niño intensifies, the more rain will fall (positive effect). The semi-arid portion of São Francisco Basin and GIWA region 40a Northeast Brazil, exhibits anomalously dry conditions during these periods (Table 15) (IPCC 2001). On the contrary, under the influence of La Niña, rainfall is significantly reduced in the southern portion of South/Southeast Atlantic Basins; meanwhile in the northeast region rainfall increases. Northern Amazon (in GIWA region 40b Amazon) follows the pattern of the northeast coast.

During the period 1982-1983, El Niño caused severe drought in the north of Brazil and flooding in the south. The rainfall in Santa Catarina (events with more than 900 mm) for instance, caused severe socio-economic impacts (Rebello 1997) (see also Socio-economic impacts in this section). Despite heavy rains during El Nino, a reduction in the average stream flow of some major rivers in the Brazil Current has occurred during the last decades, as a result of damming and consumption.

Stream flow in Uruguayan rivers exhibited a negative trend from 1901 to 1970, which reversed after this period. Multidecadal variability is also observed in discharges in Uruguay (Genta et al. 1998). However, in other parts of South America outside Brazil Current, there has been an increase of stream flow since 1970s in northwest Amazon (Marengo et al. 1998) and since 1960s in the southeastern part of South America (Patagonia region in Argentina) (Genta et al. 1998).

According to IPCC (2001), on decadal to centennial time scales, changes in precipitation and run-off may have significant impacts on mangrove forest communities. There are indications that major declines of sardines stocks previously credited exclusively to overexploitation, in some years (e.g. 1975 and 1987) were mainly due to oceanographic anomalies, such as less intense intrusions of the northward flowing colder nutrient rich South Atlantic Central Waters (SACW) onto the inner shelf and coastal regions. The process is controlled by atmospheric/oceanic conditions of regional scale. However, the contribution of each concern (Global change and Unsustainable exploitation of fish) to the decline of sardine stocks in the Brazil Current is not fully understood.

Garcia and Vieira (2001) analysed the species composition and species diversity in the Patos Lagoon estuary before, during, and after the 1997-1998 El Niño. A total of 20 hauls were made monthly at four beach stations from August 1996 to August 2000, using beach seine hauls. Species were grouped as follows: (i) estuarine resident; (ii) estuarine dependent; (iii) marine vagrant; and (iv) freshwater vagrant. Species diversity was evaluated by H' index, species richness by the rarefaction method and evenness by the Evar index. Confidence intervals were obtained by the bootstrap method. The El Niño phenomenon causes higher than average rainfall in southern Brazil and directly affects river discharge, which changes salinity in estuaries. Rainfall exceeded the average and salinity was lower than average during the studied El Niño event. Fish species diversity was higher in Patos Lagoon (South/Southeast Atlantic Basins) estuary during the El Niño, and this was strongly influenced by an increase in the number of freshwater species, and to a lesser extent, due to an increase in species evenness.

Sea level change

The environmental impacts due to changes in sea level, were considered slight. According to IPCC (2001), a slightly rising rate of global warming and sea levels have been observed in the world. Modelling indicates that there will be an increase in the frequency and intensity of atmospheric fronts, leading to growing problems of coastal erosion because of so-called spring tides, a phenomenon which is most evident in the south portion of the South/Southeast Atlantic Basins and in the neighbouring GIWA region 38 Patagonian Shelf. In the South/Southeast Atlantic Basins many engineering constructions along the coast have been destroyed during the last decade. The sea level along the Brazilian coast has been subjected to changes between 18-40 cm per century (IPCC 2001) and there has been a sea level rise in the middle section of the Brazilian coast, which is found to be within the normal worldwide variation and changes in ocean streams. Studies of vulnerability to sea level rise (Perdomo et al. in IPCC 2001) have suggested that countries such as Uruguay could suffer adverse impacts, leading to losses of coastal land and biodiversity, saltwater intrusion, and infrastructure damage. Likely impacts would be multiple and complex, with major economic implications.

Rising sea level may eliminate mangrove habitat at an approximate rate of 1% per year (IPCC 2001). Decline in some of the region's fisheries at a similar rate would be observed because most commercial shellfish use mangroves as nurseries or refuges. Coastal inundation stemming from sea level rise or flatland flooding resulting from climate change may seriously affect mangrove ecology and associated human economy (IPCC 2001). Sea level in a global change perspective is associated to temperature increase. Temperature anomalies related to the El Niño event and coral bleaching has long been observed along the Brazilian coast. In Abrolhos archipelago, an environmental protected area in the littoral of Bahia state in the East Atlantic Basins that has been studied regarding the environmental impacts (Ekau 1999), two episodes of coral bleaching have been recorded related to a rise of sea surface temperature (Leão 1999). The first episode was during a sea surface temperature anomaly in the summer of 1994 when 51-88% of colonies of the genus *Mussismilia* were affected (Castro & Pires in Leão 1999). The second one was related to the strong ENSO event that begun by the end of 1997 in the Pacific Ocean, and also caused a rise of the sea surface temperature on the eastern coast of Brazil. The most affected species were *Porites branneri* and *Mussismilia hispida,* both with more than 80% of their colonies totally bleached, *M. harttii* with an average of 75% of its colonies affected, and *Porites asteroides* with all colonies showing some sign of bleaching (Leão 1999). According to the authors, although the species *Agaricia agaricites* did not show a totally bleached colony, more than 90% of them had a pale colour.

Increased UV-B radiation as a result of ozone depletion

There is no known impact of increased UV-B radiation as a result of ozone depletion in the South/Southeast Atlantic Basins and São Francisco River Basin, and slight impact in the East Atlantic Basins. However, the destruction of the ozone layer would probably increase the effects of UV-B radiation.

Changes in the ocean CO_2 source and sink function

The are no known impacts of changes in CO_2 source/sink function in the aquatic systems of Brazil Current. On a global level, there are indications of modifications in the CO_2 exchange between the atmosphere, the land and the sea. These indications support the theory that global changes could interfere in the ocean's function as a CO_2 source/sink. However, on the Brazil Current's level, there are no sufficient studies or information on this matter. No known impact is, therefore, the most appropriate assessment for environmental impacts due to this issue.

Socio-economic impacts

Economic impacts

One methodological approach recently applied to assess economic impacts due to global changes is to estimate the aggregate monetised impact, based on current economic conditions and populations, for a 1.5 to 2.5°C temperature increase (Tol et al. in Beg et al. 2002). According to this criteria, developing countries have greater economic vulnerability to climate change. At lower levels of climate change, damages might be mixed across regions; for example, poorer countries are likely to be net losers, and richer countries might gain from moderate warming.

Economic activities such as tourism and fishing, settlements and structures are particularly vulnerable to physical changes associated with sea level rise. Tourism is one of the most prominent economic activity in the Brazil Current region. Protection, replenishment, and stabilisation of existing beaches might represent a relevant mitigation to the economic impacts. However, it is difficult to separate the impact of climate-induced sea level rise from erosion associated with changes in the sediment transport dynamics due to damming and the continuous effect of the sea on the coast.

In South/Southeast Atlantic Basins, the economic impact due to flooding caused by El Niño/La Niña is severe and affects many economic sectors, however, these impacts are not continuous. The sectors more affected by flooding are: services, urban/housing, transport, industry, agriculture and fishing. Civil engineering works for flood prevention and recovery of affected areas represent considerable costs to the local, state and eventually, federal governments, and also contribute to the economic impacts. Silviculture is a major land use in Brazil and is expected to expand substantially over coming decades (Fearnside 1998). Climatic change can be expected to reduce silvicultural yields to the extent that the climate becomes drier in major plantation states such as Minas Gerais and Espírito Santo (East Atlantic Basins) among other parts of Brazil, as a result of global warming and/or reduced water vapour transport from the Amazon River (Eagleson 1986). Dry-season changes can be expected to have the greatest impact on silvicultural yields. Modelling results (Gates et al. 1992) indicate that annual rainfall changes would cause yields to decrease by 8% in southern Brazil (South/Southeast Atlantic Basins) and increase by 4% in the northeast (East Atlantic Basins and São Francisco River Basin). During the June-July-August (JJA) rainfall period, yields would decrease 14% in southern Brazil, and 21% in the northeast (Fearnside 1999).

Potential effects of climate change in Brazil suggest changes of 4 to 4.5°C in surface temperature as a result of increased CO_2 concentrations (de Siqueira et al. 1994, de Siqueira et al. 1999). Agriculture is impacted by temperature increase in different ways: (i) it reduces crop yields by shortening the crop cycle; and (ii) it reduces fishing and forestry productivity (IPCC 2001). Based on General Circulation Models (GCMs) and long-term crop model forecasts, decreased yields for some crops in South/Southeast Atlantic Basins (e.g. wheat, maize) are expected due to increase in the temperature (IPCC 2001). In Uruguay, a yield reduction of 5 to 10% is foreseen (Baethgen & Magrin 1995). However, this impact might be felt mostly in the Uruguayan portion of region 38 Patagonian Shelf, where the main wheat plantations are found. It has been pointed out that lack of consistency in the various GCM precipitation scenarios makes it difficult to make a precise assessment of crop production under climate change, even when the relationships between precipitation and crop yields are well known. Some of the relatively weak cold surges may exhibit unusual intensity, causing frosts and low temperatures in coffee-growing areas of southeastern Brazil (South/Southeast Atlantic Basins), resulting in heavy damage and losses in coffee production (Marengo et al. 1997).

Health impacts

The magnitude of the impacts of climate change on health primarily depends on the size, density, location, and wealth of the population. It is likely that extreme weather events increase death and morbidity rates (injuries, infectious diseases, social problems, and damage to sanitary infrastructure) particularly in developing countries (IPCC 2001). There is evidence that the geographical distribution of vector-borne diseases (e.g. malaria, dengue) in Brazil change when temperature and precipitation increase. On longer time scales, El Niño and La Niña cause changes in disease vector populations and the incidence of water-borne diseases in Brazil. The exact distribution of these diseases, however, is not clear (IPCC 2001). Additionally, floods represent risks mainly to the population that live in risky areas, not only from the safety but also from the health viewpoint, because of water-borne diseases. Areas of high risk include all poor settlements and shanty towns on hill slopes and river banks in metropolitan areas of the Brazil Current in both South/Southeast and East Atlantic Basins.

Other social and community impacts

Flood and drought periods are related to migrations or relocations, giving rise to social and community impacts, which affect a significant part of the population. The severity of the impact is high during events but the duration is short and not frequent, since episodes of population displacement from areas affected are usually followed by the return of the displaced population to their original area. According to IPCC (2001), under climate change conditions, subsistence farming might be severely impacted in areas such as the Northeast region of Brazil, which includes the upper part of East Atlantic Basins and the lower São Francisco River Basin. In many coastal societies, cultural values are associated to the use of a wide range of natural products from the coastal wetlands and surrounding waters (Field 1997). Sea level change and erosion promote changes in the coastal environment.

During the last two decades, the most severe El Nino events in the Brazil Current region occurred in 1982-1983, 1986-1987 and 1997-1998 (Rebello 1997). The floods was considered a result of synergy between El Niño and stream flow changes due to land erosion and siltation (See Pollution, Suspended solids). In the south portion of South/Southeast Atlantic Basins severe socio-economic impacts have taken place (Rebello 1997). During the event 1982-1983, three states were most impacted: Rio Grande do Sul, Santa Catarina and Paraná. Of the total area of the state of Santa Catarina (95 000 km^2), 79% (75 000 km^2) were affected by flooding, including 135 cities, and 300 000 inhabitants that needed to leave their homes. Taking only the city of Blumenau, the magnitude of the flooding event is illustrated by the following indicators (Defesa Civil de Blumenau, in Rebello 1997):

- 31 days of duration (from 6 of July to 5 August 1983);
- On the 9th July 1983, the Itajaí River reached its highest water level: 15.34 m above normal;
- The previous experience of flooding at this level of severity was recorded in the year 1911;
- 50 000 inhabitants moved out from their homes and 38 000 households were affected.

The harvesting losses in 1983 due to the flooding included (Rebello 1997):

- State of Rio Grande do Sul: 693 777 tonnes;
- State of Santa Catarina: 1 626 298 tonnes;
- State of Paraná: 1 568 700 tonnes.

Conclusions and future outlook

Among the global climate changes foreseen for the next 100 years, in a "business as usual" scenario, the most significant ones for Brazil and in particular for GIWA region 39 Brazil Current are associated to changes in the hydrological cycle and ocean circulation such as temperature and sea level rise, changes in the rainfall regime and alterations in the distribution of extreme climate events, such as drought and flooding (Nobre 2001). However, insufficient information or lack of significant impacts due to some issues means that the overall impact for Global change is slight. The information available globally seems to indicate that a general worsening on environmental as well as socio-economic impacts is foreseen due to global changes. However, to express this expectation, the GIWA baseline is too short (year 2020) and it would be pointless to predict changes in such a short time, the reason the severity of impacts remains the same in the future conditions of GIWA (see Annex II). The following comments refer to the expected impacts in a long-term perspective, as has been discussed globally.

Although climate change may bring benefits for certain regions of Latin America (e.g. rainfall intensification in semi-arid areas during La Niña), increasing environmental deterioration, combined with changes in water availability and agricultural lands, may reduce these benefits to a negligible level (IPCC 2001). The adaptive capacity of socio-economic systems in Latin America is very low, particularly with respect to extreme climate events, and vulnerability is high. Some economic and health problems could be exacerbated in critical areas, fostering migrations from rural and small urban settlements into major cities and giving rise to additional stress at the national level and, at times, adversely affecting international relations between neighbouring countries (IPCC 2001).

Therefore, under climate change conditions the risks to human health may increase.

According to Beg et al. (2002), although climate change does not feature prominently within the environmental or economic policy agenda of developing countries, evidence shows that some of the most adverse effects of climate change will be in developing countries, where populations are most vulnerable and least likely to easily adapt to climate change. According to Beg et al. (2002), climate change could exacerbate current inequalities due to uneven distribution of damage costs, in addition to the cost of mitigation and adaptation efforts. Some synergies already exist between climate change policies and the new sustainable development agenda in some developing countries, including Brazil and Uruguay, such as energy efficiency, renewable energy, transport and sustainable land use policies (La Rovere 2002). In Brazil, renewable energy production and efficiency improvements in energy use in the 1980s have made a significant contribution to reducing green house gas (GHG) emissions. The programme of energy efficiency improvements in the use of electricity (PROCEL) alone, has led to significant GHG emission mitigation (La Rovere 2002). La Rovere (2002) also predicts that changes in rainfall patterns and in ENSO induced by climate change may further affect the already limited availability of water resources and aggravate the risk of famines due to the disruption of agricultural and cattle raising activities.

Understandably, vulnerability to the adverse impacts of climate change is one of the most crucial concerns of developing countries engaged in climate policy discussions, which including the countries that form GIWA region 39 Brazil Current (Brazil and Uruguay). It is also a critical element in planning any long-term climate and development strategy. According to IPCC (2001), climate change does not in itself stimulate development of new adaptive strategies, but it encourages a more adaptive, incremental, risk-based approach to water management.

Priority concerns

Establishing the priority concern for further analysis

Drainage basins and coastal zones in developing countries, densely occupied, heavily exploited in terms of their natural resources and with diverse and increasing economic activities, are likely to suffer from moderate to severe impacts due to at least four of the five GIWA concerns (Freshwater shortage, Pollution, Habitat and community modification, and Unsustainable exploitation of fish and other living resources). This is the result of high anthropogenic pressures due to population and economic growth, associated to institutional weakness and governance failure, which are common root causes of environmental degradation in developing countries. The fifth GIWA concern, Global change is dependent on anthropogenic activities occurring in a global context, plus complex interactions with global climate; therefore local/regional impacts caused by global changes does not necessarily reflect the local/regional anthropogenic pressures.

The results of the GIWA assessment confirmed that the majority of the Brazil Current drainage basins fit into the above-description and therefore, not surprisingly, the overall impacts caused by four of five environmental concerns in the Brazil Current were considered moderate with trend of becoming severe, if no clear and strong response is given by society. Such parity of severity of four concerns represents a difficulty when establishing their priority rank for further analysis (Causal chain analysis and Policy options analysis), as required by the GIWA assessment protocol. The need to select a priority concern arises from the limited availability of financial and human resources to support the initiatives needed to mitigate the impacts. If differences in fractions of units between scores calculated from the weighting and averaging procedures were considered significant, the ranking could be established (e.g. score 2.4 for Pollution, considered higher than score 2.2 for Habitat and community modification). However, the scores become the same if the decimal fractions are rounded off (e.g. score 2 for Pollution; score 2 for Habitat and community modification).

Criterion of precedence

After the degree of severity of the impacts is scored, in the case of equality between concerns, there is a further criterion based on the concerns' precedences (Figure 35), which is useful to give them priority rank.

Concerns and their constituent issues may be linked in a causal chain. One concern, for instance, can be one of the causes that lead to another concern. The Assessment section illustrates several situations in the Brazil Current when such causal links occurs. Concerns may also be linked to each other through their combined impacts and/or common causes. The scoring procedure combined with the analysis of the precedence function in sub-regions (Figure 35) revealed that the concerns Pollution or Freshwater shortage are placed as the first priority depending on the system studied (Table 16) and Habitat and community modification is the second priority in all systems. According to the GIWA methodology, where the precedence function increases the importance of a concern for policy purposes, this should be taken into account in ranking of priorities. The most relevant causal-effect relationships among different concerns in the Brazil Current, based on available information of impacts summarised in Figure 35, indicate that, among them, pollution is the concern that contributes to raise all the other main concerns.

Selecting the aquatic systems for causal chain and policy options analyses

Due to the existing diversity in the Brazil Current regarding different aspects (biodiversity, water availability, economy, social and cultural aspects, etc.), it is very unlikely that one policy option proposed for the whole region Brazil Current would have a good performance in terms of effectiveness, efficiency, equity, political feasibility and implementation capacity. Therefore, in order to elaborate policy options with good performance in terms of these criteria, it is necessary to focus on specific aquatic systems inside the region. Having this in mind, some aquatic systems or "hot spots" included in the Brazil Current region were selected. To select aquatic systems for the Causal chain analysis four criteria were considered:

1. The aquatic systems is international (shared by more than one country) and therefore, present transboundary issues;
2. The aquatic system is a one-nation transboundary system (shared by more than one state), and present a high degree of complexity in terms of planning and management of integrated strategic plans, in the executive spheres of more than one state;
3. The aquatic system suffers environmental and/or socio-economic impacts at a degree of severity representative of/or higher than the degree of severity assessed for the whole region Brazil Current;

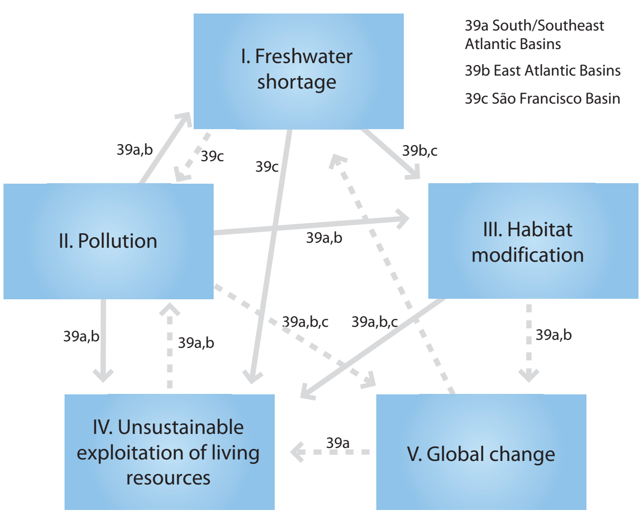

Figure 35 The main causal-effect relationships among the five GIWA concerns in the Brazil Current region.

Numbers in the cycles represent the sub-regions where the link is substantiated. Dashed arrows are those causal links with controversial or still-inconclusive indications supporting them.

Table 16 Priority concerns selected for each basin in GIWA region 39, Brazil Current.

Rank	39a South/Southeast Atlantic Basins 39b East Atlantic Basins	39c São Francisco River Basin
1st	Pollution	Freshwater shortage
2nd	Habitat and community modification	Habitat and community modification
3rd	Unsustainable exploitation of fish and other living resources	Pollution
4th	Freshwater shortage	Unsustainable exploitation of fish and other living resources
5th	Global change	Global change

4. The aquatic system is strategic in terms of multiple uses (human consumption, irrigation, industrial supply, etc.) or in terms of the importance of the habitats, ecosystems and biodiversity hosted and threatened by anthropogenic activities (coral reef, endemic species of fish, etc).

Only one aquatic system in the Brazil Current region meets criterion 1: Mirim Lagoon in South/Southeast Atlantic Basins, which is a bi-national aquatic system shared by Brazil and Uruguay. A number of aquatic systems in the Brazil Current meet criteria 2, 3 and 4. Among them, the Doce River basin in East Atlantic Basins was selected. It is a national transboundary basin shared by two states: Minas Gerais and Bahia and represents a common environmental problem in Brazil Current basins: Pollution associated to land use, erosion, changes in the transport/sedimentation dynamics of suspended solids, siltation of rivers and flooding. Based on the assessment results, São Francisco River Basin can be seen as one of the strongest candidate for further causal chain and policy options analysis. However, an on going GEF/UNEP project is already carrying out the policy options analysis and significant investments from both national and international sources are already planned for the mentioned Basin.

Causal chain analysis

Lanna, A.E., Marques, M., Abdallah, P.R. and M. Polette

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details, please refer to the chapter describing the GIWA methodology.

Patos-Mirim Lagoon system

Introduction

In addition to its environmental, economic and social importance, both in Brazil and Uruguay, the Mirim Lagoon stands out because it is the only transboundary water body in GIWA region 39 Brazil Current. The Patos-Mirim Lagoon system is located on the coastal plain of Rio Grande do Sul in Brazil, which lies between 29° 18' and 33° 48' S, occupying a strip adjacent to the Atlantic Ocean, 620 km long by approximately 70 km wide (Figure 46).

In 1963 the Bi-national Commission for Development of the Mirim Lagoon Basin (CLM) was created to promote development in this catchment area, shared by Brazil and Uruguay. The strategic importance of Mirim Lagoon is illustrated by the fact that it is considered one of the most important freshwater resources in Uruguay.

Quaternary sand plains where sand dunes, lagoons, littoral fields and swamps predominate represent the dominant landscape along the southern Brazilian coast. Several economic activities such as fishing, cattle raising, agriculture and tourism are well developed (Tagliani 2002). The central landscape of the coastal area is dominated by the Patos-Mirim-Mangueira Lagoon system, and this system constitutes one of the largest lagoon systems in the world. It includes several temperate habitats, saline wetlands, submerged fields and estuarine areas. The shallow estuarine waters provide habitats that are essential to coastal fishing in the south of Brazil, which in the past accounted for approximately 25% of the total Brazilian catch.

Mirim Lagoon, together with the São Gonçalo Channel, is 185 km long (in the south-north direction) with a total surface of 3 750 km^2, 2 750 km^2 (73% of the surface) in Brazilian territory, and 1 000 km^2 (27% of the surface) in Uruguayan territory. The Mirim Lagoon drainage

Figure 36 Mirim Lagoon and its drainage basin.

The bi-national Mirim Lagoon shared by Brazil and Uruguay is connected to the Brazilian Patos Lagoon (upper right corner) by the São Sebastião Channel. The system is connected to the ocean through the Patos estuary in the coast of Rio Grande do Sul state.

basin has a total area of 62 250 km^2, 47% being located in Brazilian territory (29 257 km^2) and 53% (32 992 km^2) in Uruguayan territory. Patos Lagoon has a drainage area of 31 050 km^2, entirely located in Brazilian territory (PNRH 2003). The Brazilian population of the Patos-Mirim Lagoon system is approximately 5.6 million and 91.2% live in urban areas, the main cities being the capital of the state of Rio Grande do Sul (Porto Alegre, to the north of Patos Lagoon), Pelotas (near the southern part of Patos Lagoon, close to São Gonçalo Channel) and Rio Grande. The labour force is concentrated in the rice processing industry and government services. The principal economic activities on the Brazilian side of the Patos-Mirim Lagoon system are: agriculture, livestock, industry, urban development, fishing and tourism. On the Uruguayan side the main activities are livestock and rice cropping. Environmental, social and economic impacts in Mirim Lagoon are aggravated by different development policies and strategies acting in each of the countries, causing a lack of synchronisation in the common use of a single aquatic system.

The concern Pollution was investigated in more detail for the Mirim Lagoon system in order to identify the causes that made this concern the highest priority for region 39 Brazil Current. An additional causal chain analysis was performed for the concern Unsustainable exploitation of fish and other living resources, since it is particularly important for the Patos Lagoon system. Only pollution in the Mirim Lagoon will be further studied for the purpose of policy option analysis.

System description

The description of one of the largest lagoon systems in the world, the Patos-Mirim Lagoon system, is equivalent to the description of the coastal plain of Rio Grande do Sul, basically the southern part of the plain and the northern portion of Uruguay.

Location, demographic settings and sanitation

Patos Lagoon (30° 30'S and 32° 12'S) has a surface area of approximately 10 150 km^2, and is 250 km long and 40 km wide. It is relatively shallow, with mean depths of 5 m. It is connected to the Atlantic Ocean through the Barra do Rio Grande channel, which is 20 km long, 1 to 2 km wide and 12 m deep. The small tidal range of 0.32 m at the mouth of the Lagoon limits the intrusion of salt water, which reaches only to a point known as Ponta da Ilha da Feitoria. Seawater can penetrate further north when the water level of the Patos Lagoon is low (Calliari & Tagliani 2000a). The Patos-Mirim Lagoon system on the Brazilian side is responsible for a GNP of 5.5 billion USD, corresponding to 24% of the total GNP generated by all the 467 municipalities of Rio Grande do Sul state (IBGE 2000). Some of the main cities of Rio Grande do Sul state, such as Porto Alegre (the capital, in the north of Patos Lagoon), Pelotas (in the southern segment of the Patos Lagoon) and Rio Grande (in the estuarine region) are located in this region (Calliari & Tagliani 2000a). In 2002, the whole basin of Patos Lagoon had an urban population of 4 778 870 and a rural population of 434 979 inhabitants (PNRH 2003). The Brazilian population of Mirim Lagoon/São Gonçalo Channel Basin includes an urban population of approximately 306 708 inhabitants, whereas only 53 203 persons live in the rural area (PNRH 2003). The fraction of town dwellers in these two basins (Patos and Mirim) is higher than 85%. According to PNRH (2003), 93.1% of the households are connected to the water supply system, a figure that is higher than the Brazilian national average (89.2%). However, sewerage covers only 12.1% of the households in Rio Grande do Sul, which is well below the national average (52.5%). The percentage of sewage treated in the state of Rio Grande do Sul is even lower (6.4%), well below the national average (20.7%).

The São Gonçalo Channel connects the Mirim and Patos lagoons from southwest to northeast. The channel is 62 km long, 200 to 300 m wide and 6 m deep. A port at Pelotas, bridges and a dam are located on this channel. The flow in the channel can be in both directions, depending on the water levels in the lagoons and the wind. A dam was constructed to prevent saltwater intrusion into the Mirim Lagoon during drought periods.

Mirim Lagoon's eastern boundary is the Atlantic Ocean, over 250 km, from the fortress of Santa Tereza (department of Rocha in Uruguay) up to the Rio Grande Bar (Rio Grande do Sul state in Brazil). To the north, the boundary is an arc that extends from the municipality of Rio Grande to Canguçu; to the west, from Canguçu to Bagé, following the dividing line of the departments of Cerro Largo and Treinta y Tres. To the south, it is limited by part of the dividing line between the department of Lavalleja, and in an arc from Piraraia to the fortress of Santa Tereza. The Brazilian side corresponds to the areas of the municipalities in the far south of the state of Rio Grande do Sul, while the Uruguayan side includes the departmentos in the north and northeast of the country. The municipalities on the Brazilian side of Mirim Lagoon Basin are: 11 municipalities existing before the 1960s: Santa Vitória do Palmar, Rio Grande, Pelotas, Jaguarão, Herval do Sul, Arroio Grande, Pedro Osório, Pinheiro Machado, Piratini, Canguçu and Bagé, plus another nine municipalities created after 1960. On Uruguayan territory, there are five departamentos (political and administrative units): Cerro Largo, Treinta y Tres, Lavalleja, Rocha and Maldonado. In 1995, the total Uruguayan population of the Mirim Lagoon Basin was 185 000. The rural population is widely dispersed, only 1.09 inhabitants/km^2. Most rural dwellers depend on livestock activities. Some 80% of the population lives in urban centres of which three have more than 25 000 inhabitants, 13 have 1 000 to 10 000, and 17 have fewer than 1 000 inhabitants. The rice industry is an important business for these smaller towns and cities whose populations provide various business services and urban amenities - housing, electricity, water, sanitation and communications - with the labour force in jobs created by local government. Along the Atlantic coast, tourism is increasingly the mainstay of income generation.

Geology and geomorphology

The evolutionary history of the Patos-Mirim Lagoon system was decisively influenced by the development of a complex multiple barrier, resulting from eustatic changes in the sea level during the Quaternary (Villwock 1984). At least four successive transgressive-regressive cycles deposited discontinuous sand barriers parallel to the coast. Littoral transport generated by waves progressively isolated the lagoon system, except for the channel, through which the waters of the extensive drainage basin reach the ocean. In general, the system can be classified as a partially closed lagoon (Calliari et al. 1998). At the peak of the transgressive process, which took place during the Holocene (5 100 BC), a higher sea level formed a marine abrasion cliff on the Multi-complex barrier, as well as in the lagoon terraces existing at the margins of the Patos-Mirim. The following regression closed the barrier (isolating the Patos Lagoon system) through the deposition of the last barrier (Barrier IV). This last event also allowed the installation of a retro-barrier lagoon system, the best known of which is Mangueira Lagoon in the extreme southern portion of the coastal plain. The vast lagoon terraces along the São Gonçalo Channel, as well as a complex system of elongated sand spits formed during this last event (Calliari 1997, Calliari & Tagliani 2000a).

Hydrography

There are three main lagoons in the area: Patos, Mirim and Mangueira, and an additional number of small lagoons distributed along the coastline. These water bodies receive waters from the two drainage basins (Patos-Mirim) which cover 60% of Rio Grande do Sul state and a small portion of the Uruguayan territory. All of this water, after being collected by the lagoonal bodies on the western border, is discharged into the Atlantic Ocean via the Rio Grande Channel (Calliari & Tagliani 2000a).

On the Uruguayan side, the strip of land between the Mirim Lagoon Basin and the Atlantic Ocean is named in Spanish Vertiente Atlántica and is numbered as 89 in Figure 2. The eastern border of both lagoons (Patos and Mirim) is characterised by a long sandy strip, which extends laterally to the ocean. Since it is a flat area and has a high permeability and porosity, the drainage pattern is poor. Major watercourses are insignificant. However thousands of small washouts (ephemeral creeks), which drain the dune fields, located behind the frontal dunes, contribute with significant amounts of freshwater and sand size sediment to the surf zone. Both the ephemeral creeks and all the other small water bodies represented by ponds and swamps play a very important ecological role for the coastal avifauna. To the west of the lagoon system the drainage network is very different, being a transition between the highlands of the shield and the low flat areas of the coastal plain. The main watercourses are directed from west to east. The more important watercourses that enter the coastal lagoon system include the following rivers from south to north: Jaguarão or Yaguarón in Spanish (the River that defines the border between Brazil and Uruguay and therefore is a bi-national river), Piratini, Pelotas, Turuçu (Arroio Grande), Camaquã and Jacuí. As they reach the low flat areas of the coastal plain, close to the regional base level, they start to meander in open valleys with weak currents. The sediment load (mainly sand) is deposited in such areas. Uruguayan rivers which flow into the Mirim Lagoon are: San Miguel, San Luis, Estero, Pelotas, Tacuarí and Cebollatí - with its tributaries Altérez, Olimar and Parao.

The São Gonçalo Channel, which connects the Mirim Lagoon to the Patos Lagoon, is exceptionally important from several environmental and socio-economic standpoints since it is the only outflow of Mirim Lagoon. Until 1977, when a dam was built, salinisation problems were common, causing serious problems to the rice cultures irrigated by its waters. Additionally, the potable water for Rio Grande municipality came from the São Gonçalo, through a 20 km long constructed channel. Except for sandstone, basalt and volcano-clastic rock formations near 29°, which offer a certain degree of shelter, the 653 km long coastline between 29° S and 35° S is totally exposed. Beaches are composed of fine quartz sand, and most (95%) have a low gradient. Only a 45 km stretch of shore south of Albardão lighthouse (33° S) is composed of coarse shell fragments and fine quartz sands. These beaches display a higher gradient (4°), erosional scarps at the backshore, and frequently well developed beach cusps (Calliari & Klein 1993, Calliari & Klein 1995, Klein & Calliari 1995, Seeliger et al. 1997). Based on morphodynamic characteristics, the beaches are considered generally intermediate, but immediately south of 32° and 33° S the beaches are dissipative and intermediate/reflective, respectively.

The Mirim Lagoon has a mean annual flow of 440 m^3/s and Patos Lagoon, 647 m^3/s. The mean specific flow of Mirim Lagoon is 15 l/s/km^2 and Patos Lagoon is 21 l/s/km^2. Sediments of fluvio-marine and aeolian origin associated with acid and basic volcanic rocks predominate in the portion corresponding to the Patos-Mirim Basin, located in Rio Grande do Sul. The sediments form porous aquifers, with a mean discharge of 2 m^3/h, which could possibly reach 10 m^3/h (PNRH 2003). The productivity of the groundwater wells increases in the area of the Guaraní Aquifer (mainly located in GIWA region 38 Patagonian Shelf), with discharges ranging from 30 to 70 m^3/h. The volcanic rocks form fractured aquifers, with wells having flows ranging from 5 to 50 m^3/h (PNRH 2003). Along the whole coastline of the basin, there are porous aquifers associated with marine and alluvial sediments, with wells discharging around 5 m^3/h. In these regions there is a risk of saline intrusion and the aquifer is highly vulnerable to contamination (PNRH 2003). The situation concerning water availability and demand for the Patos-Mirim system is presented in Table 17. The total water demand in the Patos Lagoon Basin is 62.8 m^3/s, which is 9.7% of the mean flow in the Basin. The total demand is higher in the Mirim Lagoon/São Gonçalo Basin, 101.3 m^3/s. Of the two lagoons, irrigated agriculture, particularly for rice fields, imposes the highest pressure on the water resources.

Table 17 Water demand in Patos Lagoon and Mirim Lagoon basins.

Demand	Patos Lagoon basin		Mirim Lagoon basin	
	m^3/s	%	m^3/s	%
Human	0.4	0.6	1.1	1.1
Animal	0.9	1.4	0.8	0.8
Irrigation	61.1	97.3	98.4	97.1
Industrial	0.4	0.6	1.0	1.0
Total	62.8	100	101.3	100
Mean annual flow (m^3/s)	647		440	

(Source: PNRH 2003)

Climate

According to IBGE (1986), the climate in the state of Rio Grande do Sul is characterised by the presence of abundant rainfall, without defining the existence of a dry period throughout a normal year. The total annual mean precipitation varies from 1 200 mm in the littoral strip to 1 700 mm in the northern areas of the state. The climate in the coastal area, between latitudes 29° and 34° S, is controlled by the high pressure centre of the South Atlantic anticyclone, whose latitudinal migration causes the injection of polar air into the lower latitudes (polar frontal system) at 6 to 10-day intervals, modifying and influencing the seasonal cycle of the climate. The closeness of the sub-Tropical Convergence Zone and the stabilising influence of the Patos-Mirim Lagoon system give the coastal region a temperate-warm and marine characteristic. Associated with the fauna and flora distribution pattern, it characterises a temperate-warm biogeographical transition zone (Klein 1998, Seeliger & Costa 1998). The inter-annual rainfall variations in the southwest Atlantic, with long periods of rain or drought, appear to be associated to the effects of the El Niño Southern Oscillation Cycle effects over the global climate (see Assessment, Global change), directly influencing the amount of continental freshwater discharged, and therefore the biogeochemical processes in coastal and marine ecosystems of the Southwest Atlantic (Klein 1998). In the Köppen classification, the Rio Grande do Sul coastal plain is included in type "C" (sub-tropical and humid), characterised by a mean annual temperature of 17.5°C, January and February being the warmest months and June and July the coldest (Moreno 1961). Wind is the main agent responsible for the coastal dynamics since it acts markedly on the development and migration of the coastal dune field. The strong influence of the South Atlantic Anticyclone determines a wind regime for the south coast of Brazil, with a predominance of winds from the northeast quadrant in the months of spring and summer, and of the west-southwest winds in the winter months, associated with the passage of cold fronts (Tomazelli 1993). The Holocene dune field of Rio Grande do Sul, with a mean width ranging from 5 to 8 km along the more than 600 km coastline, according to Tomazelli (1993), corresponds to one of the most significant active eolian systems in Brazil. The age of the dune field was estimated as less than 1 500 years which is interpreted as possibly resulting from a rise in the relative sea level, associated with a tendency to coastal erosion, making sediments previously retained by embryonic and frontal dunes available (Tomazelli 1993). The dune field is controlled by a system of high-energy winds, whose dominant direction (northeast-southwest) drives the free dunes inland, at a rate of 10 to 38 m/year, transgressing over lagoons, lakes, and coastal swamps. This situation, which is responsible for the segmentation of many lagoons in a rosary along the coast, creates a critical situation for one of the ecologically most important areas for the migratory cycle of sea birds and coastal birds in the south of Brazil - the Peixe Lagoon National Park, in the municipality of Mostardas, state of Rio Grande do Sul. Climate instability is the cause of loss of productivity in these sectors, as well as of disturbances in urban life (frequent flooding) and in the health of the population (Calliari & Tagliani 2000b).

The portion of Mirim Lagoon basin in Uruguayan territory is defined as temperate-humid "Cfa" type, according to Köppen's classification. The average annual temperature is 19°C. The rainfall reaches an annual value of 1 400 mm in the northeast, the boundary between Uruguay and Brazil, which is considered the region with the highest average rainfall in Uruguay (Corsi 1978).

Soil

The soil distribution on the coastal plain displays a more or less uniform pattern with a distribution roughly parallel to the current coastline (Delaney 1962). This suggests firm control by the geological-geomorphologic evolution of the region. Generally, the higher areas of the crystalline basement to the west are characterised by the predominance of non-hydromorphic soils, with abundant rock outcrops which are not recommended for agricultural purposes. In the transition from the coastal plain, the wavy topography characterises the "coxilhas" formed by rocks of granitic composition where the yellow-red podzolic soils predominate. Such soils are moderate to well drained, with variable fertility and there is some restriction to their use due to their high susceptibility to laminar erosion. In these regions, agriculture plays a significant role and some areas have actually been used as multi crop areas by small properties (BDT 2001). In the Quaternary sedimentary domain, the gentle relief displays elevations ranging from 20 to 60 m. In such areas the hydromorphic minerals (plain-soils with low humidity) predominate. These areas are highly favourable to annual rice cultures which are periodically irrigated. On the inundated plains, at the border of the lagoon bodies, hydromorphic diversified soils occur. Due to the high risk of inundation (saltwater intrusion in the Lagoon) they are used as pasture for cattle during the summer months. In the barrier islands region at the lagoon margins there is a widespread use of lagoon terraces for irrigated rice culture (Tagliani 2002). Soils with medium fertility and poor drainage consist of a mixture of fine sand and clay. The higher areas, corresponding to the Pleistocene marine barriers, are used for grasslands (cattle) and onion crops on small properties. In partly flooded areas (beach ridges of Rio Grande), and the borders of the sea and lagoon, the soil is too sandy for agriculture (hydromorphic podzol and quartzy sands), but extensive portions of these areas are being used for forest plantation of Pine. The quartzy sands of the beaches and dunes do not have any potential agricultural use, although they are of value for conservation. The constantly flooded plains are constituted from completely sandy and clayey soils, badly to very badly drained (humic gley, not very humic gley, thiomorphic organic soil, solonchack, hydromorphic podzol), that are also not appropriate for agriculture and are only used for livestock in the summer months (Tagliani 2002).

Vegetation

The combination of geological, geomorphological, climatic, hydrologic and pedological attributes, as discussed above, determines the composition of plant cover in the region. A survey performed by Tagliani (2002) for the central portion of the coastal plain, identified a pattern of distribution for the vegetation and current land use. The survey generally describes the situation found throughout the coastal plain, especially as regards current uses. The vegetation of the Pioneer Formation Areas (IBGE 1986) is typical of the first occupation phases of new soils, and is independent of the climate and sparsely distributed throughout the coastal plain. The species may be non-woody and woody with a variable range of botanical forms adapted to the different soil conditions. None of the 1 072 species of Phanerogams analysed by Rambo (1954) is endemic, and non-woody species of the central Brazil savannahs predominates (Tagliani 2002).

In the areas of marine influence, the distribution of the plant community shows a direct association with the geomorphology. This in turn has conditioned the development of different soils in the region. The relief in this area shows a great variety of forms, reflecting not only the origin of the Quaternary region, but also the high natural dynamism induced by the wind. Even with the micro changes in the relief, which favour the preferred location of woody or non-woody species, the region is relatively homogeneous in the floristic sense. With the exception of a few woody species, the areas that are not flooded are wide fields formed mostly by grass, rushes (juncos) and cyperaceous. The anthropogenic activities have strongly modified the natural landscape, characteristically represented by cattle and rice and onion cultures, besides the intense use of land for pine. The woody species are associated with watercourses, in the primary forest, at the side of the barrier, scarps and lagoon terraces (Tagliani 2002, Calliari & Tagliani 2000a).

Forest plantation with exotic species occupies a large area. Pine is more frequent than Eucalyptus. Both occupy old sandy fields. In São José do Norte city, the pine forests occupy an area of 12 839 ha and the eucalyptus only 2.6 ha. However, in the city of Rio Grande, the area occupied by pine is about 2 727 ha, while eucalyptus occupies only discontinuous areas with a total of 5 094 ha. The pine forests in both municipalities were planted preferentially over obliterated dunes and eolian aspersion sheets behind the active dune fields (Calliari & Tagliani 2000a).

The wetlands are an important element in determining the natural landscape, and constitute low altitude water-saturated areas, lying on quaternary plains and covered with hydrophilic vegetation. With the intense dynamics resulting from the physical process operating in the area, there is a growing tendency to increase the wetlands as a result of the transgressive sand sheets. The vegetation, which grows over the unconsolidated quartz sands, constitutes a continuous strip along the barrier island. Non-woody plants exclusively colonise the coastal foredunes, whilst woody climax vegetation is restricted to older inland dunes (Seeliger et al. 1997). Owing to the recent formation of the coastal plain, most species are migrants from neighbouring provinces, and endemic species are rare. The terrains that lie more distant from the coastline, as well as the obliterated dunes, display a higher diversity and biomass mainly due to a more stable substrate which is under the influence of the water table. Seeliger (1992) identified 71 foredune species which exhibit perennial, as well as annual species (Cordazzo & Seeliger 1987). In the Uruguayan portion of the Mirim Lagoon, those wetlands still preserved are extremely important resting sites for birds such as *Phimosus infuscatus* and *Plegadis chihi* (Threskiornitidae). Field surveys have identified 500 members of *Phoenicopterus chilensis*, 262 *Cygnus melanocoryphus* and 293 *Coscoroba coscoroba*, 1 563 *Anas georgica* and 1 804 *Dendrocygna bicolour* (Menegheti 1998).

The littoral fields represent the predominant vegetation community in regional terms. They include all the non-woody formations of low height and similar taxonomic composition according to the habitat occupied. The geomorphology occupied by these fields includes terraces, barriers, eolian sheets, obliterated dunes and beach ridges. Changes in composition and structure are due to well-defined soil-related factors. The native forests are characterised by a restinga (coastal sandspit) forming elongated narrow clusters parallel to the coastline (Calliari & Tagliani 2000a).

Intertidal marshes occupy the island borders and margins of the Patos Lagoon estuary, and are essentially flooded by brackish water, and occupied by annual and perennial tidal marsh and wetland plants (Costa & Davy 1992). According to Costa (1987), there are approximately 70 species in the lower estuarine marsh flora. This community plays an essential role in the stability of the substrate, controlling erosion, serving as habitat for several organisms and constituting an important source of detritus for the estuarine food chain (Cordazzo & Seeliger 1998). This plant community is found predominantly in the estuarine portion of the Patos Lagoon around the city of Rio Grande, where it occupies an area of 59 km^2.

Economy

Due to better access, the north coast of Rio Grande do Sul state has the most popular bathing resorts, giving rise to a more homogeneous urban settlement along the coast. As one moves away from the coastline towards the slopes of the Serra do Mar Mountains, agriculture and livestock activities are developed on small properties. It should be mentioned that fishing is a highly important and traditional activity throughout the lagoon system. It is the oldest economic activity in the region, involving, throughout the system, a large number of artisanal fisheries. The development process that this region underwent, allowed industrial fishery plants to be established in the municipality of Rio Grande, and the mode of fishing became industrial. Fishing activities have an economically important role in creating income and jobs in the region. The presence of the Rio Grande Channel, which connects the Patos Lagoon and the Atlantic Ocean in the extreme south of Brazil, enabled the development of port activities, and consequently the setting up of various industries (fertilisers, oil/petrol, fishing, soybean derivates, etc.). They constitute an industrial district in the municipality of Rio Grande, which is very important in the socio-economic context of the Patos-Mirim Lagoon region as it creates income and jobs. In terms of agricultural aptitude, a large part of the area studied consists of soils for annual crops, and approximately 3 500 000 ha are potentially suitable for rice cultivation. The crop stands out as the main activity developed in the Patos-Mirim Lagoon system, especially in the Mirim Lagoon Basin (both on the Brazilian and the Uruguayan side), where irrigation represents the main water demand. Most of the water consumption comes from the cultivation of rice by flooding. The increasing importance of the rice cultivation for the economy of the state of Rio Grande do Sul is illustrated by the fact that in 2002/2003, rice cultivation in Rio Grande do Sul occupied 951 000 ha and produced 5 million tonnes. Compared to the values registered during the 1920s (1922/1923), these figures represented an increase of 2.5 times the productivity, 11.2 times the cultivated area and 27 times the total annual production (Agroagenda 2003).

Table 18 Main economic activities in the Patos-Mirim Lagoon system.

Sector		Economic activity
Primary sector	Agriculture	Deforestation/Reforestation with Pinus and Eucalyptus. Production of rice, soybean, corn, vegetables, greens and fruits, annual crops.
	Livestock	Breeding of cattle, pigs and sheep.
	Fishing	Fishing activity - fish catch.
Secondary sector	Industry	Rice processing, chemistry (fertilisers), oil production, food, tanneries etc.
Tertiary sector	Tourism/Port	Trade and services.

(Source: PNRH 2003)

Environmental impacts

Among environmental impacts acting on the Patos-Mirim Lagoon system, there are those that are due to natural causes and those that are due to anthropogenic activities. The main immediate causes of environmental impacts are sea level rise, agriculture and livestock. In the Uruguayan portion of Mirim Lagoon Basin, for instance, there are significant wetland areas replaced by rice plantation, which has caused habitat and community modification as well as pollution related to changes in the sediment transport dynamics, nutrients and chemical pollutants run-off from agriculture areas.

Suspended solids transport/sedimentation dynamics

Erosion along with other immediate causes have produced loss of habitats in the Patos-Mirim system. The vulnerability of the Lagoon system and its adjacent lands to sea level rise was briefly addressed by Muehe and Neves (1995a, b). Besides erosion in the coastal area, sea level rise causes an increase in salt water intrusion with impacts on fisheries and water uses such as irrigation. The major impacts related to erosion are loss of habitat and loss of public and private property. The combination of mesoscale tropical storms and tides of larger amplitude produce marked erosion along the Rio Grande do Sul coastline and

Figure 37 Erosion at Torotama Island.
(Photo: Lauro Júlio Calliari)

along the margins of the lagoons. Such a combination has a greater probability of occurring during April and May. Many areas of the Patos estuary are undergoing severe erosion processes, especially around the islands of Torotama (Figure 37) Leonídio, the beaches of Laranjal and the inner portion close to the Patos Lagoon inlet (Calliari & Tagliani 2000b). Deforestation is present throughout the Patos-Mirim system. The areas have been occupied with livestock, agriculture and urban areas. This resulted in the releases of large amount of suspended solids, ultimately changing the water quality and increasing the turbidity. Increasing sedimentation also requires more frequent dredging, aggravating the sediment erosion-transport-deposition cycle. Siltation causes loss of habitats in the Patos-Mirim system and impacts on navigation activities, which require more frequent dredging, increasing the frequency of impacts on the quality of water, particularly turbidity with great influence on primary productivity and the trophic chain (PNRH 2003).

Inadequate occupation of flood plains or lakes and rivers

Floods frequently occur in the Patos-Mirim basin and they affect mainly the low-income populations living in the cities. They are usually the result of inadequate occupation of the flood plains. Periodical floods occur on the large flood plains around the lagoon systems and the main water courses affecting over 500 000 ha in a 10 to 15 year period. Low-income neighbourhoods on the outskirts of cities occupy regions that are not appropriate for housing, causing deforestation, which worsens erosion, among other effects.

Discharge of untreated domestic sewage and industrial effluents and agriculture run-off

The discharge of untreated domestic sewage and industrial effluents is concentrated mainly in the Patos Lagoon in the region of Pelotas and Rio Grande municipalities in Brazil. With urban and industrial development, there has been a significant increase in the emission of these effluents. The level of effluent treatment is very low, significantly compromising the quality of surface sources of water. The contamination caused by the excessive use of pesticides and fertilisers on the rice crops, although not fully studied in the Patos-Mirim system, is another important factor that involves environmental aspects of chemical pollution.

Unsustainable exploitation of fish

The impacts on fish and fisheries must also be considered for the Patos-Mirim system. Chemical pollution in the lagoon system may contribute to the reduction of fish stocks, aggravating the impacts of inappropriate fishing practices, which have been used throughout the economic development of the Patos-Mirim system, constituting a risk of extinction of these resources.

Besides reduction of fish stocks, changes in the composition of species, biological diversity, the food chain structure, as well as the extinction of fish species have been observed, especially those with high commercial value. Especially in the Patos Lagoon, overexploitation of fish has been one of the main environmental problems. Over the years, urbanisation, development of fishing technologies and processing, and market has put pressure on the natural resources. This affects the lagoon system by extinction and change in the species composition, as well as impacting the living resources of the sea, which is related to changes in the food web and in biological diversity.

Socio-economic impacts

Socio-economic impacts identified in the Mirim Lagoon and addressed in the Causal chain analysis are mainly associated to pollution due to land use, in which there is an outstanding presence of rice plantation, cattle and pig raising and urban development, the latter more intense in the Brazilian portion of the Basin. In Patos Lagoon, in addition to the mentioned activities, industrial development and tourism are placed among the important economic activities. The socio-economic impacts described below are associated with the concern Pollution and also with Habitat and community modification and Unsustainable exploitation of fish. The socio-economic impacts are:

- Higher cost of water treatment due to pollution, since all the water that supplies the city of Rio Grande, for instance, comes from the São Gonçalo Channel and Mirim Lagoon;
- Increasing health risks and costs associated with pollution affecting the population that lives in the Patos-Mirim Basin;
- Increasing risk to human health and costs associated with flooding and irregular occupation of coastal areas in the Patos-Mirim system;
- Increasing risks of international conflicts, as a consequence of the deterioration of the water quality in the bi-national water body Mirim Lagoon;
- Transaction costs involved in the negotiation processes of water use in order to treat different types of pollution, and to solve institutional conflicts inherent to fishing activities;
- Fewer options for the development of tourist activities (ecotourism) and aquaculture, since loss of significant wetland areas, the presence of erosion, chemical pollution and nutrient discharge modify the quality of the water resources. The aesthetic value, which is a crucial factor for tourism may also be reduced;
- Loss of income due to the unsustainable exploitation of fish in the region. The economic impact shows itself in lower catches in extractive fishing, especially of fish with a high market value. The social impact of overexploitation practices is poverty for most of the people in the sector i.e. the artisanal fishermen, who have no alternatives for income at present.

Methodology

The methodological procedure to assemble the causal chains for Pollution and Overexploitation of fish in the Patos-Mirim Lagoon system consisted of: (i) system characterisation (site, geography, soil, vegetation, climate, hydrography); (ii) identification of the predominant socio-economic activities in the study area; (iii) identification of the main environmental impacts due to the pressures exerted by the economic activities; and (iv) identification of the main socio-economic impacts present in the Patos-Mirim Lagoon system and their links to the environmental impacts. The immediate causes and the economic activities that generate the environmental and socio-economic impacts were identified. Considering the information collected (socio-economic/environmental impacts, activities in different sectors and the links between them), the root causes common to the environmental problems were identified.

Throughout the Patos-Mirim system inadequate land occupation in the estuarine areas is common, mostly associated with the phenomenon of urbanisation in the Patos Lagoon basin and agriculture/livestock in Mirim Lagoon basin. Erosion and sedimentation/silting processes are derived from land use, and cause serious environmental impacts, especially loss of habitat in the system. The Mirim Lagoon Basin was occupied with livestock, and this was the predominant activity throughout the economic development process until recently, when rice fields expanded in the Basin. In contrast, in Patos Lagoon, industrial and port activities have historically been the most important activities. In this context they are important in order to identify root causes of pollution. These two economic activities are concentrated in the municipality of Rio Grande. The discharge of industrial effluents from e.g. fertiliser-producing plants and oil refineries into the estuary of Patos Lagoon without appropriate treatment is responsible for contamination of the lagoon with heavy metals and other substances.

Causal chain analysis for Unsustainable exploitation of fish – Patos Lagoon

One of the concerns chosen for Causal chain analysis in the Patos-Mirim Lagoon system was unsustainable exploitation of fish (Figure 38), which is an environmental concern of highest importance worldwide,

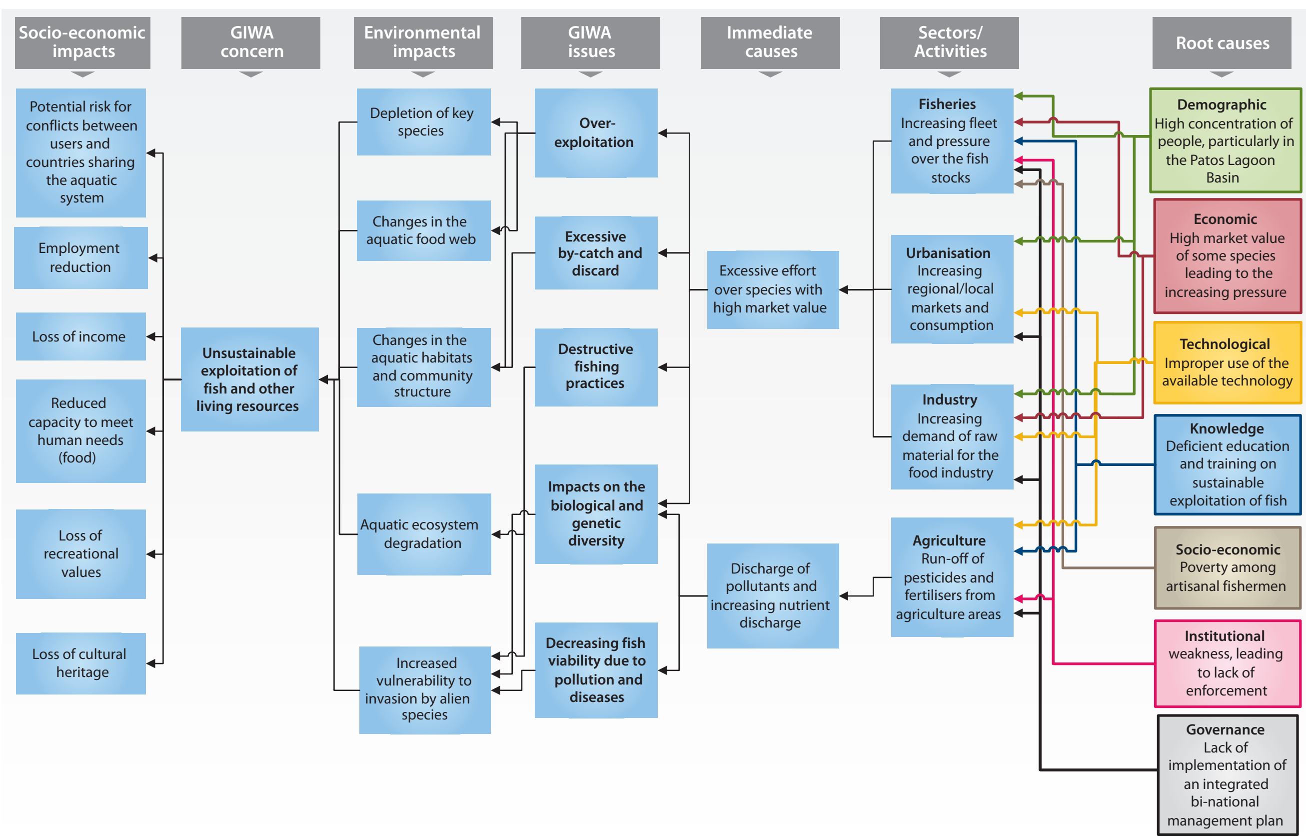

Figure 38 Causal chain diagram for the concern Unsustainable exploitation of fish and other living resources in Patos-Mirim Lagoon system.

addressed by the United Nation Conference on Environment and Development (Chapter 17 in UNCED 1992). As mentioned previously in this section, fishing activities are very important in the Patos-Mirim system, particularly in Patos Lagoon, in various ways: social, historical, cultural, environmental and economic. Since the end of the 19th century, fishing has been an economic activity in the region. Fishing activities benefit from the migrations of crustaceans and fish into and out of the Patos Lagoon estuary. This estuary is the most important breeding and growth area for most of the fish and crustaceans commercially exploited on the southern coast of Brazil (Chao et al. 1986). This region concentrates most of the subsistence and small-scale (artisanal) fishing in the south (Chao et al. 1986, Reis 1994). More than 90% of the total catch of artisanal fishing in the state of Rio Grande do Sul comes from Patos Lagoon and the adjacent coast. The landed catch of artisanal fishing of teleostei fish and the adjacent marine region ranges from 43 705 tonnes (1972) to 13 121 tonnes (1989), and at one point represented 42.6% of the total catch landed in the port of Rio Grande. However, in recent years, this type of fishing has undergone a strong decline and is now simply an alternative means of subsistence (Reis 1994, Haimovici et al. 1998). The current picture is so serious that, according to data from CEPERG/IBAMA (Monteiro & Caldasso 2001) the mean catch landed by artisanal fishing in Patos Lagoon and the adjacent marine region, during the period from 1998 to 2001, was 8 396 tonnes per year, which is a fraction of historical levels. Artisanal fishing in the estuary, which at one time point involved approximately 10 000 fishermen, now involves less than 4 000 (Reis et. al. 1994, Reis & D'Incao 2000). Reis (1994) ascribes the current low landings to factors such as the high proportion of juveniles captured, the fishing of adults during reproductive periods, overfishing, and environmental degradation.

According to Abdallah (1998), the introduction of synthetic nets and modern transport and storage, after 1945, and the federal public policy of incentives to fishing in Brazil, implemented in the mid-1960s, contributed to the current state by encouraging increased production, without taking into account the size of the fish stocks. This, together with the lack of research and planning, the use of inadequate fishing methods and the lack of enforcement, caused the collapse of estuarine stocks of miragaia, corvina and bagre (catfish) by the 1970s. One of the main fishing products in the Patos Lagoon Estuary is now the pink shrimp, camarão-rosa (*Penaeus paulensis*). A region in the Patos Lagoon Estuary recognised as having a high potential for the natural production of camarão-rosa is the Saco da Mangueira, an environmental conservation area located near the access channel to the port of Rio Grande and next to an urban area occupied by dense industrial activities e.g. fertiliser industries, oil refinery, soybean oil processing plant, and others. In this context, effects on the Patos Lagoon estuary are clearly seen, specifically in the Mangueira Lagoon. Industrial and domestic effluents are constantly discharged into the Patos Lagoon Estuary due to the lack of public sanitation and sewage treatment. Landfill and clandestine/irregular occupations without any kind of urban infrastructure are common on the banks of Mangueira Lagoon. Different types of solid waste are disposed into this lagoon, which causes bad odours and pollute the site, affecting the health of the people living on the banks (EIA/PRG 1998). This scenario contributes also to the reduction of camarão-rosa viability. This information supports the identification of root causes for the concern Unsustainable exploitation of fish, which are shown in the causal chain (Figure 38) and are briefly discussed below.

Root causes

Demographic: High concentration of people

There are high concentrations of people, particularly in the Patos Lagoon Basin. Larger population encourages illegal fishing, both because of the market pressure in order to obtain more products for consumption and due to the possibility of working in a segment inherent to the Patos-Mirim Lagoon region: artisanal fishing.

Economic: Market pressure

The existence of a strong market for fishing products has contributed over time to more dynamic economic mechanisms to boost fishing activities. Because of the possibilities of revenues from fishing, the fishing economy became strong and production increase-oriented. Because this was done in a disorganised way it led to a process of economic self-destruction and, especially, to the exhaustion of the environmental resource (due to overexploitation).

Technological: Improper use of technology

One of the root causes that culminate in the unsustainable exploitation of fish is the presence of modern technologies at the disposal of the fisheries process. As instruments and boats were developed with equipment to find and catch fish faster, there was higher production. However, many of these technologies are not sustainable, for instance, in terms of the ideal size of the fish captured, and therefore these improvements render the fish extinct.

Governance: Lack of implementation of a bi-national integrated management plan

In order to achieve sustainable fishing in the Patos-Mirim Lagoon system legitimacy and effectiveness of an integrated management plan is required. This plan should involve both Uruguay and Brazil. Currently, isolated measures are observed, such as establishing periods of closed fishing season, based on agreements among a number of stakeholders. These initiatives, although positive, are insufficient to eliminate overexploitation and destructive practices and to change the mindset in the fisheries sector. There is a proposal to integrate the different segments involved in this activity but, in practice, few really participate, and there are mainly isolated actions. In a complex productive system, those actions do not have the strength to change the current trend. In the context of fishing in the Patos-Mirim system, the existence of conflicts among different actors involved in fisheries (IBAMA, federal, state and municipal governments, research and extension institutes and universities, city administrations, local secretariats, local organisations, etc.), creates obstacles to orienting the activity towards a sustainable path. The scenario described above justifies the assumption that governance, or the lack of skill in social, political, technical and economic organisation, is one of the main root causes of the presence of an unsustainable activity in the Patos-Mirim Lagoon system.

Institutional: Lack of enforcement

This root cause is present in most explanations of the lack of effectiveness of rules and laws established in Brazil. In the specific case of the Patos-Mirim Lagoon system, inefficient enforcement contributes to the existence of unsustainable exploitation of fish. This lack of enforcement occurs for several reasons; economic (low pay for the inspectors), institutional weakness, and social and cultural aspects (issues of ethics, principles and values).

Knowledge: Deficient education and training regarding sustainable exploitation of fish

Knowledge of how to support sustainable fishing is not yet widely disseminated in the Patos-Mirim system. Much research has been performed to increase the knowledge about the fish biology and some initiatives have been supported by the government to develop sustainable fishing (IBAMA 2002). However, following the rest of the world, the studies have frequently focused on the biological aspects, rather than management aspects (Dolmann 2003). Managerial changes are necessary to eliminate the unsustainable practices not only in Patos-Mirim Lagoon system but all over the Brazil Current region. Besides incomplete information, there is a lack of trained people working in the sector. This is easy to understand if we consider that training and technical support in different economic sectors have usually focused on productivity and profit maximisation, instead of focusing on sustainability. Only during recent years, the concept of sustainability became really part of the Brazilian government agenda and can be found in important national programmes, for instance, related to agriculture (Silva 1999), coastal management, and fisheries (Instituto do Milênio 2004).

Socio-economic: Poverty among artisanal fishermen

The low income of artisanal fishermen in the Patos-Mirim Lagoon system is a root cause of unsustainable fishing. The working conditions characterised by instability and temporary employment favour lack of awareness among fishermen. The activity performed by many of them (especially the temporary fishing of the camarão rosa (*Penaeus paulensis)* - new scientific name *Farfantepenaeus paulensis* - in the Patos Lagoon estuary) is focused on exploitation for immediate sale of the products, without taking into account the future existence of the resource. This is a mindset that acts together with disrespect to the existing fishery rules, rendering these instruments inefficient.

Selected root causes

After this brief description of root causes of unsustainable exploitation of fish, the following main root causes are highlighted for the policy options: Knowledge, Economy and Governance. They were considered the most important among those surveyed, and provide a relevant contribution to the unsustainable exploitation of the fish in the Patos-Mirim system, acting more objectively and directly. Ways of mitigating the problem may be more effective when these root causes are eliminated.

Causal chain analysis for Pollution – Mirim Lagoon

The causal chain diagram for the concern Pollution in Mirim Lagoon is presented in Figure 39. Over the years, agricultural activity has intensified rice cultivation, which occupies a large area around Mirim Lagoon, using the lagoon system to support the production. The activity currently demand 97.1% of the water used from the Mirim Lagoon and is dependent on the use of agro-chemicals such as pesticides and fertilisers. The presence of these activities for almost 30 years has generated contaminated run-off to the Lagoon, decreasing the water quality and contaminating the living aquatic resources, which in turn contributes to the reduction of the fish stocks. Reduction in soil fertility has impacted the economy in a region where agriculture is one of the most important sectors.

Root causes

Governance 1: Lack of implementation of a bi-national integrated management plan for the Mirim Lagoon Basin

The diplomatic relations between Brazil and Uruguay have been strengthened during the last years due to three factors (Radiobrás 2003): (i) gradual development of the integration ideal

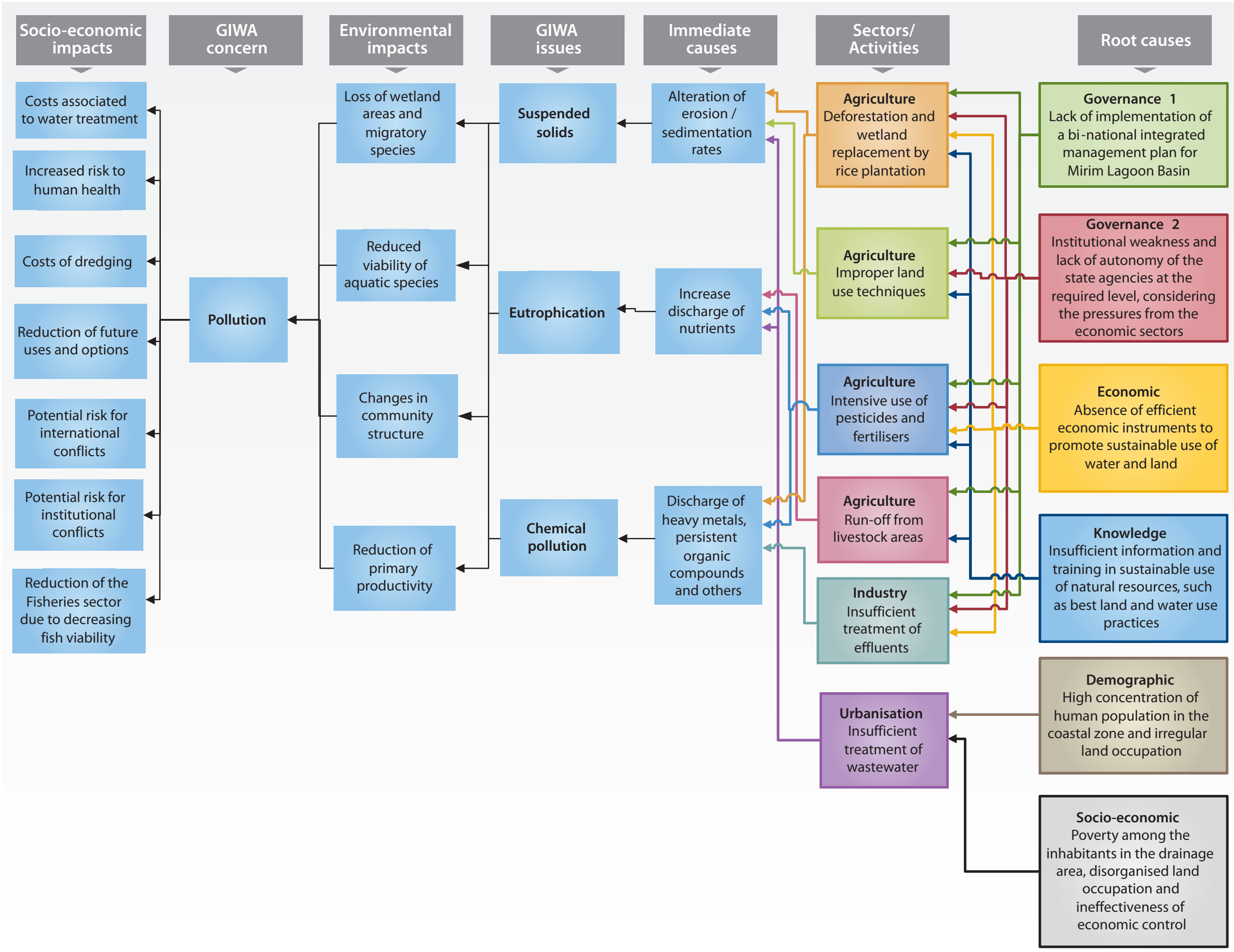

Figure 39 Causal chain diagram for the concern Pollution in Mirim Lagoon.

Note: Some causes in the economic sectors (e.g. deforestation and wetland replacement by rice plantation) also contribute to Habitat and community modification.

illustrated by the establishment of the eastern South America common market, MERCOSUR; (ii) affinities between countries regarding regional and international problems as expressed in different arenas; and (iii) revitalisation of transboundary contracts and agreements. According to recent agreement, priority should be given to the common agenda in environment and agriculture sector (Radiobrás 2003). The energy sector has been one of the important economic activities that brought the countries together. Additionally, Brazil is the main business partner of Uruguay. In 1998 Brazil imported 34.4% (790 million USD) of total Uruguayan exports. In the same year, Brazil exported 719 million USD to Uruguay, which represented 20.1% of the total imports of Uruguay. The transboundary cooperation between the countries had as the institutional starting point the General Commission of Brazilian-Uruguayan Coordination (CGC), and then, the Commission for Joint Development of Transboundary Zones (CDZF). Among existing bi-national commissions, there is The Commission for Development of Mirim Lagoon Basin (CLM). The initiatives of integrated water resource management for Mirim Lagoon Basin have received attention during recent years. There have been several initiatives (studies, projects and programmes) inside Brazil but they have failed in implementing a bi-national integrated action plan for sustainable development of the Basin. An example of such an attempt was the Regional Program of the Mirim Lagoon Basin, PR35, by the FAO/UNO at the end of the 1960s and the beginning of the 1970s (Borba 2002). This programme included a comprehensive study of the Basin, to provide an instrument that would help in establishing institutional agreements regarding the use of the water and land resources. Such a programme should highlight not only the possibilities of investments to develop the area, but also produce, via technical reports, a strategy for sustainable resource use to be supported by both countries. A mixed Brazil-Uruguay Committee was established to deal with matters related to the Mirim Lagoon. In practice, this document has not been used since the mid-1970s.

Attempts to implement different projects proposed in the report failed to activate institutionally the Regional Program of the Mirim Lagoon Basin, PR35. The lack of harmonised legal instruments between countries, among other constraints, made it impossible to implement an integrated management plan for the Mirim Lagoon Basin. Besides the difficulty in establishing international agreements and consensus, the Mirim Lagoon Basin encounters the same difficulty on a national level. Water use conflicts that arise are dealt by different institutions, which often have superimposed roles to play as far as enforcing the law. Even if the Mirim Lagoon on the Brazilian side, is located in a single state (Rio Grande do Sul), many entities co-exist, and their actions are often not integrated. Most of them have legal attributes that influence water use, protection and management. For instance, The Brazilian National Agency of Waters (ANA) and the Ministry of the Environment (MMA) are responsible for water rights assignment in the Mirim Lagoon and Jaguarão River.

On the state level, the Environment State Secretariat of Rio Grande do Sul is responsible for the water rights assignment in the tributaries of the Mirim Lagoon that flows in the state territory. As to environmental licensing, there is the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), and the Rio Grande do Sul State Foundation for Environmental Protection (FEPAM). The lack of communication between these entities that are responsible for the environment may lead to conflicts. There is a lack of integration for this institutional arrangement to work efficiently and effectively. A much simpler political/administrative system is found in the Uruguayan side of the Basin, where four departments share the portion of the Basin in the Uruguayan territory, but the central government is in charge.

Governance 2: Institutional weakness and lack of autonomy of state agencies at the required level, considering the current pressures of economic development

The root cause identified here is related to the interaction of institutional weakness and economic power, and that some institutions have the possibility to act exclusively according to their own economic interests, particularly in developing countries. Very often such power has historical roots, with political support and representation being highly articulate. Such a scenario might be simply addressed as "lack of enforcement". When institutions do not have the skills to establish the agreements advocated by law or any other instrument, the sovereignty of stakeholders' economic objectives prevails. This reality accounts for the fact that very often, the economic activity still tries to maximise the profit in a short-term perspective, in disagreement with the sustainable development principles and society cannot set aside effective enforcement tools.

Knowledge: Insufficient information regarding ecosystem function and insufficient training in sustainable use of natural resources (land and water use)

Taking into account the different studies already performed, which favour technical knowledge about the aquatic ecosystem (Delaney 1962, Villwock 1984, Klein & Calliari 1995, Muehe & Neves 1995a, Muehe & Neves 1995b, Calliari 1997, Calliari et al. 1998, Seeliger & Costa 1998, Calliari & Tagliani 2000a, Calliari & Tagliani 2000b, Tagliani 2002); information about the Patos-Mirim Lagoon ecosystem is still considered insufficient. If the Mirim Lagoon is considered alone, the insufficient investments to generate knowledge and organise information is even worse, together with the lack of necessary information is the lack of technical training in the use of the natural resources of the system, which is necessary for a sustainable use by different sectors. This insufficient knowledge and training has been present throughout the process of land occupation over the years. If the volume of information available about the ecosystem's functions, limitations and potentials, and training to perform in those more significant sectors is intensified, a positive attitude towards mitigation of pollution in the Patos-Mirim Lagoon system might be expected. Although changing attitudes is very complex, information and education may facilitate attitude change (Eagly & Chaiken 1993).

Economic: Absence of efficient economic instruments

The different economic instruments, which currently circulate in the economic literature, such as compensation mechanisms, rates, taxes (GTZ 1995, Anderson & Lohof 1997, UNEP 2000) are not yet being applied in the Patos-Mirim Lagoon system. Absence of these instruments is expressed in negative externalities, and environmental wear and tear appears. The economic activities in place such as agriculture, livestock and industry are profitable economic activities in the Basin. A growing demand from the domestic market, supported by the current system, provides the conditions to make the existing economic activities important, so that together with the root cause of governance - of the weak autonomy of agencies when faced with pressures for economic development - generate different immediate causes, such as: (i) inappropriate land use, and (ii) unsustainable agriculture practices highly dependent on chemicals.

Socio-economic: Poverty among the inhabitants of the Patos-Mirim Lagoon system

A large part of the population in the Patos-Mirim Lagoon Basin is considered poor. This fact is shown by the observations throughout the region, and confirmed by the Human Development Index (HDI) (IBGE 2000). Poverty is one of the causes that help to explain the disorganised urban occupation and the ineffectiveness of economic controls, such as taxes to be borne by the population, considering the population as an active participant in the pollution process.

Demographic: High concentration of human population in the coastal zone and irregular occupation of areas - shanty towns

The phenomenon of high urbanisation rate in Brazil is a characteristic of the second half of the 20th century. It is associated to the process of concentration of activities (and income) in the secondary (processing) and tertiary (services) sector that developed in the urban environment, to the detriment of the primary sector (agriculture). The high concentration of people particularly in cities along the coastal zone is one of the root causes of pollution. In the case of the Patos-Mirim system, the population that is concentrated in the coastal zone lives primarily in the municipalities of Pelotas and Rio Grande (Mirim drainage area inside Brazil) and close to beaches (South Coastal Plain - Patos Lagoon). Economic activities such as port activity in the municipality of Rio Grande, greatly contributed to the rise in population in this region, and to pollution. Another major economic activity that attracted the population to the region was fishing, which, at the beginning of the 20th century, added a significant number of workers such as artisanal fishermen. The income concentration process, urbanisation, growth in the service sector, together with the rise in population, are events that sustain the concentration of people in the region under study, and consequently cause the occupation of improper areas in the cities in coastal zones. These areas now suffer negative externalities, expressed in the form of pollution, modification/loss of habitats and overexploitation of fish.

Selected root causes

When analysing the above-mentioned root causes, it was assumed that the most relevant ones for the proposals of policy options associated to Pollution in Mirim Lagoon system are: Governance 1 (Lack of implementation of a bi-national integrated management plan); Knowledge; and Economic (Figure 39).

It was assumed that these root causes were at the core of the issues to be targeted and that they should benefit from the implementation of adequate policies and investments. In setting up the causal chain for Pollution, these root causes appear linked to almost all causes in the economic activities identified in the chain. Although the other root causes were not selected for the purpose of policy options, it does not mean that they are less important than the selected ones. However, the working hypothesis is that when mitigating the root causes described as Governance 1, Knowledge and Economic, better chance of success might be expected. It is also considered that other root causes such as Demographic, Governance 2 (Institutional weakness and lack of autonomy of state agencies) and Socio-economic, are deeper rooted and present a level of complexity and constraints beyond the scope of the present study.

Conclusions

Based on the description of the Patos-Mirim Lagoon system, the environmental, as well as socio-economic impacts, two main concerns were selected for the causal chain analysis purpose: Pollution and Unsustainable exploitation of fish. The main root causes selected for policy options analysis were Knowledge, Economic and Governance. Table 19 summarises the main root causes.

Table 19 Main root causes associated to the main concerns for Patos-Mirim Lagoon system.

Root cause	Unsustainable exploitation of fish (Patos Lagoon)	Pollution (Mirim Lagoon)
Governance	- Lack of implementation of an integrated management plan for fisheries sector - Insufficient existing measures	- Non-implementation of a bi-national basin integrated management plan for Mirim Lagoon - Lack of autonomy of the agencies at the required level to face the pressures of the economic development
Economic	- Market pressure	- Lack of of efficient economic instruments to minimise pollution
Knowledge	- Insufficient information and training for the sustainable exploitation of fish.	- Insufficient information regarding the lagoon system functions and training concerning the use of land and water

Table 19 shows that the root causes chosen as the most relevant for both concerns, are the same: Governance, Economic and Knowledge. The explanations inherent to each root cause essentially coincide in both concerns. The concern Pollution was identified as the priority concern for the whole Brazil Current. In different parts of the previous sections including this one, it has been frequently mentioned that pollution is considered as one of the causes for habitat and community modification as well as the depletion of fish stocks. Based on these arguments, pollution was selected for the purpose of conducting the Policy options analysis.

Doce River basin

Figure 40 Doce River basin.

Doce River basin includes two Brazilian states: Minas Gerais and Espírito Santo, both in sub-region East Atlantic Basins.

Introduction

According to the conventional definition used for transboundary waters, the Brazil Current region has no other water system in this category, except for the Mirim Lagoon in the South/Southeast Atlantic Basin. Therefore, the criteria to select aquatic systems inside the Brazil Current region for Causal chain and Policy options analyses purposes were based on a wider concept of the transboundary nature of the aquatic systems and the way issues are expressed. The criteria used to select systems for further analysis were:

- The aquatic system is shared by two or more Brazilian states;
- The aquatic system present challenges and complexities related to geo-political aspects of water resources/coastal zone management and planning, similar to those observed in international water bodies;
- The aquatic system hosts concerns/issues of global relevance, such as unique biodiversity and ecosystems.

The Doce River basin fulfils the above criteria, which is the reason why it was selected for further studies and Policy options analysis. The Doce River basin lies in the Southeastern Region of Brazil, and is shared by two Brazilian states: Minas Gerais and Espírito Santo. The Doce River basin has the largest basin surface in the Southeast coastal region, according to the division of the National Waters Resources Plan (Figure 40) and is the second largest basin of the Brazil Current region after the São Francisco River Basin.

The whole drainage basin covers 83 400 km^2, 86% located in the state of Minas Gerais and 14% in the state of Espírito Santo. According to Lacerda et al. (2002), it is a medium-sized basin, in the context of Latin American rivers (between 10 000 to 200 000 km^2 in area).

The major socio-economic impacts in the Basin have a transboundary nature. The Minas Gerais state, responsible for the upstream portion of the Basin, has practiced a development policy and strategy that during decades has caused severe environmental and socio-economic impacts to the downstream portion of the Basin; the Espírito Santo state. The majority of economic activities (e.g. mining, agriculture, urbanisation) and the impacts generated by them are found in the Piracicaba River basin, a tributary located in the state of Minas Gerais. However, the major concern, Pollution with its main associated issue, suspended solids, is behind the major socio-economic impacts caused by flooding that occurs throughout the Basin, as well as other relevant pollution issues such as chemical and microbiological pollution. Box 1 provides a further explanation of the water domain issues in the Doce River basin.

The Doce River basin hosts a portion of the Atlantic Rainforest, one of the most important biomes of the world, stretching from the Rio Grande do Norte (in GIWA region 40a Brazilian Northeast) down to the southern extreme of Brazil. The Atlantic Rainforest is characterised by the highest diversity and endemism of species including aquatic species, plants, insects, reptiles and mammals (Mittermeier et al. 1982). Inside this large biome, there is a regional diversity that follows biogeographic patterns with known endemism, such as the endemism found in the Doce River basin (Kinsey 1982). Because of the high degree of deforestation experienced by the Atlantic Rainforest (only 6-8% of the original area still exists), it is considered one of the endangered tropical ecosystems in the world, with several species at risk of extinction (Bernardes et al. 1990).

Causal chain analysis was performed for two closely associated concerns: Pollution and Habitat and community modification. The main outcome from the Causal chain analysis is that the economic sectors causing the problems as well as the root causes are the same for both concerns. Consequently, policy options addressing the causes of Pollution will also address the causes of Habitat and community modification. Such a win-win situation improves the cost-effectiveness of the proposals.

Box 1 Water domain issues in the Doce River basin waters.

A characteristic of the Brazilian Water Resources System is that the water, from a constitutional viewpoint, may be in the domain of the individual states or of the federal government. Waters in the state domain are the groundwater located under its territory and the surface waters of the water bodies (lakes and rivers) that are entirely located within the territory of that state. Waters in the federal government domain are the surface waters of water bodies that are transboundary, either because they are in more than one state, or in a neighbouring country. In the case of the Doce River basin, the waters flowing in the Doce River are in the federal government domain. However the waters flowing in most of its tributaries, such as those of Piracicaba River, are in the domain of the state where this tributary has its source and mouth. This establishes a triple domain for the waters to be the object of the concession of rights of use. Those of the Doce River are to be granted by the National Agency of Water (ANA), a federal entity. Those of the tributaries belonging to the state of Minas Gerais, such as Piracicaba River, by the Minas Gerais Institute of Water Management (IGAM) (Instituto Mineiro de Gestão das Águas). Those of the tributaries belonging to the state of Espírito Santo, by the State Secretariat for Environmental Issues of Espírito Santo (SEAMA) (Secretaria de Estado para Assuntos de Meio Ambiente). Licensing potentially polluting activities in Brazil is part of the National System of the Environment. In this case the following coexist: a national agency, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), and state agencies: State Foundation for the Environment of Minas Gerais (FEAM) (the Fundação Estadual do Meio Ambiente de Minas Gerais) and the aforementioned SEAMA, in the state of Espírito Santo. The National Council of the Environment establishes the competencies for licensing potentially polluting activities. In brief, in one and the same basin, five organisations coexist, with legal attributions that may affect the use, protection and management of waters belonging to three jurisdictions, two of them at state-level and one of them federal. Three of them have attributions to grant water use rights: ANA, IGAM and SEMA; three of them have attributions related to environmental licensing: IBAMA, FEAM and SEAMA. This institutional arrangement presents great risks of inefficiency and ineffectiveness in the sustainable management of water and environmental resources, due to the lack of communication and cooperation, and the mechanisms to provide these. A river basin plan is the most logical alternative to integrate the actions of these entities harmoniously.

System description

Geographic and demographic settings

The Doce River, the main watercourse in the Basin, has its source in the municipality of Ressaquinha, at an altitude of over 1 000 m, in the mountain ranges of the Espinhaço and Mantiqueira complex, state of Minas Gerais, under the name of Piranga River. It runs 853 km to its mouth at the Atlantic Ocean, close to the district of Regência, in the municipality of Linhares, state of Espírito Santo. Over 230 municipalities, with almost 500 districts, are fully or partially contained in the Doce River basin. The population of these municipalities is 2.26 million in the urban areas and close to 1 million in the rural areas, and an urbanisation rate of approximately 70% (IBGE 2000). Urban growth in the Basin is lower than the average values found in the states of Minas Gerais and Espírito Santo. There is a general exodus from rural areas. The analysis of demographic data shows that the region in the Basin called "Vale do Aço" meaning "Steel Valley", in the River Piracicaba sub-basin located in the state of Minas Gerais, has the highest population density, with migration to one of its largest cities: Ipatinga. Consequently, there is a trend towards a diminishing population in municipalities with up to 20 000 inhabitants, representing approximately 93% of the municipalities in the Doce River basin. In year 2000, about 69.2% of the Basin population was served by public water supply systems, 57.6% by public sanitary sewerage systems, only 4.7% of the latter being treated (IBGE 2000). The population with water supply and the percentage of collected sewage treated is below the Brazilian average, equal to 81.5% and 17.8% respectively. However the population covered by a public sanitary sewerage network is above the Brazilian average of 47.2%.

Climatic and hydrologic characteristics

Figure 41 identifies the boundaries of the climatic regions in Doce River basin. Four types of climate are found in the basin, according to the Köppen classification:

- On the slopes of the Mantiqueira and Espinhaço mountains and in the southern area of the Basin, a high altitude tropical climate predominates with summer rainfalls and mild summers;
- At the sources of the Doce River tributaries, the climate is high altitude tropical, with wet and warm summers;
- In the middle and lower reaches of the tributaries and in the Doce River itself, a warm climate with summer rainfalls predominates;
- In a small region to the southeast, the climate is sub-tropical with distributed rainfall and hot summers.

The highest rainfall rates are found on the slopes of the Mantiqueira and Espinhaço mountains, and in the southern part of the basin, in the order of 1 500 mm per year. The rainfall rates diminish gradually as far as the town of Aimorés, and then begin to rise again towards the coast. According to the Water Resources National Plan (PNRH 2003), the mean annual precipitation in the basin is 1 238 mm and annual mean

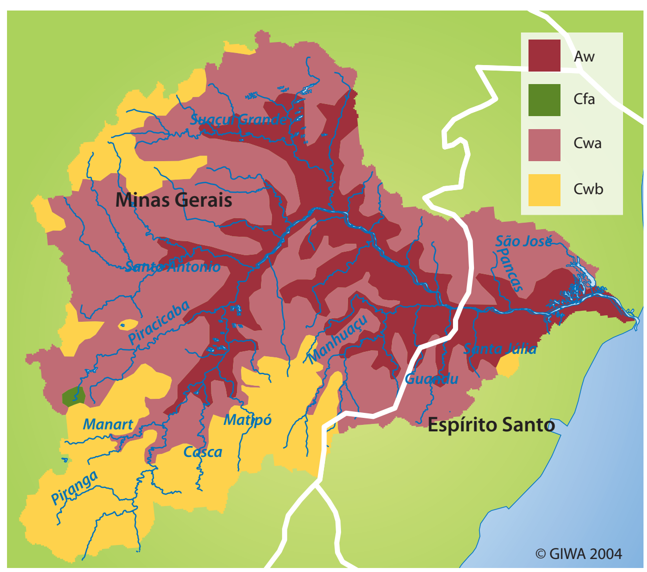

Figure 41 Doce River basin climate types.

Doce River Basin climate types, according to Köppen's classification. "Aw "- tropical hot and wet summer; "Cwa" - tropical of altitude (sub-tropical) wet and hot summer; "Cwb"- tropical of altitude (sub-tropical) wet and mild summer; "Cfa" - sub-tropical well-distributed rainfall and hot summer.

(Source: Gerenciamento Integrado da Bacia do Rio Doce 2003)

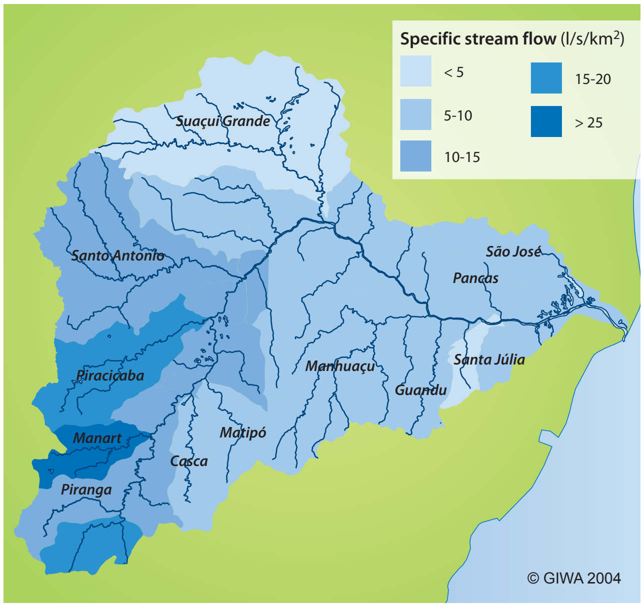

Figure 42 Specific stream flows in the Doce River basin.
(Source: Gerenciamento Integrado da Bacia do Rio Doce 2003)

evapotranspiration is estimated at 827 mm. At the mouth of Doce River a 95% permanence stream flow of 368 m^3/s is estimated ($Q_{95\%}$ is the value in the observed stream flow record that is surpassed by 95% of the daily observations, used as a measure of water availability), with an average stream flow of 1 136 m^3/s. Figure 42 shows the distribution of specific flows in the Basin, which, on average, is 13 $l/s/km^2$.

Economy

Timber as well as mineral extraction play an important role in the economy of the Basin. The integrated examination of physical, biological, socio-economic and cultural aspects enables the identification of great internal heterogeneity in the Doce River basin. The natural potential of the region determines or limits the spatial location of economic activities. The main activities are presented in Table 20. The industrial sector significantly contributes to the economic

Table 20 Main economic activities in Doce River basin.

Sector		Economic activity
Primary sector	Agriculture and livestock	Eucalyptus, sugar cane, vegetables and fruit, cocoa, hog farming and dairy and meat cattle.
	Mining	Iron, gold, bauxite, manganese, limestone, precious stones etc.
Secondary sector	Agro-industry	Sugar and alcohol, dairy products.
	Industry	Steel mills, metallurgy, mechanics, chemistry, food, beverages, alcohol, textiles, tanneries, paper and paper pulp etc.
	Hydropower generation	Installed capacity of 326 MW in hydropower plants.
Tertiary sector	Services	Trade and services to support the industrial complexes.

(Source: PNRH 2003)

and social development of this region that has an outstanding position in terms of Value Added Tax (VAT) on sales and services, and in the participation in resources of the Municipalities Participation Funds.

Water consumption in the Basin is estimated at 39.07 m^3/s, i.e. about 10% of the $Q_{95\%}$ at the mouth (PNRH 2003), with a distribution among users illustrated in Figure 43. Irrigation dominates the consumption while industry, despite its economic relevance, consumes relatively little. The organic load generated in the Basin is estimated at 118 tonnes BOD_5/day (PNRH 2003).

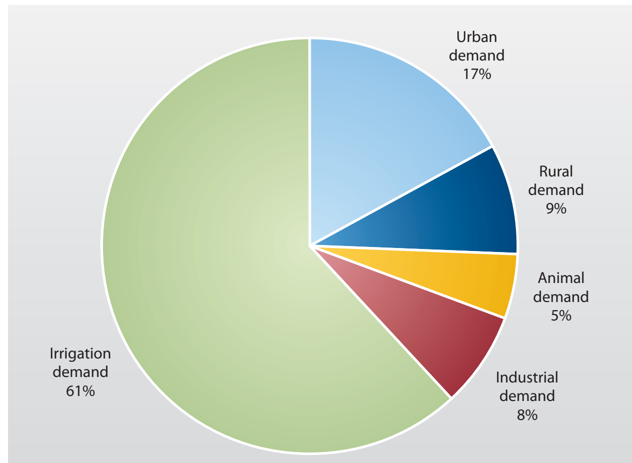

Figure 43 Water distribution/use in the Doce River basin.
(Source: PNRH 2003)

Environmental impacts

Since almost all of the native vegetation cover in Doce River basin has been removed or reduced due to timber extraction, extensive livestock breeding and agriculture, erosion has carried off the basin soils, and speeding up the siltation of riverbeds and reservoirs. Figure 44 illustrates the levels of severity of erosion in the Basin. Gold mining activities have destroyed river banks, worsening erosion and siltation, and contaminating the rivers with mercury. Toxic pollution due to intense mineral and industrial activity in the River Piracicaba sub-basin has polluted the water and downstream rivers. The pollutants discharged with domestic sewage, industrial and mining wastes have significant impacts on water quality in the Doce and Piracicaba rivers. Figure 45 illustrates the quality observed at the monitoring points, considering water quality as established by the National Council of Environment (CONAMA), Resolution No. 020 of 1986.

Socio-economic impacts

The erosion and siltation processes affect primary production and also make floods worse during the wet seasons and reduce the stream flow during the dry periods, causing scarcity of water supply in several cities.

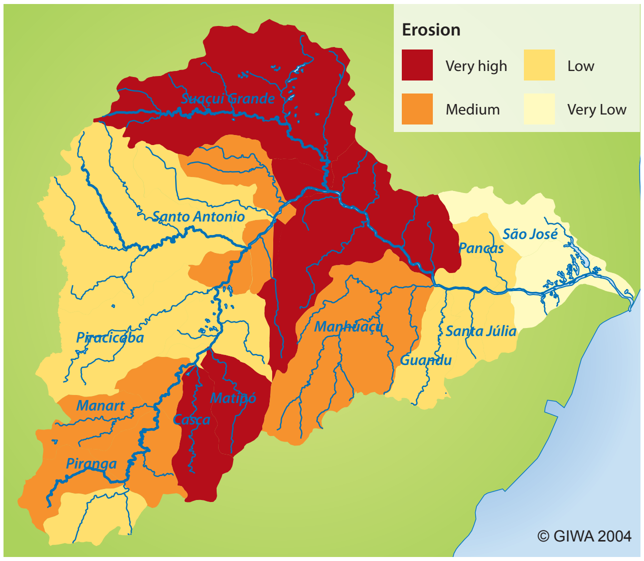

Figure 44 Degree of erosion in the Doce River basin.
(Source: Gerenciamento Integrado da Bacia do Rio Doce 2003)

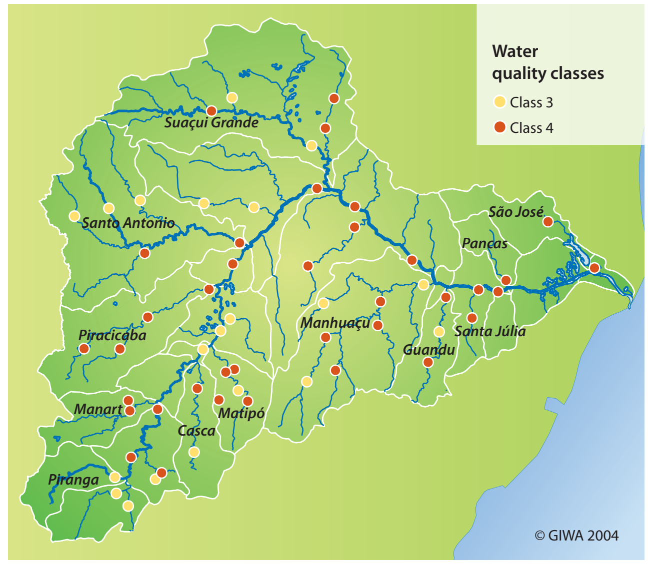

Figure 45 Water quality in the Doce River basin.
In 59 sections of the Doce River basin, water quality monitoring indicated Class 3 or 4 (based on CONAMA, Resolution No. 020/1986), despite the fact that guidelines indicate that water quality should be at least Class 2 based on assigned uses (see Annex III, Note 3).
(Source: Gerenciamento Integrado da Bacia do Rio Doce 2003)

Although most of the large industries have invested in environmental control systems, industrial pollution by small and medium-sized industries is still a problem in the Basin. Basic sanitation is critical: many towns have problems with the quality of water supply, there is a lack of investment in sewerage networks, there is practically no sewage treatment, and solid wastes are deposited mainly along river banks.

In brief, the main environmental impacts that lead to socio-economic problems in the Basin arise from the following factors (Gerenciamento Integrado da Bacia do Rio Doce 2003):

- Generalised deforestation and mismanagement of agricultural soils that led to loss of fertility and high erosion rates, and consequently to loss of agricultural productivity, increased rural poverty and migration to the outskirts of large cities;
- Siltation of riverbeds caused by erosion, leading to reduced stream flow during the dry period and increased problems during floods, with effects on urban supply, irrigated agriculture and public safety;
- Floods, resulting from natural conditions but worsened by the human occupation of the flood plain, deforestation, soil erosion and siltation;
- Vulnerability of reaches where the intake of domestic supply are located, considering previous accidental toxic pollution events, at several points in the Basin (the cities of Ponte Nova, Governador Valadares, in Minas Gerais, and Colatina in Espírito Santo, cities in the Vale do Aço (Steel Valley) in Minas Gerais, among others), with potential risks to public health;
- The precarious state of basic sanitation (networks, sewage treatment, disposal of solid wastes) and the lack of drinking water supply in several urban agglomerations and rural communities, reflecting on public health and on the economy.

A schematic illustration of the most degraded areas is found in Figure 46.

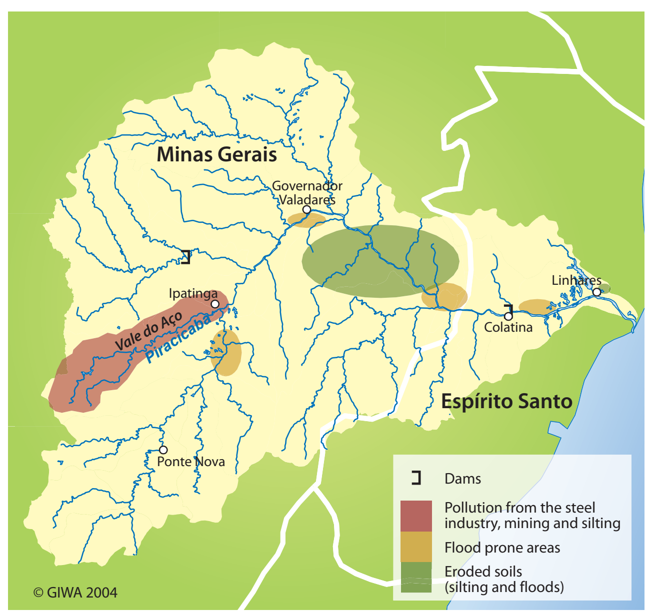

Figure 46 Doce River basin and its main environmental problems.
(Source: PNRH 2003)

Methodology

The methodology adopted to prepare the Causal chain analysis was to invert the course of the causal chain. In other words, based on the main socio-economic impacts identified in the Doce River basin, the environmental impacts that cause them were sought. The immediate causes of the latter and the economic sectors activities that generate them, due to the non-sustainable management of land and water resources, were identified.

Considering the activities in the economic sectors and their un-sustainable management, the root causes that enabled or encouraged this unsustainable scenario were sought. For this purpose, several technical reports on studies and plans concerning the Basin were analysed, and specialists from the Brazilian National Agency of Water (ANA) who work with activities in the Doce River basin were interviewed. These activities include mobilising society to create the management committee for the Doce River basin, and the preparation of an action agenda for the committee. Since the GIWA concerns Pollution, and Habitat and community modification were identified as priority concerns in the Assessment, the causal chains pertinent to them were identified. It was decided that the problems do not result only from the environmental vulnerability of the basin, but rather from the institutional framework and management framework of the basin. The situation of the basin, with respect to these two frameworks, was considered in detail, cross matching information from the reports consulted with the current stage of implementation of the National Water Resources Management System, and with the ANA specialists' perception of the problems. Based on this analysis, the root causes were identified and the causal chains for the Pollution and Habitat and community modification were constructed. The causal chains related to the selected GIWA concerns Pollution and Habitat and community modification are presented below.

Causal chain analysis for Pollution – Doce River basin

The concerns chosen for causal chain analysis in Doce River basin were Pollution and Habitat and community modification. The historical occupation of Doce River basin was associated with mining and exploitation of iron and precious metals, together with agricultural practices that did not consider proper management of soil and water, followed by the intensive use of wood as fuel. These economic activities destroyed the major portion of the Basin's native vegetation, created soil erosion, which in turn, generated two parallel sequences of impacts. On one hand, accelerated erosion and siltation aggravated the problems of flooding and caused considerable risks to the population living in the upstream portion of the Basin. On the other hand, the soil degradation increasingly reduced the agriculture productivity, resulting in the migration of the people from the countryside to the outskirts of the cities. An excessive concentration of low-income and unemployed people in the cities, without adequate infrastructure (e.g. sewage collection and treatment) caused pollution due to the organic load, in addition to the suspended solids. The industrialisation process in the Basin, especially in the Piracicaba River Valley, stimulated by the iron mining and processing, caused chemical pollution. Suspended solids, increasing organic load, microbiological and chemical pollution increased the risk of health problems due to consumption of low quality water. Six root causes have been identified for the causal chain of Pollution. Two of them are related to aspects of governance as discussed below.

Root causes

Governance 1: Lack of basin-wide management plan

Due to the lack of a master plan in the Basin, several managerial problems are identified, contributing to the worsening of pollution problems. A basin plan could establish an inter-institutional structure for communication and cooperation, and harmonise the water use demands, especially those related to its consumption and use as a receiving body for wastes. Above all, the integrated management should take into account the upstream uses in the Basin, especially waste discharges and quality demands of downstream domestic and agricultural users. The state and federal water resources and environmental entities, for instance, should have a common agenda for water protection actions (granting rights of use, licensing potentially polluting activities), which would be negotiated in the plan.

Box 1 provides a further explanation of this issue, which arises from the characteristics of water domain, established by the Brazilian constitution. Equally, an integrated plan including different economic sectors should be established, especially among the industry, mining, agriculture and urbanisation sectors, the first three being the main agents of degradation (urban supply from polluted sources and worsening of floods). The urban sector also causes degradation (untreated sewage discharged into watercourses, inadequate land occupation causing erosion and obstructing the free flow of the waters). The current lack of integration, resulting from this multiplicity of entities and sectors acting in the Basin, renders the balancing of the interests of the different stakeholders difficult. A river basin plan would lead to the negotiations needed to promote the balance and harmonisation of interests. One of the relevant aspects of the absence of a river basin plan is the lack of "city statutes" (called "urban master maps" in Brazil, which guide the occupation of land, limiting inadequate uses) which, when they do exist, do not take water-related demands into account. This has led to: (i) the occupation of hill slopes, worsening the problem of erosion and later siltation of bodies of water; and (ii) building in the river flooding zones, which has the effect of containing the waters and greatly worsening flooding problems upstream. The built up areas themselves may suffer flooding and during large floods the obstacles that have been artificially created may be destroyed, and flood waves may be generated, with catastrophic effects downstream.

Governance 2: Lack of legitimacy in negotiations commanding decisions regarding investments

Manoeuvring by powerful stakeholders and their influence over the government creates a risk that the government may make decisions of doubtful legitimacy value, which will privilege certain powerful groups, without taking the public interest into account. An aspect that contributes to this lack of legitimacy is that there is not enough public involvement in decision-making. The Management Committee of the Doce River basin is currently being set up, but it will take some time until its action becomes effective to solve this problem. A lack of instruments for public participation is also observed, i.e. instruments that will encourage, guide and promote the mobilisation of society with a view to taking on the role that the National Water Resources Policy expects it to perform in the decision process that is part of water management. According to the National Water Resources Policy (in accordance to the Agenda 21, UNCED 1992), among other principles it is established that the water resources in Brazil shall be managed in an integrated approach with participation of different stakeholders. It can be observed that, due to the lack of this participation and social control, the public institutions lack accountability, which makes it easier to exempt them from being held responsible for basin pollution problems: the causes of problems are always "the others" (Montada 2001), and there is no clear definition of responsibilities regarding the failure of water quality management.

Finally, contributing to this problem, the Brazilian judicial system takes too long to execute legal procedures, which helps create a lack of definition of guilty parties, and, what is equally bad, leads to the late identification of responsibilities when very little or nothing can be done, in terms of mitigating measures. The other root causes are related to economics (economic distortions are not correct), lack of knowledge (insufficient training regarding best land use practices), socio-economic (poverty among the population living in the Basin) and demographic (population growth and migration to cities followed by illegal land occupation - shanty towns). Some of their characteristics are discussed below.

Economics: Economic distortions are not correct

Although foreseen by the National Water Resources Policy, economic instruments to promote more sustainable use of natural resources, such as charging for water use, have not yet been implemented in the Basin. This results in inefficient use of water, and the non-correction of negative externalities, the clearest example of which is water pollution (Mendes & Motta 1997).

Knowledge: Insufficient training regarding best land use practices

The problems of inadequate land occupation are exemplified by the agricultural management adopted in the Basin, which caused generalised deforestation, the removal of gallery forests, land erosion and loss of its productive potential. It is also observed in the inappropriate location of structures on the steep hillsides and in the river flood zone. It is assumed that these practices are mostly the result of insufficient training regarding best land use practices.

Socio-economics: Poverty among the population living in the Doce River basin

This root cause is almost always present in any causal chain analysis performed in Brazil, since it is not possible to ignore the impacts of poverty on the environmental concerns and issues addressed by the GIWA assessment. Poverty, together with the demand to immediately overcome adverse living conditions, makes it difficult to use economic instruments in environmental management, challenges the implementation of the rules and legal standards, and prevents the transfer of basic knowledge regarding the relations between man-society-environment. The reason for this is that the economic logic which makes it possible to adopt economic instruments is based on a relationship of exchanges, or the market. In a situation of poverty, there is no such exchange relationship, strictly speaking, since the poor have comparatively little to offer and a lot to demand. Poverty leads to social exclusion, which in turn, induces (or encourages) those who suffer it, to behave outside the legal rules or norms that govern society. It is not, directly, the cause of ignorance, but since it monopolises all the individual's resources to overcome the problems it causes, poverty prevents planning for the medium or long-term, and, thus, from setting aside some time to learn.

Demographic: Population growth & migration to cities followed by illegal land occupation - shanty towns

This root cause is generated by the impoverishment of the rural population, caused by population growth together with loss of soil productivity. The causes of high urbanisation rate are those already indicated (Demographic root cause of pollution in the Patos-Mirim Lagoon system). The Doce River basin exhibits this phenomenon, one of the consequences of which is the "swelling" of the cities. This root cause is partly a consequence of the previous root cause: poverty. However, its causes may go beyond this. Population growth, together with loss of productivity in the rural area (which in turn may be caused by erosion) generates a search for work opportunities in the cities, in the secondary and tertiary sectors of the economy. As the city becomes crowded, increasing demand for housing leads to higher prices. As a result, a significant portion of the migrants settle in urban areas where housing is lower, particularly in regions farther away from the downtown area. For the interests of this causal chain analysis, the most important issue is the illegal occupation of land with significant risks of flooding or other natural disasters.

Selected root causes

Figure 47 (Causal chain diagram for Pollution) shows that some root causes have a greater number of causal relations with the sector activities. The number of connections cannot, a priori, be considered a good criterion to rank the root causes according to their relevance. In this case, however the most important root causes in the process of pollution of the Doce River basin waters are precisely those that are grouped under the class of Governance, Economics and Knowledge, and that have closest connections to the sector activities. This is confirmed by the severity of degradation problems that are perceived in the Basin, related to microbiological and chemical pollution, eutrophication and suspended solids.

The inappropriate occupation of the riverbeds, one of the immediate causes that generate increased suspended solids and siltation, aggravated by the inappropriate use of land, also worsens the floods with risk of damage to life and property. This socio-economic impact was listed in the pollution causal chain due to the relevance of the problem in the Basin, and the fact that its consequences are analogous to pollution, although the GIWA methodology does not list this problem as a socio-economic impact. In other words, like pollution, the worsening of floods is an undesirable side effect of human activities.

The socio-economic and demographic root causes are probably less relevant in accounting for the Basin pollution process in this case. The proposal of policy options to mitigate the latter root causes is also less credible over the short and medium-term. Figure 47 presents a comprehensive version of the causal chain analysis for the concern Pollution in Doce River basin. Figure 48 summarises the most relevant causal chain links for Pollution. Figure 49 shows the causal links selected for further consideration and policy option analysis.

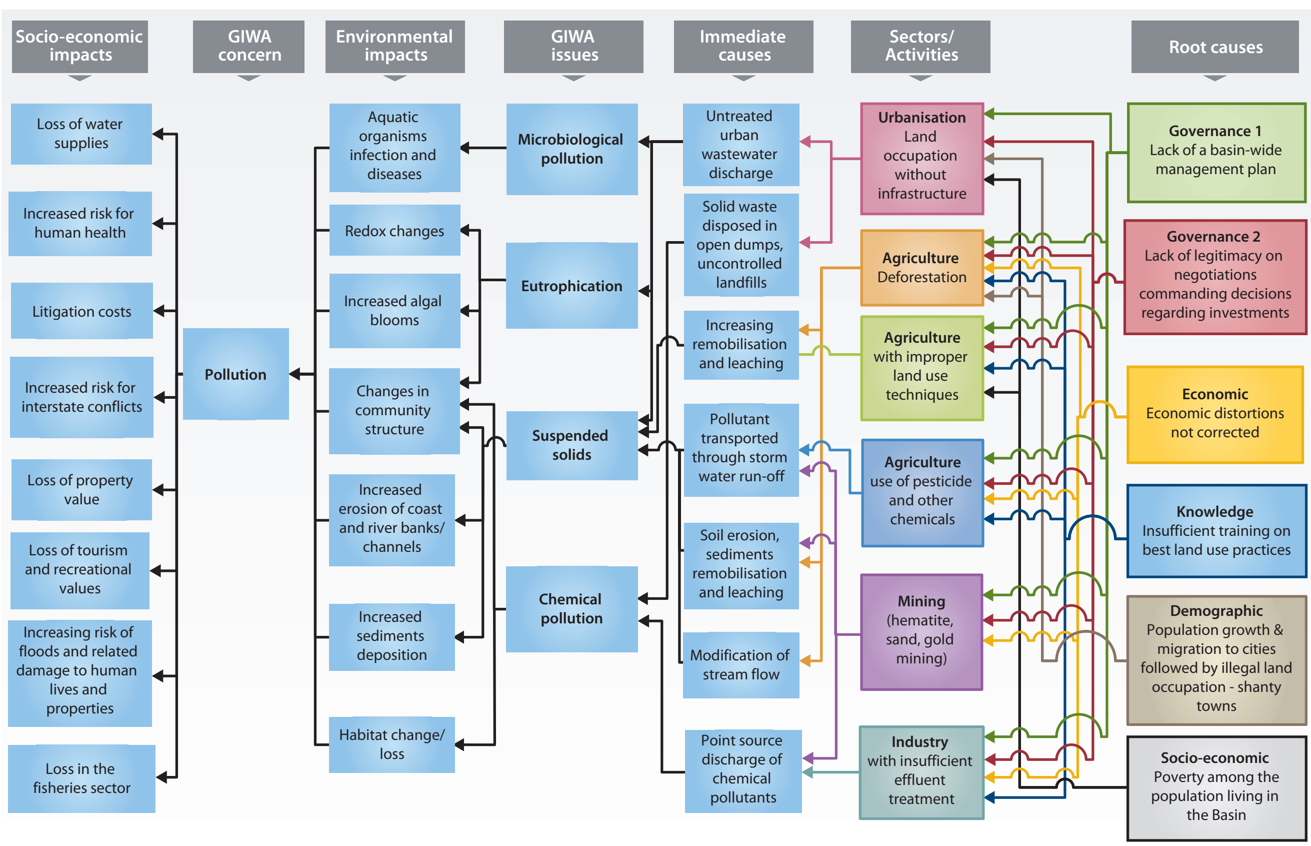

Figure 47 Causal chain diagram for the main concern Pollution and its issues in Doce River basin: Comprehensive version.

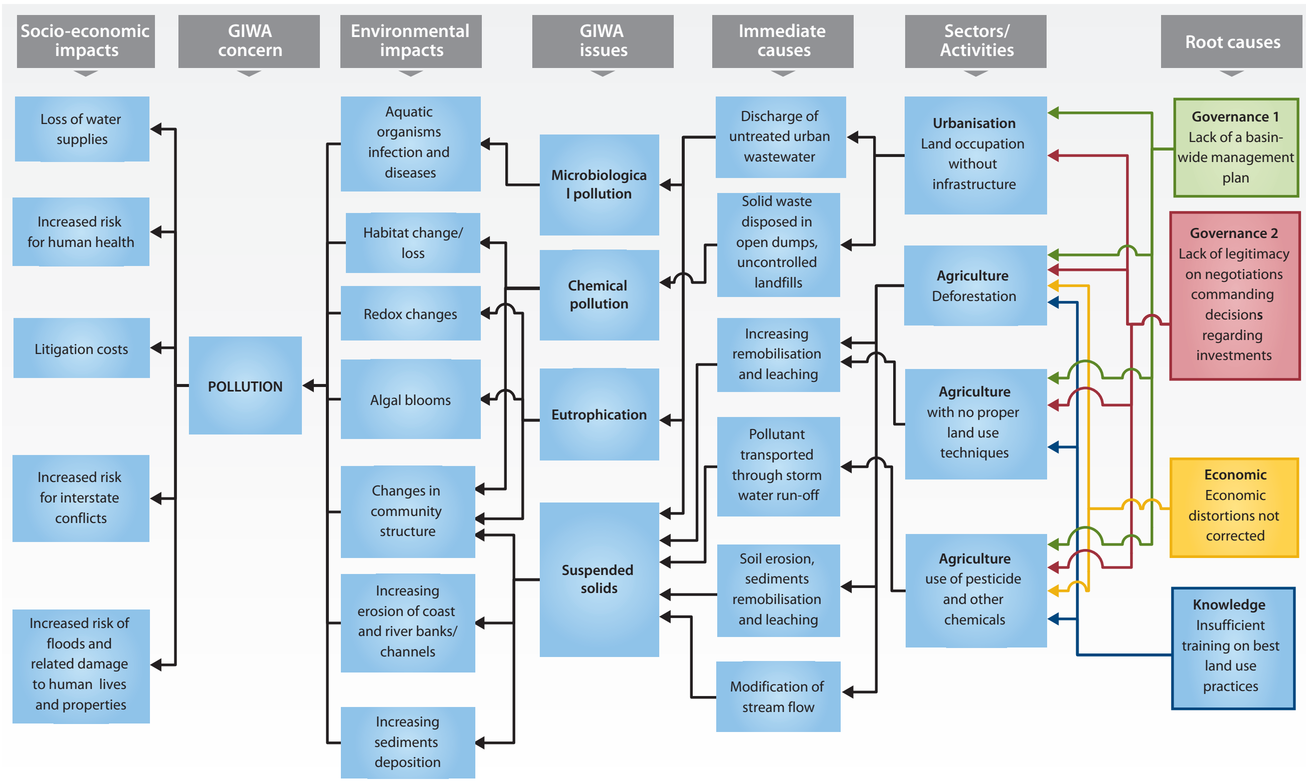

Figure 48 Causal chain diagram for the main concern Pollution and its issues in Doce River basin: Version focused on the main sectors and root causes.

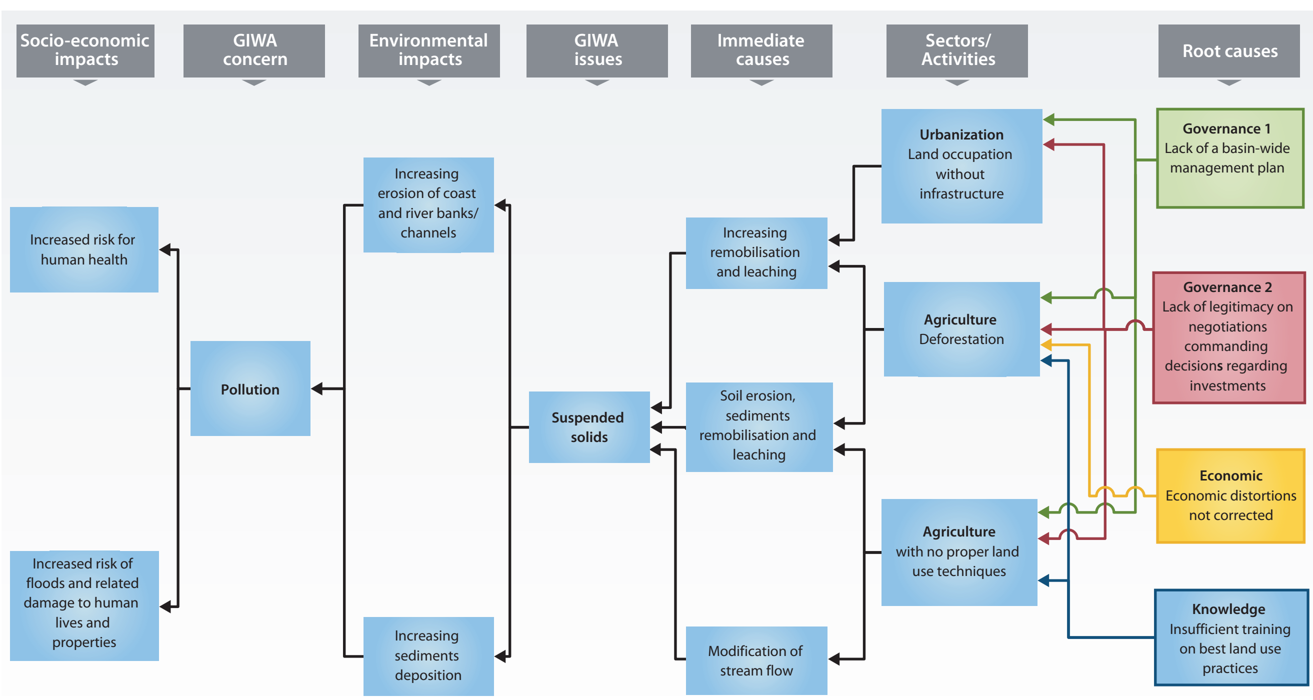

Figure 49 Causal chain diagram for the main concern Pollution and its issues in Doce River basin: Selected root causes for policy options analysis.

Causal chain analysis for Habitat and community modification – Doce River basin

The causal chain analysis presents common root causes for Habitat and community modification and Pollution, except for the Demographic (Figure 50). In this case, the analyses and characterisations performed for the concern pollution are valid to a large extent. Therefore, it can be assumed that some root causes generate two sequences of effects related to pollution and habitat and community modification, respectively. Policy options selected to minimise/solve one of these concerns probably will have a similar effect on the other concern.

Conclusions

The causal chain analyses for Pollution and for Habitat and community modifications have their main root causes as outlined in Table 21.

Table 21 Summary of root causes for Pollution and Habitat and community modification in Doce River basin.

Root cause	Pollution and Habitat and community modification
Governance	Basin-wide management plan not implemented yet. Lack of legitimacy in negotiations commanding decision regarding investments.
Economic	Economic distortions are not correct.
Knowledge	Insufficient training regarding best land use practices.

The policy options selected will contribute to mitigating these root causes and thus to the mitigation of the problems of Pollution and Habitat and community modification.

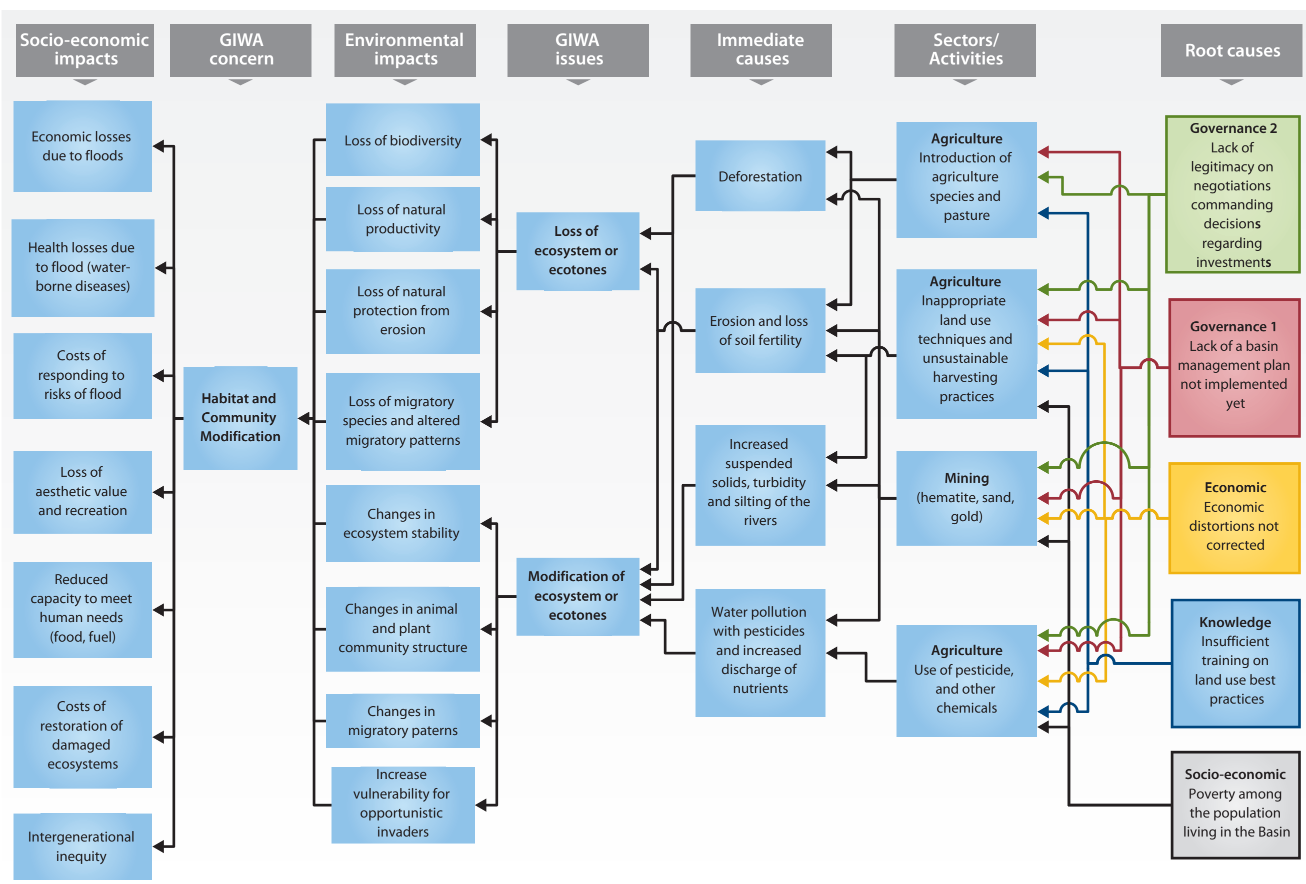

Figure 50 Causal chain diagram for the main concern Habitat and community modification in Doce River basin.

Policy options

Abdallah, P.R., Marques, M., Lanna, A.E. and M. Polette

This section aims to identify feasible policy options that target key components identified in the Causal chain analysis in order to minimise future impacts on the transboundary aquatic environment. Recommended policy options were identified through a pragmatic process that evaluated a wide range of potential policy options proposed by regional experts and key political actors according to a number of criteria that were appropriate for the institutional context, such as political and social acceptability, costs and benefits and capacity for implementation. The policy options presented in the report require additional detailed analysis that is beyond the scope of the GIWA and, as a consequence, they are not formal recommendations to governments but rather contributions to broader policy processes in the region.

Patos-Mirim Lagoon system

Before preparing the policy options to be recommended for the chosen concern (Pollution), it should be emphasised that the success of future actions is associated with their connection to the legal policies and institutions acting in the system studied. Thus, in the case of the studied aquatic systems, for instance, those policy options selected should be in harmony with the national policy concerning water resources and, also, provide the basis for joint action with the governmental agencies and the ministries of the environment of both Brazil and Uruguay. The Policy options analysis for the Patos-Mirim Lagoon system will focus mostly on Mirim Lagoon basin, the bi-national component of the system.

Definition of the problems

Based on the Causal chain analysis for Pollution in Patos-Mirim Lagoon system, a number of policy options to minimise the environmental problem will be proposed. Those with the best performance, according to a checklist of criteria, will be indicated. Pollution is a selected concern for both lagoons in the Patos-Mirim Lagoon system; however, the anthropogenic activities that cause the pollution are lagoon-specific. In Mirim Lagoon, the main activities causing pollution are limited to: use of pesticides, fertilisers and other chemical products; and erosion/sedimentation dynamics caused by deforestation and conversion of land and wetland areas into rice and cattle fields, resulting in increased suspended solids in the water. Patos Lagoon basin, which is more densely populated, has many important sources of pollution, such as: those presented for Mirim Lagoon; chemical pollution by heavy metal and persistent organic compounds as a result of industrial activities such as petrochemical, metallurgical, pulp and refineries; and urbanisation and tourism. The Policy options analysis will focus mostly on Mirim Lagoon, since it is the only truly international water body, although there are indications that Patos Lagoon is more severely impacted by pollution than Mirim Lagoon, and there is more data/information substantiating the assessment made for Patos Lagoon (see Annex III) than Mirim Lagoon.

Policy options

The policy options listed here are attuned to the root causes identified in setting up the causal chain for pollution in the Patos-Mirim Lagoon system, i.e. Knowledge, Governance and Economic. The root causes are associated to activities in different economic sectors and the immediate causes provoked by them. Based on this, some policy options are described below.

PO-1: Plan for the control & prevention of suspended solids/chemical pollution - PC&PP

The proposal is to constitute a plan for the control and prevention (PC&PP) to act in the Patos-Mirim Lagoon system. This implies establishing an institutional arrangement required for its implementation as a legal/ institutional apparatus. The proposal is to involve representatives of different sectors and organisations (UNCED 1992 Chapters 23-34) which act and are dependent on the system studied, directly and indirectly linked to the use of the water resources in the Patos-Mirim system Lagoon (integrating the Ministry of the Environment, National Agency of Water, Municipal and State Secretariats, NGOs, companies with a high potential for pollution, municipalities involved, class and category representatives, Universities, technical and research institutions). Such a plan will create means and strategies to minimise and mitigate the negative impacts caused by suspended solids and chemical pollution and establish consensus to minimise/eliminate these impacts. It is proposed that the PC&PP will be the legal document of reference, backed up by local, regional, national and bi-national agents, in the decisions concerning the use of the aquatic systems of the Patos-Mirim system. This first policy option would include the organisation and discussion of the Patos-Mirim system data, and a dynamic preparation of programmes to be implemented over the short and medium-term, which would have the effect both of preventing and mitigating chemical pollution during the process of their implementation. This proposed plan would be developed using two approaches: (i) a plan to control and prevent chemical pollution resulting from farming; and (ii) a plan to control and prevent chemical pollution from industry. They would constitute different policy options that once implemented, would add to the PC&PP.

PO-2: Plan for the control & prevention of suspended solids/chemical pollution from agriculture - PC&PP/Agriculture

The intensive use of pesticides and agricultural chemicals on crops, especially in rice cultivation, an activity that is developed around the Mirim Lagoon, is a serious problem causing contamination of the water of this lagoon system. Thus, the idea of setting up a separate plan is to focus on chemical pollution resulting from agriculture, for the purpose of mitigating and/or eliminating this problem. In order to control suspended solids/chemical pollution caused by land use practices, particularly agriculture, the primary polluters (farmers) should necessarily be involved in setting up this plan (UNCED 1992 Chapter 32 Strengthening the role of farmers), either directly or through their legal representatives (association of farmers), together with the other stakeholders involved in setting up the PO-1 described above. This policy option should build on common agreement with representatives from the Brazilian and Uruguayan governments. For the plan to achieve success, it is necessary that they also participate in preparing and constituting the goals and actions to mitigate and/ or eliminate, whenever possible, the chemical pollution concerned. The legal/institutional character of this plan would receive favourable support when highlighting the coexistence of a potentially polluting activity and areas of environmental protection and ecological reserves, such as the Ecological Reserve of Taim. This reserve is located on the margins of Mirim Lagoon, in the extreme south of Brazil, and is an area considered as having extremely high ecological relevance, and as part of the Federal Action Plan for the Coastal Zone (FAPCZ). PO-2 is a plan that will be added to the PO-1, where a plan is outlined for the whole Patos-Mirim system, including an international vision.

PO-3: Plan for the control & prevention of pollution from industrial production - PC&PP/ Industry

Chemical pollution was identified in the Patos-Mirim system mainly around Patos Lagoon, with the presence of potentially polluting industries (fertilisers, oil, oil derivates and refinery) which, without adequate effluent treatment, contaminate a large part of the estuary of Patos Lagoon. Heavy metals and other pollutants have an impact on the environment and aggravate human health problems. The general purpose of this policy option is the same as described in PO-1, although the focus is now put on the industrial sector: close cooperation and participation of representatives of industry is required in preparing this plan (UNCED 1992 Chapter 30 Strengthening the role of businesses and industries). Among the stakeholders to be engaged, no international organisation is required (as in the case of PO-1), since the root causes are confined to Brazilian territory. The presence of stakeholders involved in the fisheries sector (industrial and artisanal) is essential in setting up this plan, since this will allow the integration between conflicting economic activities, such as industry and fisheries, which are dependent on common natural resources. Thus, increasing the synergy between the activities and setting up a plan backed by legal and institutional severity, the conditions to reduce chemical pollution due to industrial activities in the Patos-Mirim system are given.

PO-4: Empowerment of the Mirim Lagoon Bi-national Commission - Brazil & Uruguay

In the 1960s, when concern about regional development in the extreme south of Brazil became an issue, the FAO/UNO prepared Regional Program 35 "Regional Program of the Mirim Lagoon Basin", which highlighted possible investments and directions for development in the region (Borba 2002). Proposals for investments in specific projects for the whole region of the Mirim Lagoon basin were developed covering both the Brazilian and Uruguayan territories. The Bi-national Commission Brazil & Uruguay, which was set up during the 1960s to perform joint initiatives in the Mirim Lagoon, with Brazilian and Uruguayan agents, acted satisfactorily to address the problems and issues inherent to the proposal of regional development. However, the attempts at institutional activation of Regional Program 35 were frustrated, and the economic activities in the region began to be developed without planning (Borba 2002). During the years, each country has established its own agenda, as illustrated by investments throughout the period (e.g. building a lock in the São Gonçalo Channel to protect the rice crops from intrusion of saline water). Although there are occasional demonstrations of reciprocal interests of both countries in the Mirim Lagoon development, in practice, neither Brazil nor Uruguay stopped maintaining separate contacts with the United Nations Special Funds for fundraising (Borba 2002). During more recent years an attempt was made by both national governments in the spirit of the development of the Southern Common Market (MERCOSUR). Some bi-national initiatives for water quality monitoring and evaluation of fish stocks were started at the end of the 1990s. Currently, there is the Mirim Lagoon Agency, located in the city of Pelotas/Rio Grande do Sul, with focus on aspects inherent to the Lagoon in Brazil. Recently an important legal instrument to help reactivating the Commission was signed by the President of Brazil: the Act (Decree) No. 4 258, 04 June, 2002. The Decree approved the internal regulation by the Brazilian section of the Bi-national Brazilian-Uruguayan Commission for the Development of the Mirim Lagoon (SB/CLM), connecting it to the Ministry of National Integration. These initiatives indicate that there is a positive atmosphere towards reactivation of the Bi-national Commission. When analysing the difficulties experienced during the past it should be taken into account that during 1960s to 1970s both countries were under military dictatorships, which made it difficult to implement participatory decision-making processes. Another important factor that explains the difficulties of a joint initiative regarding water and land use between Brazil and Uruguay is that land ownership was concentrated in the hands of a few big landowners. The landowners were obviously connected to political power or were themselves in a powerful political position. The analysis of previous experiences with bi-national initiatives becomes important when discussing the policy option to reactivate the Bi-national Commission. In the new political context, better results are expected from such joint initiatives, based on the participatory approach and engagement of representatives of society and agents representing the democratic governments. This would enable the Commission to act competently in the international negotiation process of common interest to both countries and to the world, since Mirim Lagoon boasts wetland ecosystems strategically important for world biodiversity. In the new context, the Bi-national Commission Brazil & Uruguay might act to support the aspects of "governance" highlighted in the previous policy options. The Bi-national Commission might influence the process of prevention and control of suspended solids and chemical pollution in the Mirim Lagoon basin, enabling the preparation of more effective projects and initiatives and therefore, fundraising.

PO-5: Creation of Mirim Lagoon Basin Committee and empowerment of the Brazilian and the Uruguayan Mirim Lagoon Agencies

This proposed policy option is to organise a Bi-national Basin Committee with sufficient political profile in terms of representation of stakeholders. The aim is to establish common agreements between polluters/users of the Mirim Lagoon system, for the future sustainable international use of the water resource. Several international agreements about sustainable use of water have been made (UNCED 1992, WSSD 2002). In the Brazilian view, this committee should be supported by and also support the Mirim Lagoon Agency, located in the city of Pelotas/Rio Grande do Sul, which was created and meant to have a strong technical/scientific profile to prepare proposals for the basin with scientific backing. A similar Mirim Lagoon Agency should be created on the Uruguayan side, both agencies being the executive agents of the Committee's strategic plan. It is worth mentioning that the formulation of basin committees associated with basin agencies is defined by the Brazilian Federal Water Resources Law No. 9 433 enacted on January 8, 1997. The existence of this Committee will give the necessary political support to the Mirim Lagoon Agencies (Brazilian and Uruguayan) in their capacities to implement measures. The Committee and the agencies are meant to be the starting point for effective reactivation of the Bi-national Commission Brazil & Uruguay (PO-4).

PO-6: Implementation of an environmental information system for the Patos-Mirim Lagoon system

In any political strategy for water resources management and sustainable development it is of paramount importance to make information available to: (i) support the assessments and assign priorities to environmental and socio-economic concerns and issues; (ii) support research activities and development of the technical/scientific knowledge about the area studied; (iii) educational and awareness campaigns (e.g. classify and disclose lists of industries ranked by their environmental profiles); (iv) facilitate monitoring activities and enforcement; and (v) support decision making processes. The basic information included in a databank/information system should include:

- Characterisation and description of the basin with the main features mapped;
- Environmental status of the water resources, ecosystems and habitats;
- Sources of pollution geographically located in maps;
- Sources, types, patterns and levels of pollution and analysis of trends;
- Information about institutional and legal deficiencies to be solved;
- Continuous strategic impact assessment with periodic release of information;
- Links to other sources of relevant information in both countries and in the world, e.g. international programmes and projects about wetlands, biodiversity, pollution prevention/control programmes and strategies, environmental and economic sectors legislation in both countries and international environmental legislation, etc.

This item would be constructed with a broad survey of biological and ecological studies, impacts assessment, feasibility studies for engineering civil works, socio-economic aspects of different sectors (e.g. agricultural practices such as irrigation, use of pesticides and fertilisers) performed in the catchment area of the Patos-Mirim Lagoon system in both countries. The basic proposal of this policy option is the development of an efficient Information System, ranging from the Federal Government structure to the lower instances (local and municipal), creating interrelated networks concerning the cause-effect of possible actions involving the issue of environmental pollution. The idea is to supply an efficient instrument for legal, institutional and operational functions, in order to integrate the information about pollution into the decision-making process of licensing and enforcement, and making the implementation of economic instruments more efficient.

PO-7: Technical and professional training

This policy option is to prepare and implement an education and training programme to fulfil the objectives of minimising/eliminating pollution. The goal is to improve the knowledge about the Mirim Lagoon basin and sustainable practices in the economic sectors, such as water and land use, soil conservation, and agriculture pest and disease control, covering the related environmental problems and issues. The product of such a policy option is the human capital in both countries that will be able to deal with environmental problems, specifically those relevant for the Mirim Lagoon basin. The training programme should involve professionals at technical level, so that they can structure and organise themselves to foster integration, reduce conflicts and generate consensus on resolutions of aspects of soil erosion and chemical contamination. Thus, training courses would be set up for the different actors involved in these matters. Besides the technical matters, the training would include relevant topics such as establishing monitoring networks for pollution, strengthening a data base, building public awareness through public information, and establishing a dialogue with local, municipal and national governments about the matter. The importance of awareness raising and public participation is promoted by the international action plan for sustainable development, Agenda 21 (UNCED 1992 chapter 36). This policy option is associated to PO-6 (Implementation of an environment information system).

PO-8: Economic instruments for pollution mitigation in the Lagoon system - Incentives

This policy option is to give support to the implementation of the "user pays" and "polluter pays" principle. The Brazilian Federal Water Law No. 9 433 enacted on January 8, 1997, institutionalises these concepts, partially removing the burden from the public coffers. The law makes it clear that water may only be used by those who have permission to do so, and charges for water use and pollution by creating a fund that might be used in the basin to carry out projects of recovery, remediation and sustainable use of the resources. As a support to the effective implementation of the law, it is proposed to specify economic incentives that can act efficiently in the Patos-Mirim system. To create market mechanisms in order to compensate for the reduction and/or elimination of pollution is an incentive that is very much the focus of the regulating agency of the Ministry of the Environment, Brazil, for applications specifically related to agricultural production. Efficiency in choosing anti-pollution economic incentives in the Patos-Mirim system will be possible, based on the use of specific information to be outlined by PO-6.

PO-9: Pilot Project to reorganise the productive activity (Alternative: Ecotourism) on Marinheiros Island, as a way of reducing the pollution caused by the use of fertilisers

The Marinheiros (Sailor's) Island is an island in the Patos Lagoon close to the cities of Rio Grande and Pelotas. The Island is inhabited by artisanal fishermen, who are also small farmers, basically producers of greens and vegetables (Maciel 1998). These products supply a large part of the Rio Grande municipality market and also a significant part of the Pelotas municipality market. However, this production is based on intensive use of chemical fertilisers, thus contributing to pollution of Patos Lagoon. This policy option is aimed at mitigating the pollution, implementing a pilot project to reorganise economic activities on the Island and encouraging the development of ecotourism rather than agricultural activity. Besides the tourism potential identified on the Marinheiros Island, the Island presents high aesthetic value, with dunes and natural lagoons (Maciel 1998). The implementation of this project would make it possible to increase the income of the artisanal fishermen/farmers who are currently in a situation of poverty, according to the census of socio-economic statistics and surveys performed by the Brazilian Institute of Environment (IBAMA) - Rio Grande Regional Office. This socio-economic situation is linked to the slump in the economic activity of artisanal fisheries in the Patos Lagoon, and also to the high cost-benefit ratio observed in the production of vegetables and greens in this region (Maciel 1998). The idea is to propose incentives to the families living in the Marinheiros Island to stimulate investment in ecotourism projects that would be developed for this Island. It is likely that this new activity would become more profitable than the current polluting agricultural production within a short-time perspective. Additionally, this new activity would imply the substitution of conventional agriculture (intensive use of fertilisers) by sustainable practices (organic agriculture) that would be developed integrated with the ecotourism. Besides mitigating the problem of pollution (considered an environmental benefit), it would generate socio-economic benefits and improve income and health conditions for the locals. This policy option is seen as a complementary initiative to PO-2. Figure 51 outlines the policy options suggested, in order to explain the links between them.

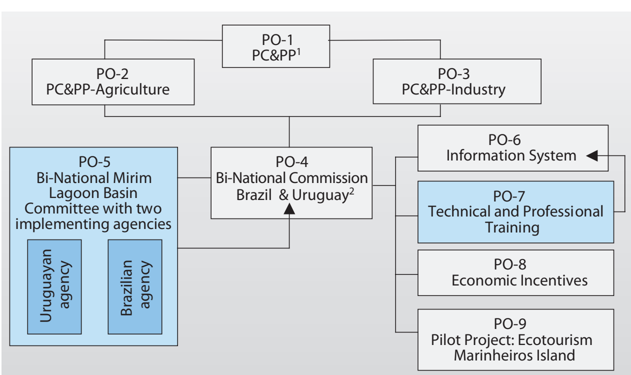

Figure 51 Policy options for mitigating pollution in Mirim Lagoon basin, their links and selected options to be implemented.

[1] PC & PP = Control and Prevention of Pollution. [2] Already existing structures which need support to perform.

Recommended policy options

One set of policy options (PO-1, PO-2 and PO-3) encompasses alternatives related to the development of a bi-national integrated plan for pollution control and prevention, and documents and guidelines to deal with the problem in the Mirim Lagoon system. To elaborate and execute these plans, there is a need for strongly supported and dedicated basin committees and agencies, from both scientific and political viewpoints. International agreements such as WSSD (2002) emphasise the importance of strengthening the capacity of national and regional programmes in order to manage impacts of ocean pollution (WSSD 2002 paragraph 33b).

Policy options related to the creation and/or empowerment of those already existing organisations are described in PO-4 and PO-5. A third group is illustrated by PO-6 and PO-7, which aim to supply the organisations with updated information and trained professionals and communities that will implement sustainable practices to reduce the erosion/sedimentation rates and reduce pollution associated to land use and agriculture activities. PO-8 and PO-9 represent respectively, an additional incentive for compliance and a concrete case study where pollution is mitigated through replacement of a currently polluting economic activity by a more profitable and environmentally sustainable economic activity. The next section describes why PO-5 and PO-7 were selected as those that should receive priority for implementation, although the entire set of policy options is considered to be an integrated way to approach the problem.

The prioritised policy options (PO) are:

- PO-5: Creation of the Bi-national Mirim Lagoon Basin Committee and empowerment of the Brazilian and the Uruguayan Mirim Lagoon Agencies;
- PO-7: Technical and professional training.

These options were chosen because they address the most basic conditions required to deal with the concern Pollution in the Mirim Lagoon system, which does not detract from the importance of the other options. Considering that the main root causes identified behind suspended solids and chemical pollution were Knowledge, Governance and Economic, the implementation of these policy options will act directly toward two of these root causes (Knowledge and Governance) and will create the basic conditions for the third cause (Economic) in a second stage, through the development of PO-8 Economic incentives, as proposed in the previous section. The reasons for choosing only two policy options and why the others were not chosen at this stage are as follows:

- Participatory activities to be developed when implementing PO-5, in the process of negotiations (working on the root cause of Governance) will be dynamic and this will reflect positively on the management of these problems;
- The outcomes of the technical and professional training (PO-7) will have reflections on economic sectors causing pollution, enabling information and knowledge to flow and also constituting technical and professional support to prepare and set up the management plan for these water resources, as proposed by PO-1, PO-2 or PO-3;
- According to the diagram presented in Figure 51, PO-5 and PO-7 are likely to provide support for other options that might be implemented in a second stage, in order to render the results more efficient;
- PO-5 is essential to give strength and an executive profile to perform to the existing Bi-national Commission;
- The exclusion of PO-1 or PO-2 and PO-3 from the priority set is due to the estimated time and technical support they would require;
- The complexity of PO-4 is much greater, since it requires international negotiations. However, since the Bi-national Commission of Brazil and Uruguay for the Mirim Lagoon is already in place and, based on recent governmental initiatives demonstrating that the issue is gaining importance in the diplomatic agenda of both countries, the empowerment of the Commission will be achieved by implementing PO-5 and PO-7.

Finally, PO-7 is one of the most important options insofar as the existence of an efficient information system is a crucial instrument to control pollution in the Mirim Lagoon system. However, this option requires rigorous and systematic work to collect and organise information, infrastructure (computers, databank), paid personnel, network construction, and above all, guarantee of continuity over a period of at least a number of years. A new globally harmonised system for the clarification and labelling of chemicals is suggested to be fully operational by 2008 (WSSD 2002 paragraph 23c). Thus, PO-7 was identified as a first stage to achieve PO-6 in a second stage.

Performance of the chosen alternatives

It is clear that the implementation of the selected policy options does not produce a complete solution to pollution in the Mirim Lagoon system, but it will produce a dynamic evolution of actions throughout the development process. These actions should be expressed in satisfactory results basically related to knowledge and governance. The options were submitted to the criteria of effectiveness and efficiency, giving the results below.

Effectiveness

Estimating the impact of the option: It is estimated that the impact will be favourable in the skill-building and training process of different players involved in water use in the Mirim Lagoon system (PO-7) and also in the organisation of these different players and stakeholders, to establish sustainable management of water resources in Mirim Lagoon (PO-5). Quantitative values cannot be established for the policy option outlined.

Concerning risks and obstacles: Serious failures in implementing PO-5 may occur, if the basin committee is not established in a participatory manner. In this case, lack of backup of all stakeholders involved, may result in "pre-established" biased consensus. This failure may be avoided if the composition of basin committees strictly obeys the rules of representation in basin committees expressed in the Brazilian Federal Water Law No. 9 433, 1997, and its regulation, which has no counterpart on the Uruguayan side. An obstacle associated with PO-7 may be the non-attendance of a critical mass of professionals and personnel to be trained or the attendance by a non-qualified group. This problem would be minimised by a strategic programme of recruitment of technicians, farmers, representatives of local government institutions, among others. The professionals require training and maybe competent professionals from other areas of Uruguay and Brazil, and eventually from abroad would be needed.

Under favourable conditions it is expected that:

- PO-5: This option will be successful in constituting a Bi-national Basin Committee, which will act to integrate opinions from different segments of the society and will have the committee agencies from both sides to implement and execute the agreed initiatives. Its success is related to participation and capacity to achieve consensus among the polluters/users (e.g. farmers) and those who seek the abatement of pollution (e.g. environmental NGOs).
- PO-7: This option will be successful when implemented by a team of competent professionals who can recruit properly, set up high quality courses and training programmes and stimulate and encourage the participants. Providing the participants with practice during and after the training will inspire them to act according to a sustainable use of land and water resources, causing minimal pollution.

Under adverse conditions it is expected that:

- PO-5: The lack of real interest in working on the issue of pollution for the purpose of sustainable use of natural resources could lead to failure in establishing the agreements needed to control pollution. The idea of setting up a Committee that should help to reactivate and give more dynamics to the Bi-national Commission Brazil and Uruguay may lead to scepticism in society about bi-national initiatives. It may even further delay the process of integrating environmental management.

- PO-7: There is a possibility that the professionals chosen for recruiting, skill-building and training will not be sufficiently competent. Maybe they will fail to motivate the audience in environmental issues and the replacement of polluting practices with sustainable ones. Such a failure would result in lack of interest, lack of motivation and inefficiency.

Efficiency

Lists of probable direct, indirect, options, bequest and existence benefits, for each option, are presented in Table 22 and 23.

Costs

The costs for each policy option are presented in Table 24.

Equity

The net winners and net losers and their gains and losses are from a general perspective and considering common objectives, the whole society (poor and rich, rural and urban, from industry, from commerce and agriculture), which gains from the implementation of a Bi-national Mirim Lagoon Basin Committee and a Technical and professional training programme. From a more limited perspective a few winners and losers can be classified, according to both policy options PO-5 and PO-7: the direct beneficiaries will be the entire population that lives in the basin, who will recover the right to have unpolluted water, a pleasant environment, and reduced health risks due to pollution. The entire society gains with the potential opportunities for future development of new economic sectors (e.g. ecological agriculture, ecotourism). The loss could be highlighted only if justified by the internalisation of environmental costs by the potentially polluting productive activities (mostly crops), which would have to adjust to the prevailing environmental standards. In other words, landowners who use conventional agriculture productive processes (intensive use of chemical products to produce rice in the Mirim Lagoon basin) may have some economic losses, particularly in the short-term perspective during the restructuring period when new agricultural practices must be accommodated. For these types of selected policy options, it is not possible to perform quantitative estimates (physical and/or monetary units) of the gains and losses. However, from a perspective of equity and social justice (included well-being), it can be assumed that market mechanisms (Huber et al. 1998) favour fair exchanges. Therefore, based on the assumption that exchanges are fair, the benefits received by the gainers are the equivalent of costs incurred by the losers. Based on current knowledge it is not possible to measure this result quantitatively.

Table 22 Probable direct, indirect, option, bequest, and existence benefits for PO-5.

Benefits	PO-5: Bi-national Mirim Lagoon basin Committee
Direct	Reduction in the costs of transactions by reducing international conflicts; and reduction of chemical pollution and the costs to treat water for human supply.
Indirect	Healthier and more productive aquatic ecosystems regarding fish stocks due to reduction of pollution; long-term improvement of human health, particularly regarding occupational health (farmers) due to reduction of contact with chemical products; idem to water consumers.
Option	Protection of the aquatic environment, which in the future may be of economic value, with an option for aquaculture and/or ecotourism in a system with unpolluted water.
Bequest	Protection of the historical and cultural heritage for future generations, by not modifying habitats and structures, caused by pollution.
Existence	Protection of species that might otherwise become extinct with the intensification of pollution in the Mirim Lagoon basin; and preservation of natural wetlands with high biodiversity value and that host important migratory species.

Table 23 Probable direct, indirect, option, bequest, and existence benefits for PO-7.

Benefits	PO-7: Technical and professional training
Direct	Reduction of conflicts, optimising time and resources for pollution reduction actions; easier implementation of initiatives to reduce pollution by a qualified group of professionals.
Indirect	Healthier and more productive aquatic ecosystems regarding fish stocks due to reduction of pollution; reactivation of the fisheries by re-population practices; reduction of costs to treat water for human supply; long-term improvement of human health.
Option	Protection of the (aquatic) environment which may, in the future, be of economic value, with the option for aquaculture and/or ecotourism in a system with unpolluted waters.
Bequest	Protection of the historical and cultural heritage for future generations, by not modifying habitats and structures, caused by pollution.
Existence	Protection of species that may become extinct as the use of chemicals in the Mirim Lagoon basin is intensified; protection of ecological reserves (Taim, Peixe Lagoon National Park) that may become extinct as pollution and their adverse effects on the environment increase.

Table 24 The costs for PO-5 and PO-7.

Policy option	Costs
PO-5: Bi-national Mirim Lagoon Basin Committee	Contract for the mobilisation team; contract for specialised consultants; costs of equipment (rental) and other costs; travelling costs, accommodation, daily allowance for consultants and stakeholders to participate in the meetings; costs of meetings (rent of rooms, contract for support personnel, material, etc.).
PO-7: Technical and professional training	Contract for professional team; contract for specialised consultants; costs of equipment (rental) and other costs (production of training material); travelling costs, accommodation, daily allowance for field visits in areas to be examined, logistics; travelling costs for the professional team and the participants in the training programme.

Political feasibility

According to the Brazilian International Trade Ministry (MRE 2003), the diplomatic relationship between Brazil and Uruguay has been strengthened during recent decades due to three factors: (i) gradual implementation of the integration ideal illustrated by the establishment of the MERCOSUR (the South Common Market including originally Brazil, Argentina, Uruguay and Paraguay); (ii) affinities between countries regarding regional and international problems as expressed in different arenas; and (iii) revitalisation of transboundary contracts and agreements. The energy sector, primarily electricity, has been one of the important economic activities that brought the countries together. Additionally, Brazil is the main business partner of Uruguay. In

1998 Brazil imported 34.4% (790 million USD) of the Uruguayan exports. In the same year, Brazil exported to Uruguay 719 million USD, which represented 20.1% of the total imports by Uruguay. The transboundary cooperation between the countries had the General Commission of Brazilian-Uruguayan Coordination (CGC) as the institutional starting point, and then, the Commission for Join Development of Transboundary Zones (CDZF). Among existing bi-national commissions, there is The Commission for Development of Mirim Lagoon basin (CLM). The initiative of integrated water resource management for Mirim Lagoon basin is a topic that has received attention during recent years. However, the effective implementation of an integrated and efficient management plan has not yet occurred. This favourable political scenario should overcome any eventual resistance by isolated segments of the agriculture sector in the basin.

Implementation capacity

Basically, there is a potential capacity to implement the policy options proposed. This may come from the national government agencies in Uruguay and Brazil, from the state of Rio Grande do Sul, and the Uruguayan departments included in Mirim Lagoon basin, as well as research and teaching institutions, such as the Brazilian Company of Agriculture Research (EMBRAPA), Brazilian Institute of Environment (IBAMA/CEPERG), University of Rio Grande Foundation (FURG), Federal University of Rio Grande do Sul (UFRGS), and the Uruguayan National Institute of Agriculture Research (INIA) among others. Some recent initiatives of developing a participative fishing management have demonstrated that the capacity to mobilise local communities for specific programmes exist (CEPERG 2003).

Conclusions and recommendations

After performing the Causal chain analysis for Pollution in Mirim Lagoon system, it was observed that pollution has three main immediate causes: suspended solids (disturbed erosion/sedimentation ratio); chemical pollution (use of pesticides); and an enrichment of the water body with nutrients, increasing the risk of eutrophication (use of chemical fertilisers in agriculture). All immediate causes are associated to agriculture as the main economic sector causing pollution in Mirim Lagoon basin, where land use is also causing fragmentation/modification of habitats in a wetland region of great importance from the biodiversity viewpoint. When searching for the root causes, three main groups of causes appeared: lack of knowledge, lack of economic incentives and governance failure, and lack of a bi-national basin integrated management plan. The fact that one sector appears to be dominant made it easier to direct and indicate the policy options. The choice of two policy options among nine originally proposed was based on the fact that: (i) the implementation of the others depends upon preparation of the adequate institutional/governance environment for development of an integrated basin management plan; (ii) these two options represent a necessary support to strengthen and empower the existing Bi-national Brazil-Uruguay Commission for Mirim Lagoon; and (iii) less time and resources (financial and human) are required for these two options than for the others, before significant results are achieved. In analysing the feasibility criteria of the project (effectiveness, efficiency, equity, political feasibility and implementation capacity), aspects favourable to the implementation of these two chosen options were identified, as well as risks of failure. In the criteria that highlighted possibilities of failures, strategies to eliminate them were briefly mentioned.

Both policy options PO-5 (Creation of Mirim Lagoon Basin Committee and empowerment of the Brazilian and the Uruguayan Mirim Lagoon Agencies), and PO-7 (Technical and professional training), have similar characteristics of learning and developing skills in the communities and may act simultaneously, exchanging information and solving difficulties. This synergy is likely to minimise the risks of failure for both options.

Finally, if successfully implemented, these two policy options will automatically act as an empowerment mechanism for the existing Bi-national Commission for the development of Mirim Lagoon basin (PO-4). These options will also create favourable conditions and increase the feasibility for implementation of more challenging or costly options, such as PO-1/2/3, PO-6, PO-8 and PO-9.

Doce River basin

The Policy option analysis conducted through the GIWA project should necessarily be developed within the scope of implementing the National Water Resources Policy, with the support of the Brazilian National Agency of Water (ANA) (Agência Nacional de Águas) and the Secretariat of Water Resources of the Ministry of the Environment. It should support the implementation of the Doce River Basin Committee that had its first meeting in April 2003 (Comitê da Bacia Hidrográfica do Rio Doce 2004) when the main challenges and the expectation of different stakeholders were discussed. Since then, the Committee has been preparing an agenda of initiatives in the basin. It is proposed that the policy options suggested should act together with this initiative, to initiate projects that contribute to the implementation of the agenda approved by the Committee. The agenda of the Doce River basin Committee is to propose a number of activities that may possibly be included in the projects to be described below.

Definition of the problems

The Causal chain analysis performed and interviews with the specialists of the Brazilian National Agency off Water (ANA) (Mr. Rodrigo Flecha and Ms. Flávia Barros, personal communication) gave rise to the conclusion that the main problem of the basin in terms of socio-economic impacts is the risk to life and property caused by floods. The floods are caused by different factors that determine changes in the sediments transport dynamics such as soil erosion and siltation, with the consequent reduction of the run-off capacity of the watercourses.

They are also aggravated by the occupation of river flood plains in urban areas, causing retention of the flow with consequent flooding upstream, and danger of flash floods downstream. The policy options presented aim to solve this problem. Since the perception of stakeholders in the basin coincides with this prioritisation, any initiative to mitigate these impacts can count on their support. This is also a good criterion to be considered in the policy options analysis, since such support will increase the feasibility and probability of success.

Policy options

PO-1: Participatory plan for flood control

As a flood control plan is the main demand in the basin, it is proposed that it should be prepared by the same institutional arrangement that is to implement it. This should be a social organisation constituted of different sectors of society. Actions should involve environmental education, reorganisation of the territorial space and in some cases, structural measures with the financial support of the communities and/or of the government authorities. The reason for this strategy is that flood problems in the basin are aggravated by human activities, both due to inadequate management of land in the rural area and due to occupation of the flood plain in urban areas.

The attempt to involve these stakeholders in preparing the flood control plan is a way to increase the understanding of the impacts humans cause, and thus induce them to take measures to avoid causing such problems. When stakeholders from the states of Minas Gerais and Espírito Santo are involved, as well as those from the Federal Government, an experience of cooperative action is sought, which will make it possible to overcome obstacles created by the situation of multiple responsibilities and jurisdictions over the waters and the land (UNCED 1992).

PO-2: Manual to prepare City Statutes (Ordinances)

The main problems of the Doce River basin, generated in the urban areas, are a result of inadequate land use, through the occupation of the flood plain. This contributes to the intensification of erosion processes, the pollution of water sources, increased flooding, and other negative factors. This project will aim to prepare a manual to guide the Statutes of the Cities in the basin, which can be employed by administrators for more adequate land use and zoning. It may guide the city administrations in the procedures required to control the main impacts caused by harmful land occupation, including land with excessively steep slopes, which causes erosion, those located in flood plains and, also those whose waters drain into the sources of water supply. This manual is to be disseminated by the Doce River Basin Committee, which, therefore, should participate in writing it. The participation of political leaders into the implementation process is very important (Hens 1996). This policy option is proposed as a complement to PO-1, which deals with the flood problem in a generic form. PO-2 targets one of the specific causes of the problem.

PO-3: Pilot project for basin reforestation, associated with the enhancement of family agriculture

One of the main problems in the basin is the erosion of mining areas and abandoned grazing areas located in areas previously occupied by the Atlantic Rainforest. This contributes to the intensification of erosion processes, the pollution of sources of water, worsened flooding, and other negative factors. The pilot project is proposed to mitigate this problem by providing incentives for family farming that would occupy these areas with self-sustainable projects that would recover the areas at the same time as they would generate income.

PO-3 is proposed as a complement to PO-1; the latter deals with the flood problem in a generic form. PO-3 targets one of the specific causes of the problem.

PO-4: Green incentives application

This policy option is part of the line of green incentives proposed in studies by the Brazilian National Agency of Water in the agricultural environment. It is intended to compensate the farmers who promote environmental protection practices, mainly those that have a potential to mitigate flood problems with practices such as appropriate land use and preservation of riparian vegetation. Thus, the polluter pays principle could be "turned around" in certain cases, generating the principle that could be called "water protector-creditor" (Irrigação e Tecnologia Moderna 2002). The viability of this approach to the basin and the incentives to be offered should be evaluated by this policy option.

PO-5: Information system on water resources in the Doce River basin

The purpose of this project is to integrate the different stakeholders that have databases of interest in the field of water resources and the environment in the Doce River basin. The aim is to build a decentralised information system based on the principle of the "Clearing-House Mechanism", made available via the Internet, in order to provide greater flexibility in seeking, collecting, compiling and disseminating data on the basin. The "Clearing-House Mechanism" is a facilitation system in which the Focal point, in this case the Brazilian Ministry of the Environment, does not necessarily need to have a centralised database, but acts as a link to the web pages that have the information. The system acts as a web in which all points interact with each other. The main function of the Focal point is to standardise the information that will be available via the Internet. This should improve and facilitate the process of management, monitoring and enforcement of the public and private actions in the basin and decision-making, and increase and further disseminate knowledge of the Doce River basin.

One of the main uses of this system will be flood control. The already existing flood alert system will be added to it. However, the system conceived is intended to go beyond simply warning about the occurrence of floods. Among other possibilities, it will map the flood risk areas, identify improvements to be implemented, make it easier to mobilise society around priority policy options, etc.

Recommended policy options

The selected policy options (PO) are:

- PO-1: Participatory plan for flood control;
- PO-2: Manual to prepare City Statutes (Ordinances);
- PO-3: Pilot project for basin reforestation associated with the enhancement of family agriculture.

These were selected because they are all oriented to solving the main socio-economic impacts (see the Causal chain analysis diagram for Doce River basin, Figure 47) identified in the basin associated to the floods (PO-1) and they also act on the two main root causes: inadequate occupation of the land in the urban area (PO-2) and inadequate management of the land in the rural area (PO-3). Besides this, these options also act on three of the other root causes outlined below.

Governance: Lack of basin-wide management plan

Although the participatory plan for flood control (PO-1) is not a basin-wide management plan, it may be considered a phase of this. Since it affects everyone, this will allow the basin stakeholders to be trained to prepare a more ambitious plan, encouraged by a socio-economic impact that has a great potential for action. Because it involves farmers in seeking new alternatives for agricultural management, PO-3 will have a relevant demonstrative effect, which will enable its dissemination throughout the Doce River basin, wherever applicable mitigating the effects of land misuse. It also presents a potential for organising groups of stakeholders that are essential for the success of public policies.

Governance: Lack of legitimacy in negotiations requiring decisions regarding investments

A participatory plan such as that of PO-1, with a potential to mobilise the stakeholders to prepare it, is a safe step to ensure the legitimacy of the negotiations that will be held for this purpose. This will be an important and probably irreversible step for the stakeholders to establish a new water management paradigm, based on a participatory decision process that will reinforce the role of the Doce River Basin Committee.

Knowledge: Insufficient training regarding best land use practices

PO-2 and PO-3 aim to develop and disseminate knowledge and hold training on its applications in the urban and rural areas. With these two policy options, the knowledge needed to promote changes in the current unsustainable practices regarding land use and soil occupation will be organised and structured with the participation of all stakeholders of importance in the basin, particularly the Basin Committee members. The material will be made available and will be disseminated by the Committee itself. This strategy is expected to perform better than implementing a conventional training programme planned, organised and offered by experts only.

Performance of the chosen alternatives

It should be understood that the root causes originate from a process of centralised water management without stakeholder involvement. The policy options aim to modify this process and therefore their results must be evaluated not by products created, but by the substantive quality of the water management that, with their aid, will be gradually implemented in the basin. The evaluation of the effectiveness and efficiency of the policy options should be performed, therefore, not by considering the products, but by considering the actual, real modifications in the water management process.

Effectiveness

The root causes identified in the casual chain analysis are to be mitigated not by achieving structural interventions, but mostly by non-structural changes in the forms of water management in the Doce River basin. For this reason, quantitative values that may estimate the effectiveness of the policy options cannot be proposed. It is understood that the policy options will have a positive impact on the process of organising society to manage water resources based on a participatory and decentralised approach (UNCED 1992).

The obstacles and risk of project failure may result from attempts to implement it in parallel with the water management in the Doce River basin, promoted by the Secretariat of Water Resources and by the National Agency of Water of the Brazilian Ministry of the Environment, and by entities from the states of Minas Gerais and Espírito Santo. These will be minimised if the policy options are developed as mentioned previously within the scope of the initiative promoted by those institutions and with their approval.

Under favourable conditions it may be expected that:

- PO-1 will be successful in promoting a Participatory plan for flood control throughout the Doce River basin, with the participation of all the stakeholders, especially the farmers who adopt inadequate management practices and the people who occupy the flood plains. The municipal governments that are sensitive to the need for the adoption of city statutes that take water demands into account participate actively in this.
- PO-2 has a technical team to prepare the manual that is joined by the stakeholders, particularly those members of the Basin Committee, with sufficient knowledge of the technical, environmental, social, legal, political and institutional aspects, which will permit the preparation of a manual to be adopted by the municipal administrations to write their city statutes.
- PO-3 has a technical team prepared for this challenge that is joined by the stakeholders members of the Basin Committee. The groups of farmers involved have already been identified. Sustainable options must be offered for family farming, generating income with appropriate management of the soil, and recovering degraded areas.

Under unfavourable conditions the scenarios could be:

- There is no interest in the participation of stakeholders in preparing PO-1, the Participatory plan for flood control. It becomes a conventional, technocratic plan, aiming to undertake projects or non-structural measures that have not been discussed and approved by the stakeholders. For this reason, no change occurs in the relationship between society and the environment, and the human activities that aggravated the flood problems in the basin continue to exist.
- The technical team prepares the manual PO-2 alone with no participation of the stakeholders and the Basin Committee does not know or finds it difficult to identify the technical, environmental, social, legal, political and institutional aspects that are involved in preparing the city statutes. The manual becomes a document that is unrelated to the reality of the basin, and is not adopted by the municipal administrations in writing their city statutes (ownership failure).
- The technical team prepares the PO-3 alone or with the participation of the Basin Committee but with no direct engagement of the main affected group, the farmers, and cannot define viable socio-economic alternatives for alternative soil management in degraded areas with the participation of family farming. Or, even if it is successful in this definition, it does not manage to attract farmers who are not ready to adopt new alternatives for land management (ownership failure).

Analysing the spectrum of scenarios, it is observed that PO-3 is the one that presents the highest risks, because besides the technical expertise and the Basin Committee participation, it requires the highest commitment of the stakeholders, particularly the farmers. PO-2 presents the lowest risks, since it requires a competent technical team and the participation of the Basin Committee, which is already organised, to prepare a qualified manual for the city statutes. This will make it relatively easy to have it adopted by the municipal administration, if necessary induced to do so by the states or the Union.

Efficiency

The lists of probable direct, indirect, option, bequest and existence benefits, for each project, are presented in Table 25, 26 and 27.

Costs

The types of costs for each policy option are presented in Table 28.

Equity

Since the projects proposed are oriented towards better water management, they do not have specific beneficiaries, because all of society will benefit directly or indirectly from them. However, if we seek to focus on the most immediate beneficiaries, the following benefits may occur:

- PO-1: Participatory plan for flood control - this should directly benefit the population subjected to flood damage. However, its indirect effects, connected to sediment reductions in the watercourses will benefit the riparian population.
- PO-2: Manual to prepare city statutes (Ordinances) - this will directly benefit the urban population, which will be less exposed to flood risks if its advice is obeyed in the city statutes. The riparian population located upstream from the urban areas will also directly benefit from the reduction in water impoundment flood effects. Indirectly, the riparian population downstream from the areas improved as advised by the city statutes will also benefit from sediment reduction.
- PO-3: Pilot project for basin reforestation associated with the enhancement of family agriculture - this will benefit the farmers involved directly. Indirectly it will benefit the riparian population, due to the reduction in the amount of sediment transported in the rivers.

The selected policy options aim to generate public good, and therefore, contribute to the well-being. In all cases, investments must be made by the government, at the federal, state and municipal levels.

Table 25 Probable direct, indirect, option, bequest, and existence benefits for PO-1.

Benefits	PO-1: Participatory plan for flood control
Direct	Reduction of damages and deaths caused by floods.
Indirect	Increased work life of reservoirs due to less siltation; reduction in dredging costs; the possibility that, eventually a waterway will be become feasible.
Option	Protection of species that may acquire economic value in the future when siltation of rivers is reduced.
Bequest	Protection of the historical and cultural heritage for future generations by reduced floods.
Existence	Protection of species that might become extinct if the siltation process is intensified.

Table 26 Probable direct, indirect, option, bequest, and existence benefits for PO-2.

Benefits	PO-2: Manual to prepare City Statutes (Ordinances)
Direct	Reduction of damages and deaths due to floods; and reduction of costs of intake and treatment of water for supply.
Indirect	Reduction of costs for changes in infrastructure as a result of the growth of cities.
Option	Protection of species that may, in future, acquire economic value to reduced siltation of the rivers.
Bequest	Protection of the historical and cultural heritage for future generations, by reduced floods.
Existence	Protection of species that might become extinct if the siltation process intensifies.

Table 27 Probable direct, indirect, option, bequest, and existence benefits for PO-3.

Benefits	PO-3: Pilot project for basin reforestation associated with the enhancement of family agriculture
Direct	Reduction of damages caused by erosion and siltation; increased agricultural production.
Indirect	Reduction of costs of housing migrants on the outskirts of the cities.
Option	Protection of species that may, in future, acquire economic value, reducing deforestation, soil erosion and siltation of the rivers.
Bequest	Protection of the historical and cultural heritage for future generations by reduced erosion process, siltation and floods.
Existence	Protection of species that might become extinct if erosion, siltation and floods are intensified.

Table 28 The costs for PO-5 and PO-7.

Policy option	Costs
PO-1: Participatory plan for flood control	Contract of the mobilisation team; contract for specialised consultancies regarding pertinent aspects; payment of transport and the stay of stakeholders to participate in the meetings; costs of meetings (rental of rooms, contract with support staff, materials, etc.).
PO-2: Manual to prepare City Statutes (Ordinances)	Contract with a technical team.
PO-3: Pilot project for basin reforestation associated with the enhancement of family agriculture	Contract with a technical team; investments in the areas of the pilot-policy options selected; costs of disseminating the results of the pilot-projects: leaflets, audio-visual materials, site visits, etc.

Political feasibility

There ought to be no opposition to the implementation of the policy options. The PO-1 and PO-3 should have the participation of society, which reduces the potential for conflicts. PO-2 foresees writing a manual to prepare City Statutes (Ordinances), which also does not generate conflicts. The implementation of the city statutes may be the object of opposition, especially by those who hold interests that will be restricted. Insofar as these interests are socially legitimate, compensation may be foreseen, reducing the potential for conflicts.

Implementation capacity

There is already an implementation capacity both in the basin and in the states where it is located. This occurs both in the public sphere, at the federal, state and municipal levels and in the private spheres and third sector entities (NGOs). The mobilisation process of society to create the Doce River Basin Committee during the last years created this capacity, which will facilitate the implementation of the selected policy options.

Conclusions and recommendations

The policy options selected for the Doce River basin were: PO-1 Participatory plan for flood control; PO-2 Manual to prepare City Statutes (Ordinances); and PO-3 Pilot project for basin reforestation associated with the enhancement of family agriculture. The policy options were proposed to address the root causes of Pollution, which in some cases are common root causes for the concern Habitat and community modification. The options have equity, political feasibility and implementation capacity, as long as they are conceived and implemented with the participation of the stakeholders currently involved in the implementation of the Doce River Basin Committee. It is emphatically recommended that any initiative to be implemented should start by approaching the Secretariat of Water Resources (SNRH) and the Brazilian National Agency of Water (ANA), which play a relevant role in the aforementioned process of improving water management in the basin.

Conclusions and recommendations

Drainage basins and coastal zones in developing countries which are densely occupied, heavily exploited in terms of their natural resources, and facing economic growth are likely to suffer from moderate to severe environmental impacts regarding different issues. This is due to a combination of the anthropogenic pressures associated with institutional weakness resulting in lack of enforcement and governance failure, which are frequently among the root causes of environmental degradation in developing countries. The current status of water resources, coastal zones and the associated living resources in the Brazil Current region fits into the above-mentioned scenario.

When analysing the severity of impacts for three separate sub-regions, only 3 among 22 issues were assessed as "no known impact": pollution by radionuclides, UV-B radiation increase due to ozone layer depletion and changes in ocean CO_2 source/sink functions. The majority of the issues were assessed as causing moderate impacts and few issues were assessed as causing severe or slight impacts. The following issues were assessed as severe, regarding the environmental impacts they produce: suspended solids (South/Southeast Atlantic Basins, East Atlantic Basins and São Francisco River Basin); ecosystems modification (South/Southeast Atlantic Basins, East Atlantic Basins and São Francisco River Basin); overexploitation of fish (South/Southeast Atlantic Basins, East Atlantic Basins and São Francisco River Basin); excessive by-catch and discard (South/Southeast Atlantic Basins, East Atlantic Basins and São Francisco River Basin); destructive fishing practices (South/Southeast Atlantic Basins, East Atlantic Basins); and modification of stream flow (São Francisco River Basin). Some issues were assessed as causing moderate environmental impacts due to the fact they are restricted to special areas (e.g. eutrophication and chemical pollution). However in those areas where they occur, the impacts caused were considered severe.

The most severe impact related to Freshwater shortage in the Brazil Current region is found in the São Francisco River Basin and is caused by modification of stream flow. This, in turn, is associated with the cascade of reservoirs built for power generation, and is aggravated by the semi-arid conditions in the middle-lower and lower São Francisco. In this basin, the social impacts due to freshwater shortage are considered severe. In all three sub-regions of the Brazil Current, the economic impacts associated with freshwater shortage are considered moderate at present, but with a strong tendency to become severe in a near future. The reasons for anticipating such worsening are: (i) demand for water is going to increase as a consequence of economic development and population growth (although the economy in the region has slowed down during recent years); (ii) pollution of existing supplies currently assessed as causing moderate impacts will demand significant investments during the coming years if the water supply shall meet the quality standards required; and (iii) water-use charging and increasing penalties and fees due to pollution of existing supplies are foreseen as a consequence of institutional strengthening and population awareness. There have been some demonstrations that the national, state and municipal governments will treat freshwater shortage as a priority during the coming years, which makes it possible to anticipate some slight reduction of health and social impacts in the East Atlantic Basins and the São Francisco River Basin and no worsening in South/Southeast Atlantic Basins. São Francisco River Basin is already the focus of a GEF - Brazilian government initiative, the project 'Integrated Management of Land-Based Activities in the São Francisco River Basin', within the international waters focal area of GEF. Several sub-projects are expected to reduce the pollution problem in this basin.

For the narrow strip of land that forms the Atlantic Basin of Uruguay (assessed separately from the Brazil Current) freshwater shortage is considered to produce slight impacts in the present conditions but these impacts are expected to increase due to the development of tourism in the region.

Pollution was the most controversial concern when assessing the severity of the impacts due to scaling and methodological aspects. Polluted sites (hot spots) assessed as being severely impacted are usually restricted to bays, estuaries and lagoons frequently placed downstream of populated and industrialised urban areas or intensively exploited areas in terms of mining, or agriculture. If the area severely impacted is compared to the whole Brazil Current Basin area in terms of km^2, it can be considered small. Additionally, most of the information about pollution is available in the form of proxy indicators (e.g. heavy metals concentration in sediments, COD); few data about the environmental impacts that the pollution is causing on living resources is available. Nevertheless, the proxy environmental impact indicators associated with the unquestionable socio-economic impacts due to pollution reveal that this concern has the highest priority in the Brazil Current region. For many issues that form the concern Pollution, such as microbiological, eutrophication, chemical pollution, assessed as causing moderate impact could easily be replaced by severe impact, if the "hot spot approach" was used, instead of the relative geographical extension of the affected area. Among eight environmental issues associated with the concern Pollution, the issue suspended solids was considered to cause severe environmental impacts in all sub-regions of Brazil Current. In several basins, significant changes in particle transport/sedimentation dynamics are the immediate cause of: siltation (e.g. Sepetiba Bay in South/Southeast Atlantic Basins, and Doce River Basin in East Atlantic Basins); coastal erosion (e.g. São Francisco River estuary and Paraíba do Sul River estuary in East Atlantic Basins); eutrophication and trapping of sediments in reservoirs (e.g. Funil Reservoir in Paraíba do Sul River, East Atlantic Basins) and oligotrophic conditions and decrease in productivity downstream some reservoirs (e.g. middle-lower, lower São Francisco River and its estuary). In all these cases, significant habitat and community modifications have been registered. The economic impacts due to pollution were considered severe in South/Southeast Atlantic Basins and East Atlantic Basins and moderate in the São Francisco River Basin with a tendency of aggravation mostly due to the increase of costs associated to water treatment and remediation and recovery of polluted sites. Pollution in the Atlantic Basin of Uruguay was assessed as causing slight impacts with a tendency of becoming moderate in the future. However, tourism also tends to increase its self-regulation mainly due to the fact that when the environmental quality is reduced, tourism moves to cleaner areas and/or the revenue per tourist is reduced.

As previously mentioned, high population density and diversified economic activities, which are heavily dependent on water and associated living resources in developing countries, are likely to develop from moderate to severe impacts. When this occurs, the ecosystems associated with the aquatic environment are among those most affected. In the Brazil Current region, the biodiversity in freshwater systems is closely related to the Atlantic Rainforest biome, which was responsible for the development of extremely high degree of endemism in fishes, among others. Due to the complex dynamism, formation and dimension, when altered by natural or human pressures (only 7% of the original area of the Atlantic Rainforest is left) these environments are irreversibly damaged. Land use, such as waterways diversion, damming, and coastal zone occupation have contributed to the severe environmental impacts on habitats and ecosystems. Even in an optimistic scenario for 2020, when a more effective response from society towards biodiversity preservation is expected, losses that have already occurred are irreversible and therefore, the assessment for future conditions remains severe. Socio-economic impacts associated to the Habitat and community modification concern were considered moderate and include reduction of fish stocks and associated loss in revenue, increase in costs associated with the control of disease vectors and invasive species, loss of scientific value and generational inequity, among others. Expansion of aquaculture in several states of Brazil Current is a matter of concern since there is a risk of aggravation in the habitat and community modifications if aquaculture is not carried out in a proper way. The impacts associated with this concern in the Atlantic Basin of Uruguay, were assessed as moderate, with a trend of being stabilised due to the awareness and international and national initiatives.

Based on global productivity estimates from SeaWiFS, the South/Southeast Atlantic Basins, corresponding to the Large Marine Ecosystem LME 15, is considered Class II - moderately high productive ecosystem (150-300 gC/m^2/year). The East Atlantic Basins and São Francisco estuary are considered Class III - low productivity ecosystem (<150 gC/m^2/year). In these ecosystems, inadequate fishing practices can produce severe impacts on the stocks and the maximum sustainable yield (MSY) is often compromised. The environmental impacts due to unsustainable practices by some economic sectors are aggravated by pollution and ecosystem modifications, such as the mangrove ecosystem. Regarding socio-economic impacts due to unsustainable exploitation of fish and other living resources, a peculiar situation is presented: although fisheries as a sector has been severely impacted due to unsustainable practices, when the whole regional economy was taken into account, the relative economic and social impacts caused by this concern were considered moderate, particularly in South/Southeast Atlantic Basins where the whole economy is stronger and more diversified than in East Atlantic Basins and the São Francisco River Basin. Based on this argument, the severe environmental impacts caused by the concern were not sufficient to place it as the number one priority. Additionally, the position of precedence (meaning that a certain concern contributes to producing another one) that Pollution and Habitat and community modification have over Unsustainable exploitation of fish lifts the first two concerns to a higher position in the priority rank. The Atlantic Basin of Uruguay is associated with the Large Marine Ecosystem LME 14 Patagonian Shelf, which in contrast to the Brazil Current is considered Class I - highly productive ecosystem (>300 $gC/m^2/year$). Unlike the Uruguay coast of the La Plata River, the impacts of unsustainable exploitation of fish and other living resources on the Atlantic coast are still moderate.

Among the issues that form the concern Global change, changes in the hydrological cycle and ocean circulation is the issue with more evidence of impacts in the Brazil Current region, mostly associated with the effects of El Niño and La Niña in the South Atlantic Basins and in the semi-arid portion of São Francisco River Basin. Changes in the hydrological cycle were assessed as causing moderate impacts and sea level change as slight impact. All other issues were assessed as causing unknown impacts, mostly due to lack of information at a regional level. The same scores were extended to the Atlantic Basin of Uruguay.

Final recommendations

The following recommendations arise from the assessment carried out for the Brazil Current region and the Atlantic Basin of Uruguay:

- When searching for the root causes responsible for pollution and habitat and community modification in two selected aquatic systems (Mirim Lagoon and Doce River), three main groups of root causes were identified: (i) governance failure when implementing integrated management plans; (ii) economic distortions that need to be corrected as well as lack of economic incentive tools; and (iii) insufficient knowledge and training regarding sustainable water and land use practices. These causes are likely to be found in the root of many environmental concerns in other aquatic systems in the Brazil Current region and therefore, special attention should be paid to them when developing strategic development plans at municipal, regional and national levels.
- The policy options prioritised for the selected system Mirim Lagoon were: (i) creation of the Mirim Lagoon Basin Committee as an empowerment mechanism for the existing Bi-national Commission for the development of Mirim Lagoon basin; and (ii) implementation of technical and professional training, focusing mostly on the agriculture sector and sustainable land/water use practices.
- For the second selected system Doce River, the policy options proposed to address the root causes of pollution are also expected to mitigate some root causes of habitat and community modification. They were: (i) implementation of a participatory plan for flood control; (ii) elaboration of the manual to prepare the City Statutes (Ordinances); and (iii) a pilot project for basin reforestation associated with the enhancement of the sustainability of family agriculture.
- In both aquatic systems (Mirim Lagoon and Doce River), the policy options selected have equity, political feasibility and implementation capacity, as long as they are conceived and implemented with the close participation of the stakeholders, particularly those that take part of the Bi-National Commission for the Mirim Lagoon and the Doce River Basin Committee.
- Aggregation of data/information generated by both Brazil and Uruguay and completion of studies to fill the gaps in knowledge should be performed to support an integrated management strategy for the bi-national Mirim Lagoon Commission.
- Continuous assessments should be carried out in hot spots/ selected drainage basins of Brazil Current and associated coastal zones (e.g. Paraíba do Sul, Doce, Itajaí-Açu and Jequitinhonha river basins) where anthropogenic activities have caused moderate to severe impacts. The priority issues should be: (i) changes in land use, erosion/sedimentation equilibrium and impacts on freshwater and coastal zones; (ii) chemical pollution associated with industry; and (iii) eutrophication of reservoirs for water supply, lagoons, lakes and bays.
- These studies and experiences in selected initiatives should be used as model/demonstration units to prevent the aggravation of the impacts in other drainage basins/coastal zones suffering the same pressures. The results of this assessment should be available in an easy and cheap format (e.g. project website), including the data and/or information generated by the studies.
- Regional studies on global change and the resulting impacts must be carried out, particularly for UV-B radiation increase due to ozone layer depletion, on which there is little information, although there is some evidence indicating that this issue might be more relevant under present conditions than has previously been considered.
- Studies associated with urbanisation and tourism development in the Atlantic Basin of Uruguay should be carried out as a starting point for implementing policies for development of sustainable tourism. The area boasts important lagoons and coastal ecosystems with valuable biodiversity, which are still relatively preserved, and which represent an enormous potential for ecotourism. Urbanisation, tourism, rice fields and livestock are the main activities to be regulated in order to mitigate and prevent pollution and habitat and community modification.
- Integrated management of drainage basins and their associated coastal zone has already been part of governmental plans/agendas during many years; however, it is necessary to prioritise it with

empowerment of the implementing agencies and the society initiatives, if any significant change in the current trend of fast deterioration of the natural resources in the Brazil Current region should be realised.

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Annexes

Annex I
List of contributing authors and organisations involved

Institutions responsible for the GIWA Assessment in region 39 Brazil Current

- Department of Sanitary and Environmental Engineering, Rio de Janeiro State University UERJ, Rio de Janeiro
- Area of Studies and Environmental Assessment AEDA, Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro PESAGRO-RIO
- Foundation of Culture and Research Noel Rosa

Expert network (Participants in the workshops)

Name	Institutional affiliation	Country	State	Field of work
Ass. Prof. Marcia Marques Region 39 Focal point/GIWA Coordinator for the Latin America and the Caribbean region	Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Impact assessment/pollution
Prof. Antonio Eduardo Lanna	Hydraulics Research Institute (IPH) Federal University of Rio Grande do Sul	Brazil	Rio Grande do Sul	Water resources management
Ass. Prof. Arno Machmann de Oliveira	Center of Exact and Natural Sciences Federal University of Alagoas (UFAL)	Brazil	Alagoas	Sedimentology
Ass. Prof. Bastiaan Knoppers	Department of Geochemistry Fluminense Federal University (UFF)	Brazil	Rio de Janeiro	Aquatic biochemistry
Prof. Carmen L. Wongtschowski Rossi	Department of Biological Oceanography, Oceanographical Institute (IO) São Paulo University (USP)	Brazil	São Paulo	Marine biology
Ass. Prof. Cláudio Antonio G. Egler	Department of Geography, Institute of Geosciences Federal University of Rio de Janeiro (UFRJ)	Brazil	Rio de Janeiro	Geography/natural resources
MSc. Dione Marinho Castro	State Foundation of Engineering and Environment (FEEMA)	Brazil	Rio de Janeiro	Enviornmental planning/geography
Prof. Jorge Xavier da Silva	Geoprocessing Laboratory Federal University of Rio de Janeiro (UFRJ)	Brazil	Rio de Janeiro	Remote sensoring/geoprocessing
Ass. Prof. Eduardo Marone	Center of Marine Studies (CEM)	Brazil	Paraná	Physical oceanography
Ass. Prof. Elmo Rodgrigues	Department of Sanitary and Environmental Engineering Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Water resources/institutional issues
Ass. Prof. Erminda da C. G. Couto	Nucleum of Oceanographic Studies State University of Santa Cruz (UESC)	Brazil	Bahia	Biological oceanography
Ass. Prof. Gisela Aquino Pires do Rio	Department of Geography Institute of Geosciences Federal University of Rio de Janeiro (UFRJ)	Brazil	Rio de Janeiro	Geography/institutional issues
Dr. Henrique Chaves	National Agency of Waters (ANA)	Brazil	Brasília, DF	Water resources management
Eng. Jander Duarte Campos	Coordination of the Water Quality Programme, River Paraíba do Sul (PNUD/SERLA/SEMA/COPPE/UFRJ)	Brazil	Rio de Janeiro	Water resource management
Ass. Prof. Mario Luiz Gomes Soares	Department of Oceanography Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Marine biology/coastal ecosystems
MSc. Manuel P. Sanches	President of Guanabara Bay Institute (IBG)	Brazil	Rio de Janeiro	Political sciences/environmental policy

Ass. Prof. Marcelo Friederichs Landim	Nucleum of Oceanographic Studies State University of Santa Cruz (UESC)	Brazil	Bahia	Biological oceanography
Ass. Prof. Marcus Polette	Center of Technology, Land and Ocean Sciences University of Valley of Itajaí (UNIVALI)	Brazil	Santa Catarina	Oceanography
Ass. Prof. Marilene Ramos	Getúlio Vargas Foundation (FGV)	Brazil	Rio de Janeiro	Water resources management
Ass. Prof. Patrízia Raggi Abdallah	Rio Grande University Foundation (FURG)	Brazil	Rio Grande do Sul	Economy/environment economy
Dr. Paulo Hargreaves	Laboratory of Submarine Technology Technological Center Federal University of Rio de Janeiro (UFRJ)	Brazil	Rio de Janeiro	Fisheries/oceanography
Ass. Prof. Paulo da Cunha Lana	Centro de Estudos Marinhos (CEM)	Brazil	Paraná	Marine biology
Prof. Yara Schaffer-Novelli	Oceanographic Institute São Paulo University (USP)	Brazil	São Paulo	Oceanography/coastal ecosystems

Technical/administrative support

Name	Institutional affiliation	Country	State	Field of work
Mr. Alceu Mendel Junior	Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Cartography/mapping
Geog. Angela Alves	Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Geoprocessing/mapping
Mr. Daniel Salle	Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Administration
Eng. Fábio Kaczala	Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Environmental engineering/indicators searching
Mr. Genilson Golveia	Rio de Janeiro State Agriculture Research Company (PESAGRO-RIO), Niterói	Brazil	Rio de Janeiro	Geoprocessing/Mapping
Eng. Maurício Manzano	Rio de Janeiro State University (UERH)	Brazil	Rio de Janeiro	Indicators searching
Eng. Renato J. de Queiroz Leite	Rio de Janeiro State University (UERJ)	Brazil	Rio de Janeiro	Environmental engineering/indicators searching

Annex II
Detailed scoring tables: South/Southeast Atlantic Basins

I: Freshwater shortage

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
1. Modification of stream flow	2	35	Freshwater shortage	1.8
2. Pollution of existing supplies	2	40		
3. Changes in the water table	1	25		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	25
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	2	50
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	25
Weight average score for Economic impacts		**1.8**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	1	35
Degree of severity	Minimum – Severe (0 1 2 3)	1	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	30
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	2	35
Degree of severity	Minimum – Severe (0 1 2 3)	1	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	30
Weight average score for Other social and community impacts		**1.7**	

II: Pollution

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
4. Microbiological	2	15	Pollution	2.0
5. Eutrophication	2	15		
6. Chemical	2	15		
7. Suspended solids	3	15		
8. Solid wastes	2	15		
9. Thermal	1	5		
10. Radionuclide	0	5		
11. Spills	2	15		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	35
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	3	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	30
Weight average score for Economic impacts		**2.7**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	2	35
Degree of severity	Minimum – Severe (0 1 2 3)	2	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	30
Weight average score for Health impacts		**2.3**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	2	35
Degree of severity	Minimum – Severe (0 1 2 3)	1	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	30
Weight average score for Other social and community impacts		**2.0**	

III: Habitat and community modification

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
12. Loss of ecosystems	2	40	Habitat and community modification	2.6
13.Modification of ecosystems or ecotones, including community structure and/or species composition	3	60		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	30
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	30
Weight average score for Economic impacts		**2.3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	2	35
Degree of severity	Minimum – Severe (0 1 2 3)	1	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	30
Weight average score for Health impacts		**1.4**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	2	35
Degree of severity	Minimum – Severe (0 1 2 3)	2	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	3	30
Weight average score for Other social and community impacts		**2.3**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	35	Unsustainable exploitation of fish	2.7
15. Excessive by-catch and discards	3	15		
16. Destructive fishing practices	3	20		
17. Decreased viability of stock through pollution and disease	2	15		
18. Impact on biological and genetic diversity	2	15		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	1	30
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	2	40
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	2	30
Weight average score for Economic impacts		**1.7**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	1	35
Degree of severity	Minimum – Severe (0 1 2 3)	1	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	30
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	1	35
Degree of severity	Minimum – Severe (0 1 2 3)	1	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	30
Weight average score for Other social and community impacts		**1.0**	

V: Global change

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	50	Global change	1.3
20. Sea level change	1	30		
21. Increased UV-B radiation as a result of ozone depletion	0	10		
22. Changes in ocean CO_2 source/sink function	0	10		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large (0 1 2 3)	2	35
Degree of impact (cost, output changes etc.)	Minimum – Severe (0 1 2 3)	3	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	0	30
Weight average score for Economic impacts		**1.8**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large (0 1 2 3)	1	35
Degree of severity	Minimum – Severe (0 1 2 3)	2	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	0	30
Weight average score for Health impacts		**1.1**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large (0 1 2 3)	2	35
Degree of severity	Minimum – Severe (0 1 2 3)	2	35
Frequency/Duration	Occasion/Short – Continuous (0 1 2 3)	1	30
Weight average score for Other social and community impacts		**1.7**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts: Environmental score		Economic score		Human health score		Social and community score		Overall score
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.75	2.3	1.8	3.0	1.0	1.1	1.7	1.4	**1.7**
Pollution	2.0	2.7	2.7	3.0	2.3	2.4	2.0	2.2	**2.4**
Habitat and community modification	2.6	2.7	2,3	2,4	1.4	1.6	2.3	2.4	**2.2**
Unsustainable exploitation of fish and other living resources	2.7	2.7	1.7	1.7	1.0	1.0	1.0	1.2	**1.6**
Global change	1.3	1.4	1.8	1.9	1.1	1.2	1.2	1.8	**1.5**

If the results in this table were not giving a clear prioritisation, the scores were weighted by assigning different relative importance to present/future and environmental/socio-economic impacts in the following way:

Weight averaged environmental and socio-economic impacts of each GIWA concern

Present (%) (i)	Future (%) (j)	Total (%)
50	50	100

Environmental (k)	Economic (l)	Health (m)	Other social and community impacts (n)	Total (%)
25	25	25	25	100

Concern	Types of impacts: Time weight averaged Environmental score (o)	Time weight averaged Economic score (p)	Time weight averaged Human health score (q)	Time weight averaged Social and community score (r)	Time weight averaged overall score	Rank
	(a)x(i)+(b)x(j)	(c)x(i)+(d)x(j)	(e)x(i)+(f)x(j)	(g)x(i)+(h)x(j)	(o)x(k)+(p)x(l)+(q)x(m)+(r)x(n)	
Freshwater shortage	2.0	2.4	1.0	1.5	**1.7**	**3**
Pollution	2.4	2.8	2.4	2.1	**2.4**	**1**
Habitat and community modification	2.7	2.4	1.5	2.4	**2.2**	**2**
Unsustainable exploitation of fish and other living resources	2.7	1.7	1.0	1.1	**1.6**	**4**
Global change	1.4	1.8	1.1	1.8	**1.5**	**5**

Annex II
Detailed scoring tables: East Atlantic Basins

I: Freshwater shortage

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
1. Modification of stream flow	2	30	Freshwater shortage	1.7
2. Pollution of existing supplies	2	40		
3. Changes in the water table	1	30		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	3	20
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	3	50
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	30
Weight average score for Economic impacts		**2.4**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	1	35
Degree of severity	Minimum 0 1 2 3 Severe	2	35
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	30
Weight average score for Health impacts		**1.4**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	2	35
Degree of severity	Minimum 0 1 2 3 Severe	2	35
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	30
Weight average score for Other social and community impacts		**1.7**	

II: Pollution

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
4. Microbiological	2	15	Pollution	2.1
5. Eutrophication	2	15		
6. Chemical	2	15		
7. Suspended solids	3	25		
8. Solid wastes	2	5		
9. Thermal	1	5		
10. Radionuclide	0	5		
11. Spills	2	15		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	2	35
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	2	35
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	30
Weight average score for Economic impacts		**2.7**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	2	35
Degree of severity	Minimum 0 1 2 3 Severe	2	35
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	30
Weight average score for Health impacts		**2.3**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	2	35
Degree of severity	Minimum 0 1 2 3 Severe	2	35
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	3	30
Weight average score for Other social and community impacts		**2.3**	

III: Habitat and community modification

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
12. Loss of ecosystems	2	40	Habitat and community modification	2.6
13.Modification of ecosystems or ecotones, including community structure and/or species composition	3	60		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	35
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Economic impacts		**2.3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	35
Degree of severity	Minimum – Severe 0 1 2 3	1	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	30
Weight average score for Health impacts		**1.4**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	35
Degree of severity	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Other social and community impacts		**2.3**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	30	Unsustainable exploitation of fish	2.8
15. Excessive by-catch and discards	3	25		
16. Destructive fishing practices	3	25		
17. Decreased viability of stock through pollution and disease	2	10		
18. Impact on biological and genetic diversity	2	10		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	0	35
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Economic impacts		**2.0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	35
Degree of severity	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight average score for Health impacts		**1.3**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	35
Degree of severity	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Other social and community impacts		**2.0**	

V: Global change

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	1	50	Global change	0.9
20. Sea level change	1	30		
21. Increased UV-B radiation as a result of ozone depletion	1	10		
22. Changes in ocean CO_2 source/sink function	0	10		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	35
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	30
Weight average score for Economic impacts		**1.1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	35
Degree of severity	Minimum – Severe 0 1 2 3	1	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	30
Weight average score for Health impacts		**0.7**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	35
Degree of severity	Minimum – Severe 0 1 2 3	1	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	30
Weight average score for Other social and community impacts		**1.4**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.7	2.6	2.4	3.0	1.4	1.3	1.7	2.5	**2.1**
Pollution	2.1	2.8	2.7	3.0	2.3	2.1	2.3	2.4	**2.5**
Habitat and community modification	2.6	2.8	2.3	2.4	1.4	1.5	2.3	2.4	**2.2**
Unsustainable exploitation of fish and other living resources	2.8	2.8	2.0	2.0	1.3	1.3	2.0	2.0	**2.0**
Global change	0.9	1.1	1.1	1.3	0.7	1.0	1.4	1.5	**1.1**

If the results in this table were not giving a clear prioritisation, the scores were weighted by assigning different relative importance to present/future and environmental/socio-economic impacts in the following way:

Weight averaged environmental and socio-economic impacts of each GIWA concern

Present (%) (i)	Future (%) (j)	Total (%)
50	50	100

Environmental (k)	Economic (l)	Health (m)	Other social and community impacts (n)	Total (%)
25	25	25	25	100

Concern	Types of impacts					Rank
	Time weight averaged Environmental score (o)	Time weight averaged Economic score (p)	Time weight averaged Human health score (q)	Time weight averaged Social and community score (r)	Time weight averaged overall score	
	(a)x(i)+(b)x(j)	(c)x(i)+(d)x(j)	(e)x(i)+(f)x(j)	(g)x(i)+(h)x(j)	(o)x(k)+(p)x(l)+(q)x(m)+(r)x(n)	
Freshwater shortage	2.2	2.7	1.3	2.1	**2.1**	**3**
Pollution	2.5	2.8	2.2	2.4	**2.5**	**1**
Habitat and community modification	2.7	2.4	1.4	2.4	**2.2**	**2**
Unsustainable exploitation of fish and other living resources	2.8	2.0	1.3	2.0	**2.0**	**4**
Global change	1.0	1.2	0.9	1.4	**1.1**	**5**

Annex II
Detailed scoring tables: São Francisco River Basin

I: Freshwater shortage

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
1. Modification of stream flow	3	40	Freshwater shortage	2.0
2. Pollution of existing supplies	1	40		
3. Changes in the water table	2	20		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	3	30
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	2	50
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	20
Weight average score for Economic impacts		**2.3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small Very large 0 1 2 3	2	50
Degree of severity	Minimum Severe 0 1 2 3	3	30
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	20
Weight average score for Health impacts		**2.3**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small Very large 0 1 2 3	3	20
Degree of severity	Minimum Severe 0 1 2 3	2	40
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	40
Weight average score for Other social and community impacts		**2.6**	

II: Pollution

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
4. Microbiological	1	15	Pollution	1.9
5. Eutrophication	1	5		
6. Chemical	2	20		
7. Suspended solids	3	35		
8. Solid wastes	1	15		
9. Thermal	0	5		
10. Radionuclide	0	0		
11. Spills	1	5		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	1	35
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	30
Weight average score for Economic impacts		**1.7**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small Very large 0 1 2 3	1	35
Degree of severity	Minimum Severe 0 1 2 3	3	35
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	30
Weight average score for Health impacts		**2.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small Very large 0 1 2 3	1	35
Degree of severity	Minimum Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	30
Weight average score for Other social and community impacts		**20**	

III: Habitat and community modification

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
12. Loss of ecosystems	2	60	Habitat and community modification	2.4
13.Modification of ecosystems or ecotones, including community structure and/or species composition	3	40		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	35
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Economic impacts		**2.3**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	20
Weight average score for Health impacts		**1.4**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	1	40
Degree of severity	Minimum – Severe 0 1 2 3	3	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	20
Weight average score for Other social and community impacts		**2.2**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	30	Unsustainable exploitation of fish	2.2
15. Excessive by-catch and discards	2	30		
16. Destructive fishing practices	2	20		
17. Decreased viability of stock through pollution and disease	1	10		
18. Impact on biological and genetic diversity	2	10		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	0	30
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	3	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight average score for Economic impacts		**2.1**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	40
Degree of severity	Minimum – Severe 0 1 2 3	1	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	20
Weight average score for Health impacts		**1.0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	0	50
Degree of severity	Minimum – Severe 0 1 2 3	3	25
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	25
Weight average score for Other social and community impacts		**1.5**	

V: Global change

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	60	Global change	1.4
20. Sea level change	1	20		
21. Increased UV-B radiation as a result of ozone depletion	0	10		
22. Changes in ocean CO_2 source/sink function	0	10		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	2	35
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	30
Weight average score for Economic impacts		**1.4**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	1	35
Degree of severity	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	30
Weight average score for Health impacts		**1.4**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	35
Degree of severity	Minimum – Severe 0 1 2 3	2	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	25
Weight average score for Other social and community impacts		**1.8**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts: Environmental score		Economic score		Human health score		Social and community score		Overall score
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	2.0	2.2	2.3	2.6	2.3	2.1	2.6	2.5	**2.3**
Pollution	1.9	2.5	1.7	2.1	2.0	1.8	2.0	2.3	**2.0**
Habitat and community modification	2.4	2.8	2.3	2.5	1.4	1.4	2.2	2.4	**2.2**
Unsustainable exploitation of fish and other living resources	2.2	2.0	2.1	2.3	1.0	1.1	1.5	1.6	**1.7**
Global change	1.4	1.5	1.4	1.9	1.4	1.5	1.8	1.9	**1.6**

If the results in this table were not giving a clear prioritisation, the scores were weighted by assigning different relative importance to present/future and environmental/socio-economic impacts in the following way:

Weight averaged environmental and socio-economic impacts of each GIWA concern

Present (%) (i)	Future (%) (j)	Total (%)
50	50	100

Environmental (k)	Economic (l)	Health (m)	Other social and community impacts (n)	Total (%)
25	25	25	25	100

Concern	Types of impacts: Time weight averaged Environmental score (o)	Time weight averaged Economic score (p)	Time weight averaged Human health score (q)	Time weight averaged Social and community score (r)	Time weight averaged overall score	Rank
	(a)x(i)+(b)x(j)	(c)x(i)+(d)x(j)	(e)x(i)+(f)x(j)	(g)x(i)+(h)x(j)	(o)x(k)+(p)x(l)+(q)x(m)+(r)x(n)	
Freshwater shortage	2.1	2.5	2.2	2.6	**2.3**	**1**
Pollution	2.2	1.9	1.9	2.1	**2.0**	**3**
Habitat and community modification	2.6	2.4	1.4	2.3	**2.2**	**2**
Unsustainable exploitation of fish and other living resources	2.1	2.2	1.1	1.6	**1.7**	**4**
Global change	1.5	1.7	1.4	1.8	**1.6**	**5**

Annex III
Detailed assessment worksheets

Report Sheet 1: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: POLLUTION/Issue: MICROBIOLOGICAL/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Faecal coliforms (MPN/100ml)	Report	São Paulo state littoral (427 km)	Weekly sampling in 124 beaches	High	Public access	Governo do Estado de São Paulo 2002	Among the rivers that discharge at the littoral of São Paulo state, 80% are responsible for the variability in terms of appropriateness for swimming (according to CONAMA[1]) found in different beaches, related to discharge of untreated sewage.
Faecal and Total coliforms (MPN/100 ml)	Report	Santos Bay and basin, São Paulo state (3 000 km^2)	1996-1998	High	Public access	Braga et al. 2000	Upper section of the basin with sewage outlets: 3.6 million MPN/100 ml (total coliforms) and 1.64 million MPN/100 ml (faecal coliforms)[2].
Feacal coliforms (MPN/100 ml)	Report	Santa Catarina state littoral (500 km of coastline)	1976-2003	High	Public access	FATMA 2003	In the monitoring programme conducted by the state of Santa Catarina environmental agency, FATMA, there are 182 sampling points distributed along 500 km of coastline, which are weekly sampled from December to March (Summer season). Otherwise, mothly sampling. Aggregated data: 23% of the samples were classified as Not proper for primary contact, according to the threshold limit of the CONAMA Resolution 20/86.
Faecal coliforms (MPN/100 ml)	Report	8 km close to the highest density and close to rivers, channels and sewage regions	Dec. 2002 to Mar. 2003	High	Public access	Instituto Ambiental do Paraná 2003	Based on the data obtained at 46 sampling points taken from the most densely occupied section of the littoral, 37% of the samples were above the threshold limit established for primary contact.
Faecal coliforms (MPN/100 ml)	Report	Guaíba Lake (Patos Lagoon, Rio Grande do Sul state) (10 000 km^2)	1998	High	Public access	Menegat 1998	Upper section: 4 000 to 20 000 MPN/100 ml, Lower section: l 000 MPN/100 ml.

Notes:[1]CONAMA is the Conselho Nacional de Meio Ambiente (National Council for Environment in Portuguese).
[2] According to the CONAMA Resolution 20/86 of June 18th, 1986, regarding total coliforms indicator, the "appropriateness for swimming" class of a certain monitored point in a beach is established by the Maximum Probable Number (MPN) of total coliforms found in 80% of the samples obtained from the same sampling point during each five-week period. The classification for appropriateness for swimming is: Excellent (minimum of 80% of the samples with a maximum of 1 250 MPN/100 ml; Very good (80% of the samples with a maximum of 2 500 MPN/100 ml); Satisfactory (minimum of 80% of the samples with a maximum of 5 000 MPN/100 ml); Not proper for primary contact (the samples do not comply with any of the previous limits). For freshwater, the CONAMA Resolution establishes that 80% of a minimum of five samples taken monthly in any month shall not exceed the following limits: Class 1 (200 MPN/100 ml of faecal coliforms or 1 000 MPN/100 ml of total coliforms); Class 2 (1 000 MPN/100 ml of faecal coliforms or 5 000 MPN/100 ml of total coliforms); Class 3 (4 000 MPN/100 ml of faecal coliforms or 20 000 MPN/100 ml of total coliforms); Class 4 (both faecal as well as total coliforms above the previous limits). For allowed uses of freshwater according to different classes established in the same CONAMA Resolution, see Note 3).

Report Sheet 2: Description of indicators substantiating ENVIRONMENTAL IMPACTS
Region 39b East Atlantic Basins/Concern: POLLUTION/Issue: MICROBIOLOGICAL/Score: 2

Environmental impact indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Total coliforms (MPN/100 ml)	Report	Doce River basin (Minas Gerais and Bahia states):station grid of 59 sampling points	1985 -1990 and 1993-1997 sampling 4 times per year	High	Public access	DNAEE 1990, SRH/MG 2003	Freshwater quality in 1998; % of stations; Total coliform MPN/100 ml Class 4: 40 % 20 000 to 50 000, Class 3: 27.5% 5 000 to 20 000, Class 2: 32.5% 5 000. Classes 3 and 4 are found along the entire Doce River; Class 2 in tributaries less polluted by sewage on the upper lower medium sectors For the multiple uses supplied by this river, the quality class should not be worse than Class 2.
Faecal coliforms (MPN/100 ml)	Report	Doce River basinStation grid of 40 sampling points	1985-1990 and 1993-1997 sampling 4 times per year	High	Public access	DNAEE 1990, SRH/MG 2003	Freshwater quality in 1998; % of stations; Total coliform MPN/100 ml Class 4: 40 % 5 000 to 20 000, Class 3: 30 % 1 000 to 5 000, Class 2: 30 % 1 000. Classes 3 and 4 along the entire Doce River For the multiple uses supplied by this river, the quality class should not be worse than Class 2.
Streptococcus sp. (MPN/100ml)	Report Data table and map	Doce River basin Station grid of 59 samples	1985-1990 and 1993-1997 4 times per year	High	Free public access	DNAEE 1990 SRH/MG 2003	Water quality class in 1998, % of stations; *Streptococcus* sp. MPN/100 ml Worse than Class 4: 16%; > 10 000, Class 4: 39 % 2 000 to 10 000, Class 3: 12 % 1 000 to 2 000, Class 2: 33 % 1 000. Sampling points with water quality worse than Class 4, were observed in highland and lower sectors of the basin.
Untreated municipal sewage (m^3/day)	Report	Paraiba do Sul River basin PSRB (Sao Paulo, Minas Gerais, Rio de Janeiro states)	2000	Medium	Public access	IBGE 2000, SNIU 2000	1 940 405 m^3/day of freshwater is supplied but only 94 440 m^3/day of the wastewater is treated. About 29 % of houses have no sanitary facilities.
Faecal coliforms (MPN/100 ml)	Reports	Upper and middle PSRB, Minas Gerais state	1997	Medium	Public Access	SIH/ANEEL 1999	> 4 000 MPN/100 ml in 80 % of the samples. According to the water quality criteria established by CONAMA (1986)[3], these values surpass to the threshold of Class 2 defined for Paraiba do Sul River.
		Lower PSRB, Rio de Janeiro state	1997	High	Public access		
		PSRB and Jaguari River, São Paulo state	1997	Medium	Public access		
		Paraiba do Sul River basin	1974-1998	High	Public access		
Faecal coliforms (MPN/100 ml)	Report	Paraíba do Sul River estuary (2 000 km^2)	1996	High	Public access	FEMAR 1998	At sewage outlets: < 1 000 MPN/100 ml. Coastal waters and beaches: 0 MPN/100 ml.
Faecal coliforms (MPN/100 ml)	Report	Coastal lagoons of Rio de Janeiro state (600 km^2)	1987-1996	High	Public access	FEEMA 1991, FEMAR 1998	Highly variable numbers in different lagoons.From Maricá Lagoon to Araruama Lagoon: < 250 MPN/100 ml, Metropolitan lagoons: > 4 000 MPN/100 ml.
Faecal coliforms (MPN/100 ml)	Report	Guanabara Bay and basin (4 500 km^2), in Rio de Janeiro state littoral	1987-1998	High	Public access	FEEMA 1991, JICA 1994, Ribeiro 1996, Kjerfve et al. 1997, FEMAR 1998	Upper portion of the bay: > 4 000 MPN/100 ml (up to 72 000 MPN/100 ml at sewage outlets). Central portion of the bay: > 50 and < 1 000 MPN/100 ml, Lower portion of the bay: > 25 and < 250 MPN/100 ml.
Faecal coliforms (MPN/100 ml)	LOICZ Report	Southeastern coast of Brazil (20°-30°S)	Several	High	Public access	Lacerda et al. 2001	High concentration of faecal coliforms (5 000 MPN/100ml) are found in beaches in the southeastern Brazil.
Faecal coliforms (MPN/100 ml)	Report	Sepetiba and Ilha Grande Bays in Rio de Janeiro state (1 400 km^2)	1987-1989 1996-1998	High	Public access	FEEMA 1991 FEMAR 1998	At sewage outlets: > 4 000 MPN/100 ml. In the central and lower sections of the bays: from 0 to less than 250 MPN/100 ml.

[3]CONAMA Resolution No 020/86 defines the classes for water bodies in Brazil, according to threshold limits and permitted uses. According to this resolution the water bodies are classified into five classes (special, Class 1, 2, 3 and 4), based on the water uses. The rivers in the special class are those that can be attained only in completely preserved basins, which have not suffered anthropogenic impacts, due to the requirement of complete absence of pollution. The Class 1 rivers are those that, among other uses can irrigate crops that grow close to the ground and are eaten raw, without peeling. Class 2 waters are those that need conventional treatment to become potable but can be used for primary contact (e.g. swimming). Class 3 waters can only be used for public supply once they have received conventional treatment and no primary contact is allowed. Class 4 waters are those that can be used only for landscape composition and navigation.

Report Sheet 3: Description of indicators substantiating ENVIRONMENTAL IMPACTS
Region 39c São Francisco River Basin/Concern: POLLUTION/Issue: MICROBIOLOGICAL/Score: 2

Environmental impact indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Faecal coliforms (MPN/100 ml)	Report	Middle São Francisco River basin 73 912 km^2	One sampling event with 62 samples	Low	Public access	FEAM 2002	The average concentration of faecal coliforms from 62 samples collected in one sub-basin was 2 400 NPM/100ml, which corresponds to water quality Class 3 (see Notes 2 and 3).
Domestic sewage network (% of population connected)	Report	Entire São Francisco River basin 640 000 km^2	Census every five years	High	Public access	IBGE 2000	In the entire basin only 28.1% of the population is connected to a sewage network and 23.5% have on-site sewage disposal such as septic tank.

Report Sheet 4: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: POLLUTION/Issue: EUTROPHICATION/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Standard trophic state indexes (Rast et al. 1989, Nixon et al. 1996). Nutrient concentration (μg/l), ratios, particulate, organic carbon, dissolved oxygen (mg/l) and chlorophyll a (μg/l)	Report	Santos Bay and basin, Ribeira de Iguape River and Cananéia Lagoon (28 000 km^2)	State governmental monitoring programme	High	Public access	Braga et al. 2000, CETESB in Governo do Estado de São Paulo 2002	Discharge of untreated domestic sewage and industrial effluents in the basin. Santos Bay: varies from eutrophic to hypertrophic conditions. Ribeira de Iguape - Cananéia Lagoon: mesotrophic conditions.
Standard trophic state indexes (Rast et al. 1989, Nixon et al. 1996). Nutrients concentration (μg/l) and ratios, particulate organic carbon, N and P (μg/l), BOD (mg/l) and chlorophyll a (μg/l)	Report	Coastal Lagoons of Santa Catarina state (100 km^2)	1984-1994	High	Public access	Ledo & Soriano-Sierra 1994, Knoppers et al. 1999b	Lagoons under eutrophic to hypertrophic conditions. References cited for the individual lagoons also embed some information on nutrient loading.
	Report	Patos Lagoon, basins and lower estuary (10 000 km^2)	1985- 1997	High	Public access	Baumgarten 1995, Baisch et al. 1997, Niencheski & Baumgarten 1997, Odebrecht & Abreu 1997, Seeliger et. al. 1997, Almeida et al. 1993	Eutrophic in the upper section, mesotrophic in the lower sections and oligotrophic in the estuary.
Registration of algal blooms; species identification and toxicity test in laboratory	Conference paper	Barra Lagoon in Maricá, Rio de Janeiro	1990-1992	High	Public access	Huszar et al. 1992	Few blooms of cyanobacteria have been observed in Barra Lagoon, Maricá, Rio de Janeiro state, when fish kills where reported and the toxicity of the causative organism (*Sinychocystis aquatilis f. salina*) was demonstrated.
Significant growth of the aquaculture activity	Scientific paper	Santa Catarina state littoral	1994-1999	High	Public access	Madrid 1999, Wainberg 2000, Seiffert & Loch 2000	The fish production thorugh the marine aquiculture increased from 2 385 tonnes in 1994 to 7 260 tonnes in 1998, and 15 000 tonnes in 1999 within an area of 5 000 ha. In 2003 this area was expected to expand to 35 000 ha (seven times the area in 1999) generate 35 000 direct jobs, 140 000 indirect jobs and a production of 100 000 tonnes/year, equivalent to 400 million USD/year. Santa Catarina state is the main producer of molluscs through marine aquaculture and shrimp culture is expanding in the state. The risk of eutrophication has increased. Severe environmental impacts due to the expansion of the marine aquaculture is expected based on the former experience in several countries and continents, unless effective environmental control is implemented.
High concentration of nutrients and toxic algal blooms (μg/l)	Scientific papers and reports	Patos Lagoon (30°20'S to 32°10'S)	Several events during 1987-1998	High	Public access	Odebrecht et al. 1987, Yunes et al. 1997, Yunes et al. 1996, Rorig et al. 1998, Baumgarten et al. 1995, Garcia 1997, Niencheski & Baumgarten 1998	In the Patos Lagoon catchment basin there are more than 3 million inhabitants living in several cities, towns, fishing villages and summer resorts. From the north, a drainage basin of approximately 200 000 km^2 formed by several rivers, provides 75-80% of freshwater to the Patos Lagoon and estuary. Massive blooms of toxic cyanobacteria *Microcystis* sp., particularly *Microcystis aeruginosa* have been observed during the last 15 years in the Patos Lagoon. Odebrecht et al. (1987) described blooms of *Mycrocistis aeruginosa* in the limnic waters and at the estuary. Up to 9 000 μg Chl a/l was found; the microcystin concentration was up to 1.1 μg/mg dry weight. Since 1987 several algal bloom events have been reported. Eutrophic conditions were found in the upper section of Patos Lagoon. The blooms of *Microcystis aeroginosa* in Patos Lagoon have been associated to favourable environmental conditions, including pH, temperature and nutrients availability (Niencheski & Baumgarten 1998). During spring, high values of ammonia, nitrate and silicate were found, causing eutrophication and blooms in the estuarine waters close to Rio Grande municipality; high concentrations of phosphate were assumed to be caused by the fertiliser factories located in the basin (Baumgarten et al. 1995).

Report Sheet 5: Description of indicators substantiating ENVIRONMENTAL IMPACTS
Region 39b East Atlantic Basins/Concern: POLLUTION/Issue: EUTROPHICATION/Score: 2

Environmental impact indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Standard trophic state indexes (Rast et al. 1989 and Nixon et al. 1996) Nutrients (µg/l), ratios, particulate organic carbon, dissolved oxygen (mg/l) and chlorophyll a (µg/l)	Report	Guanabara Bay, Sepetiba Bay, Ilha Grande Bay and respective basins (10 400 km^2)	1994-1998	High	Public access	JICA 1994 FEMAR 1998 Kjerfve et al. 2001	Basins: Discharges of untreated domestic sewage and industrial effluents. Guanabara Bay: hypertrophic in the upper section and eutrophic in the lower section. Sepetiba Bay: eutrophic in the upper section and mesotrophic in the lower section. Angra dos Reis Bay: oligotrophic conditions.
	Report	Sepetiba Bay	Several	High	Public access	Lamardo et al. 2000	Dissolved oxygen has significantly declined and algal growth is evident. Many of the references cited for the individual sub-regions also embed some information on nutrient loading.
	Report	Coastal Lagoons of Rio de Janeiro state (600 km^2)	1985-1997	High	Public access	FEMAR 1998 Bidone et al. 1999 Knoppers et al. 1999a	Basins: Variable degree of untreated domestic sewage. Lagoons under eutrophic to hypertrophic conditions increased by their high residence times. During summer some fish kills have been observed.
Concentration of chlorophyll a (µg/l) and dissolved oxygen (mg/l)	Report of the State Environm. Protection Agency	Western margin of Guanabara Bay	State monitoring programme	High	Public access	FEEMA 1990	This part of the bay is considered the most polluted one, due to organic load. The average dissolved oxygen is 3.1 mg/l near the bottom. It presents anoxic bottom mud, excessive level of ammonia and phosphate. The chlorophyll concentration exceeds 130 µg/l as compared to the average level of 57 µg/l.
Standard trophic state indexes (Rast et al. 1989 and Nixon et al. 1996)	MSc Thesis	Piauitinga River, Sergipe state (river, reservoirs and inner estuary) (77 km^2)	1995-1997 monthly	High	Public access	Souza 1993	Effluents from a fertiliser plant and citric industries. Eutrophic conditions in the entire reservoirs and inner part of the estuary.
Nutrient concentrations (mg/l)	Table	Cachoeira River, Bahia state (3 700 km^2)	2000	Low	Restricted access	M.F.L. Souza (pers. comm.)	High ammonium concentrations in the estuarine waters. Presence of untreated sewage discharge upstream (City of Itabuna) and the estuary (City of Ilhéus).
Quantitative assessment of benthic organisms in the reef flat; Concentration (mg/l) of nitrate, nitrite, ammonia, phosphate and silicate; indicator of microbiological contamination *E. coli*. The results found evoke the effects of eutrophication on this coral reef ecoregion.	Scientific paper	2 coastal coral reef regions in Bahia state with different levels of human occupation: Guarajuba reefs (densely urbanised area) and Papa Gente reefs (under-developed area)	Samples taken from coastal lakes, groundwater and coral reefs during both rainy and dry seasons in 1997	High	Public access	Costa et al. 2000	Coral reefs extend from 20 km along the north coast of the state of Bahia. During the last 15 years, this region has experienced an acceleration of generally unplanned urbanisation, with the construcition of septic tanks in urban centres contaminating the groundwater. High densities of macroalgae and heterotrophic organisms were found impacting Guarajuba coral reefs but not Papa Gente reefs. A model of nutrient enrichment via groundwater seepage is the mechanism proposed (Costa et al. 2000) to explain the eutrophication occurring in coral reefs on the northern coast of Bahia. The data suggest that the high availability of nutrients is affecting the trophic structure in Guarajuba, with increased turf and macroalgae growth, reducing light penetration to the coral colonies, competing with them for space and inhibiting the settlement of new coral larvae.
Algal bloom	Paper	Pampulha artificial lake in Belo Horizonte, Minas Gerais, Upper-SFRB	1980s	High	Public access	Goodwin & Giani 1997 and 1998	During the 1980s the eutrofication process in the Pampulha reservoir resulted in frequent blooms of phytoplankton and some fish kills. During 1984/1995 the blooms were associated to *Cylindrospermopsis raciborskii*. In 1989 the blue-green algae *Microcystis aeruginosa*, represented the major portion of annual phytoplankton biomass in the reservoir. More recently this species has shown blooms together with *M. flosaquae* and/or *Coelosphaerium naegelianum* during August and October excluding the years 1993 and 1995.
Standard trophic state indices from Rast et al. 1989 and Nixon et al. 1996	MSc Thesis, Reports	Estuary and coastal waters of Paraiba do Sul River (2 000 km^2)	1995-1996 and state monitoring programme since 1996	High	Public access	Carneiro 1998 Costa 1998	Discharges of untreated domestic sewage and organic matter from sugar cane processing. Mesotrophic estuary and Oligotrophic coastal waters. Many of the references cited for the individual sub-regions also embed some information on nutrient loading.
Industrial effluent load estimates, remaining after treatment (tonnes/day)	Report	Paraiba do Sul River basin	1997	Medium	Public access	COPPE/ UFRJ 2002	Total inputs: Organic matter: 177 tonnes/day, Total suspended solids: 215 tonnes day, Total Nitrogen: 1.1 tonnes/day, Total Phosphorus: 2.2 tonnes/day.
Municipal wastewater, pollutant load that remains after applying the standard reduction factor (tonnes/day)	Report	Paraiba do Sul River	1997	Medium	Public access	COPPE/ UFRJ 2002	Total inputs Organic matter: 103 tonnes/day, Total suspended solids: 43 tonnes/day. Total Nitrogen: 16 tonnes/day, Total Phosphorus: 7 tonnes/day. The values represent approximately 36 % of raw loads. Values obtained by per capita indices and the application of reduction factors considering the absence, presence and degree of sewage treatment.
Increase of organic matter loads expressed in BOD loads (tonnes/day)	Report	Upper Paraiba do Sul River basin, São Paulo state	1978, 1988 and 1995	Medium	Public access	CBH-PSM 1995	From 1978 to 1995 an increase from 20 to 78 tonnes BOD_5/day of untreated effluents is estimated.
Efficiency of wastewater treatment plants expressed in % of BOD_5 (kg/day)	Report	Upper Paraiba do Sul basin, São Paulo state	1997	Medium	Public access	SIGRH-SP 1997	Only 10 % of the organic loads of collected wastewater remain.
Dissolved oxygen (mg/l)	Report	Paraiba do Sul River basin	1974-1998	Medium	Public access	SIGRH-SP 1997 SIH/ANEEL 1999	Except for some stretches along the middle Paraiba do Sul River basin and at effluent discharge point, the river is well oxygenated due to its physiographic and hydrological characteristics.

P-tot, dissolved inorganic phosphorus and ammonia (mg/l)	Report	Paraiba do Sul River basin	1997 and 1974 –1998	Medium	Public access	SIH/ANEEL 1999	Above permissible levels for Class 2 according to the water quality standards (CONAMA 1986). Regarding total phosphorous content: most of the river presents mesotrophic conditions and in some stretches, eutrophic conditions.
P-tot mass balance in Funil reservoir (% of P-tot input that remains in the reservoir)	Report	Funil Reservoir (PSRB - Rio de Janeiro)	1978-1979 1989-1990	High	Public access	SIH/ANEEL 1999	Significant accumulation of total phosphorus in Funil Reservoir according to the monitoring during 1978-1979 and during 1989-1990. About 64% of the total P input was deposited in the reservoir. In 1991 this cummulative value was reduced down to 45% of the previous value. Due to lack of more recent data the cause of this reduction cannot be confirmed. It might be either due to a tendency of higher exportation of P, variability due to sampling procedure or variation in the hydraulic discharge.
Oxygen demand due to nitrification processes in the reservoir	Report	Funil Reservoir (PSRB- Rio de Janeiro)	1978-1979 1989-1991	High	Public access	SIH/ANEEL 1999	The mass balance indicates that part of the oxygen demand in the reservoir occurs due to nitrification processes, observed as reduction of ammonia, partially transformed in organic N and the increase in the amount of nitrate as output from the reservoir. Nitrite values were too low and were not considered in the analysis. The global net budget of N-tot (organic + inorganic) does not indicate accumulation in the reservoir (output minus input of N).
Qualitative and quantitative changes in phytoplankton associated to eutrophication	Report	Funil Reservoir (PSRB-Rio de Janeiro)	1978-1979 compared to 1989	High	Public access	SIH/ANEEL 1999	Significant changes in the species composition due to eutrophication in Funil Reservoir. During 1978-1979: low density and large diversity of phytoplankton species in Funil. Group of chlorophycea prevailed in number of species and individuals (50 % of the total) meanwhile cyanoficeas (dominant forms in eutrophic environment) were 17%. In 1989: The cyanophycea became the dominant group during almost all year reaching levels of relative abundance higher than 90% during summer when the blooms are observed for *Microcystis flos-aquae aeruginosa*, *Microcystis* sp., *Oscillatoria* sp. and *Anabaena* sp.
BOD_5 (mg/l)	Report	Middle and lower PSRB states of Minas Gerais and Rio de Janeiro	1997	Medium	Public access	SIH/ANEEL 1999	Above permissible levels for Class 2 according to the water quality standards (CONAMA 1986).
BOD_5 (mg/l)	Report	Upper Paraíba do Sul River, São Paulo state	1997	Medium	Public access	SIH/ANEEL 1999	Above permissible levels for Class 1; Some tributaries surpassing water quality standards for Class 2 (CONAMA 1986).
Ammonia (mg/l)	Report Data table and map	Doce River basin, Station grid of 59 samples	1985-1990,1993-1997, sampling 4 times per year	High	Public access	DNAEE 1990 SRH-MG(2003	Overall classification of the basin: Class 3 with a range of 0.5 to 1.5 mg/l. Mean levels < 1 mg/l at all sampling stations.
Total phosphate (mg/l)	Report Data table and map	Doce River basin Station grid of 59 samples	1985-1990 1993-1997 4 times per year	High	Public access	DNAEE 1990 SRH-MG 2003	Overall classification of the basin:Class 4 with values higher than 0.025 mg/l. Phosphate mainly in the form of orthophosphate.
BOD_5 (mg/l)	Report Data table and map	Doce River basin Station grid of 59 samples	1985-1990 1993-1997 4 times per year	High	Free public access	DNAEE 1990 SRH-MG 2003	Freshwater quality according to BOD_5 (1998): Class 3 in 17 % of the sampling stations (5 to 10 mg/l); Class 2 in 15 % of the sampling stations (3 to 5 mg/l); Class 1 in 68 % of the sampling stations (< 3 mg/l) The highest BOD conc. was found downstream urban centers of Doce River basin (Ipatinga and Governador Valadares cities) and along the Piracicaba, Cratinga, Guandu and Manhuaçu tributaries.
COD (mg/l)	Report Data table and map	Doce River basin Station grid of 59 samples	1985-1990 1993-1997, 4 times per year	High	Free public access	DNAEE 1990 SRH-MG 2003.	Freshwater quality according to COD values (1998): Class 4 in 2 % of the sampling stations (40 to 80 mg/l); Class 3 in 25 % of the sampling stations (25 to 40 mg/l); Class 2 in 73 % of the sampling stations (< 25 mg/l); Highest COD conc. in the upper-medium and lower-middle Doce River basin.
Dissolved Oxygen (mg/l)	Report Data table and map	Doce River basin Station grid of 59 samples	1985-1990 1993-1997, 4 times per year	High	Free public access	SRH-MG 2003	In general the waters are well oxygenated. During the period, one value was recorded below 5 mg/l.

Report Sheet 6: Description of indicators substantiating ENVIRONMENTAL IMPACTS
Region 39c São Francisco River Basin/Concern: POLLUTION/Issue: EUTROPHICATION/Score: 1

Environmental impact indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Blooms of toxic algae in reservoirs	Report	Paulo Afonso and Itaparica reservoirs in the São Fracisco River basin	Several years	High	Public access	Braga et al. 1999	The environmental impact due to eutrophication was scored as slight due to the eutrophication process and blooms of toxic algae recorded in some reservoirs such as Paulo Afonso and Itaparica.

Report Sheet 7: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: POLLUTION/Issue: CHEMICAL POLLUTION/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Concentration of organic compounds and PCBs in mussels (mg/g)	Report	Coast of Brazil (2 600 km)	1993	High	Public access	UNEP 2000	Total BHCs, Chlordane, Total DDTs, Total PCBs in five sites.
Concentration of organochlorines (ng/g)	Report	Ubatuba and São Sebatião, São Paulo state	1987	High	Public Access	UNEP 2000	High concentrations of organochlorines.
Concentration of heavy metals in water (mg/l)	Report	Estuaries in Santos and São Vicente, São Paulo state (400 km)	1998	High	Public Access	UNEP 2000	High concentrations of heavy metals as a result of industrial activities.
PAHs concentration (µg/g) in sediments	MSc Thesis	Santos Estuary, Sao Paulo state	Several years	High	Public access	Nisighima 1999	High concentrations of total PAHs, close to the industrial complexes of Cubatão were found: 0.08-42.39 µg/g, levels that can affect benthic organisms.
Concentration of chlorinated hydrocarbons and PAHs	Report	Santos Estuary and Guanabara Bay	1991-1992	High	Public access	Taniguchi et al. 1999	Bivalves sampling during the International Watch Programme IMW 1991-1992 were used to access the occurrence of selected chlorinated hydrocarbons and PAH along the Brazilian coast. The highest concentration of these compounds were measured in Santos and Guanabara Bay.
Metals and cholorinated organics	Report	Cubatão complex, Santos Estuary	Several years	High	Public access	Boldrini et al. 1989	High concentrations of metals and chlorinated organics found in sediments, water and aquatic organisms such as fish and crabs.
Intensive port acitivites and inadequate handling of chemical products	Chapter of book	Iguape, Cananéia and Port of Paranaguá in Santa Catarina state	Not given	Medium	Public access	Lamardo et al. 2000	The port of Paranaguá is considered the third most important in Brazil. Due to inadequate handling of chemical products the port activities contribute to the degradation of Santa Catarina littoral, including estuarine lagoons of Iguape, Cananéia and Paranaguá.
Concentration of Cr, Ni and Zn, iron oxide, low pH in effluents and impacts on artisanal fisheries	Report	State of Santa Catarina coast	Unknown	Medium	Public access	Lamardo et al. 2000	The coal mining complex in Santa Catarina, located between Florianopolis and Cabo de Santa Marta Grande discharges effluents with high acidity (low pH), iron oxide and heavy metals such as Cr, Ni and Zn. It has been reported that these pollutants are affecting artisanal fisheries.
Concentrations of Cd and Ni in biotic components of mangroves (ppm)	Report	Mangroves at Itacorubí municipality Santa Catarina state (5 km^2)	1996	High	Public access	UNEP 2000	High concentrations of heavy metals associated to industrial activities.
Concentrations of heavy metals in sediments (µg/g)	Report	Mangroves at Itacorubí municipality, Santa Catarina state	1989	High	Public Access	UNEP 2000	High concentrations of heavy metals associated to industrial activities.
Proxy indicator of chemical pollution: pesticides use	LOICZ Report	Catchment area of Patos Lagoon, Rio Grande do Sul	Several	High	Public Access	Lacerda et al. 2002	The excessive application of pesticides over large areas of agricultural lands around Patos Lagoon (e.g. 890 000 ha with only rice plantation) is likely to contribute to the pollution of the estuary.
Heavy metals concentrations in estuarine sediments (µg/g, dry weight)	Report	Patos Lagoon, Rio Grande do Sul state (10 000 km^2)	1988	High	Public access	UNEP 2000	High concentrations of heavy metals as a result of Industrial activities such as petrochemical, metallurgical, pulp and refineries, whose effluents are discharged in the rivers.
Heavy metals in the water column (µg/l)	Report	Patos Lagoon, Rio Grande do Sul state (10 000 km^2)	1997	High	Public access	Niencheski & Baumgarten 1997	High concentrations of metals in the water column. Pb up to 20 µg/l, Cd up to 6.5 µg/l. Other pollutants were phenol up to 30 µg/l and oil up to 30 mg/l.

Report Sheet 8: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39B east Atlantic Basins/Concern: POLLUTION/Issue: CHEMICAL POLLUTION/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Presence of hydrocarbons due to anthropogenic activities, (µg/l)	MSc Thesis	Japaratuba River and inner estuary, Sergipe state (4 000 km^2)	Not mentioned	Medium	Restricted	Souza 1993	Hydrocarbon concentrations related to chronic discharge of oil production water.
Presence of hydrocarbons due to anthropogenic activities, (µg/l)	MSc Thesis	Sergipe River and inner estuary, Sergipe state (3 800 km^2)	1995 bimonthly sampling	Medium	Restricted	Souza 1993	Hydrocarbon concentrations related to chronic discharge of oil production water.
Fish kills related to chemical pollution, one event per basin annually	PhD Thesis	Piauí River and inner estuary, Sergipe state (4 200 km^2)	1996	High	Public access/ Personal comm.	Souza 2002	Reported annual occurrence of fish and mussel kills related to the washing out of textile/organic effluents from a reservoir.
Concentrations of Hg (µg/l)	Paper	Todos os Santos Bay, Bahia	1980s	High	Public access	Seeliger & Costa 1998	Hg concentrations reach about 2-5 times baseline levels in hot spots.
Heavy metals concentrations (mg/l)	Report	Upper Paraiba do Sul River basin, São Paulo state	1997	High	Public access	SIGRH-SP 1999	Conc. higher than permissible levels for Cr, Cd, Ni and Hg. Abides to Class 2 of water quality (CONAMA 1986).
Heavy metals concentrations (mg/l)	Report	Middle and lower PSRB, Minas Gerais and Rio de Janeiro states	1997	Medium	Public access	ANEEL 1999, COPPE/UFRJ 2002	Conc. higher than permissible levels for Cu, Cd, Zn, As and Al in water samples. Water quality standard either Class 2 or 3 (CONAMA 1986), depending on presence of industrial point sources.
Heavy metals concentrations in suspended matter and sediments (mg/g)	Report	Middle and lower PSRB (only Rio de Janeiro)	1998-1999 392 samples	High	Public access	CPRM 2001	Conc. higher than permissible levels for Cu, Cd, Zn, As and Al in sediments (192 samples) and suspended solids (200 samples).
Phenol concentrations (mg/l)	Reports	Paraiba do Sul River basin	1997	Medium	Public access	SIGRH-SP 1999, SIH/ANEEL 1999	Concentraion of phenol higher than permissible levels for Class 2 (CONAMA 1986).
Contamination of existing water supply by sodium sulphate, calcium hypoclorite, heavy metals, lignine; change of pH from 7.6 up to 11 and death of animals and fishes	National newspaper, Official reports; TV news	PSRB Source: Industrial hazardous waste reservoir in Cataguazes- Minas Gerais. Affected area: Several municipalities in Northern Rio de Janeiro state	April 2003	Medium	Public access	FEEMA 2003a and b O Globo 2003a and b	In March 29, 2003 about 1.2 billion litres of contaminated water entered into PSRB at Minas Gerais state, after wastewater from an accident in the industry Cataguases Papeis Ltda (paper-pulp industry). 40 municipalities in Minas Gerais and Rio de Janeiro states were affected. Fisheries, agriculture, tourism were the most impacted sectors. Fisheries kills and intoxication of animals in the region due to consumption of contaminated water (reptiles, birds, cattle, horses).
Heavy metals concentrations in surface coastal waters (nmol/kg)	Report	Rio de Janeiro state coastal zone (400 km)	1991	High	Public access	UNEP 2000	High concentrations of some heavy metals as a result of industrial activities.
Presence of hydrocarbons and chlorinated organics	Oficial Report	Cabo Frio, Rio de Janeiro state	1997	High	Public access	Lamardo et al. 2000	Presence of hydrocarbons and chlorinated organics.
Concentration of Cd and Zn in sediments and biota	Several scientific papers	Sepetiba Bay, Rio de Janeiro	Several years	High	Public access	Lima et al. 1997, Lacerda et al. 1988, Amado Filho et al. 1999	Several studies demonstrate contamination of sediments and biota by Cd and Zn in Sepetiba Bay.
Total mercury concentration (mg/l)	Report	Sepetiba Bay, Rio de Janeiro state (400 km^2)	1996	High	Public Access	UNEP 2000	High levels of heavy metals concentrations as a result of industrial activities and Sepetiba harbor.
Concentration of Zn, Mn, Pb, Cr and Cd (µg/l)	Scientific papers	Sepetiba Bay	Several years	High	Public access	Lacerda et al. 1988, Niencheski & Baugarten 1998	High concentrations (equal or higher than acceptable levels of Zn, Mn and Pb in the suspended material. Cr and Cd in the water and bottom sediments).
Concentration of Zn in the trophic chain (µg/l)	Scientific paper	Jacarepaguá Lagoon sub-region (Jacarepaguá, Tijuca and Camorim Lagoons)	Several years	High	Public access	Fernandes et al. 1993	High levels of Zn were recorded. Records of particulate metals accumulated in the trophic chain. The author indicate that the steel chemical industries located around the lagoonal complex may be responsible.
Heavy metals above the threshold limits (µg/l)	Report	Guanabara and Sepetiba Bays and Ribeira do Iguape River (32 000 km^2)	1988	High	Public access	Barcellos 1994, Lacerda et al. 2001, Lacerda et al. 1993b, Seelinger 1988	High concentrations of Cd, Cu and Zn in bivalves at Sepetiba Bay/RJ, 20 times more than the maximum allowed for human consumption.
Concentrations of heavy metals in oysters *Cassostrea brasiliana* and macroalgae	Scientific papers	Sepetiba Bay, Rio de Janeiro state	Samples taking in different years	High	Public access	Lima et al. 1986, Lacerda et al. 1988, Amado Filho et al. 1999	Among organisms from different taxonomic groups, oyster (*Cassostrea brasiliana*) and macroalgae had the highest Cd and Zn concentrations. Some organisms had concentration 4-25 times higher than those from nearby clean areas.
Contamination of biota by organochlorines (mg/g)	Report	Cabo Frio, Guanabara Bay, Santos Bay, Paranaguá Bay, Patos Lagoon (2 600 km^2)	1996	High	Public access	UNEP 2000	Organochlorines compounds found in tissue of bivalve molluscs.

Report Sheet 9: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39c São Francisco River Basin/Concern: POLLUTION/Issue: CHEMICAL POLLUTION/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Arsenic (mg/l)	Report	Tributary of the upper São Francisco basin 2 000 km^2	1994 – 1998	High	Public access	IGAM 2001	Maximum As concentration: 0.340 mg/l; average concentration: 0.029 g/l. Total load: 838 kg/year. The affected area is a small portion of the São Francisco basin.
Zinc (mg/l)	Report	Tributary of the upper São Francisco basin 2 000 km^2	1994 – 1998	High	Public access		Zn average concentration 0.16 mg/l. Total load: 5 367 kg/year. The affected area is a small portion of the São Francisco basin.
Copper (mg/l)	Report	Tributary of the upper São Francisco basin 2 000 km^2	1994 – 1998	High	Public access		Cu average concentration 0.05 mg/l. Total load: 1 677 Kg/year. The affected area is a small portion of the São Francisco basin.

Report Sheet 10: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: POLLUTION/Issue: SUSPENDED SOLIDS/Score: 3							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Dredge material (m^3)	Report	Estuary of Patos Lagoon (900 km^2)	1996	Medium	Public Access	SUPRG 1996	Intense dredging from 1980 to 1995, ranging from 1 200 to 1 800 000 m^3, depending on the site.
Suspended solids reaching the Patos Lagoon estuarine zone	Report	Patos Lagoon Estuary	Unkown	Medium	Public access	Baisch pers. comm. Portobrás 1979, Torres 2000	The estimated amount of suspended solids that reach the Patos Lagoon Estuary is 2 million tonnes per year (Baisch, pers. comm.) Part of this amount is deposited in the estuary, beaches, lowlands, and channels. Another part is exported to the ocean and a third portion (1.4 million m^3/year) is responsible for silting of the canal and port area (Portobrás 1979). The amount of marine sediments entering into the estuary zone is not estimated.

Report Sheet 11: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: POLLUTION/Issue: SUSPENDED SOLIDS/Score: 3							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Suspended solids load remaining in the wastewater discharged after treatment (tonnes/day)	Report	Paraiba do Sul River basin	1997	Medium	Public access	SIH/ANEEL (1999)	Industrial effluents: suspended solids: 215 tonnes/day. Municipal effluents: suspended solids: 43 tonnes/day.
Estuary and coastal zone erosion: Loss of suspended solids (tonnes/year)	Reports	Paraiba do Sul River estuary and coastal zone	1989-1999	High	Public access	Carneiro 1998, Muehe & Neves 1995a and b Argento 1989	Reduction of suspended solids loads, associated to dams construction, resulting in coastal erosion and instability. The amount of sediment delivery is about 0.6-2.0 million tonnes/year. Loss of habitats and valuable proprieties.
Loss of seasonal inundation of floodplains	Report	Lower Paraiba do Sul River basin, Rio de Janeiro state	Since 1970s	High	Public access	SIH/ANEEL 1999	Construction of dams almost suppressed seasonal inundation of floodplains.
Suspended solids accumulated in the reservoir (% of input)	Funil Reservoir	Funil Reservoir in PSRB (RJ)	1978-1979 1989-1991	High	Public access	COPPE/UFRJ 2002	High rates of suspended solids accumulation in the reservoir (70-80% of the input). This can compromise de electric power generation and represent a risk factor in the sustained energy in a medium- long-term perspective.
Total Suspended solids (mg/l)	Report Data table and map	Doce River basin station grid of 59 samples	1985-1990 1993-1997, sampling 4 times/ year	High	Public access	DNAEE 1990 SRH/MG 2003	Suspended solids concentrations exhibit a highly heterogeneous distribution in the sub-basins and along the Doce River itself. In general, it's a turbid river, with the highest concentrations in its upper middle sector defined by Classes 3 and 4 (range from 100 to 1 000 mg/l). The upper regions are characterised by low concentrations (e.g. 1-10 mg/l, Class 1). The average annual value at the rivers mouth is 130 mg/l. The main causes of increase is the soil and river margin erosion. The river is subject to siltation. Deforestation has been one of the main processes inducing erosion.
Sedimentation rates (cm/year)	Report	Coastal Lagoons of Rio de Janeiro state (600 km^2)	1999	High	Public access	Knoppers et al. 1999a and b	Sedimentation rate in lagoons: between 0.1-0.6 cm/year and approx. 1 cm/year in highly impacted metropolitan lagoons.
Sedimentation rates (mg/m^2/year) or (cm/year)	Report	Guanabara and Sepetiba Bays and basins (7 500 km^2)	1999	High	Public access	Lacerda et al. 2001, Forte 1996	Sepetiba Bay: Around 320 mg/m^2/year during 1971-1995. Increased ten-fold since 1900. Guanabara Bay: 0.2 (lower section) to 2.0 cm/year (upper section).
Suspended solids load (mg/l)	Report	Small rivers of coastal lagoons of Rio de Janeiro state (600 km^2)	1985-1990	High	Public access	Knoppers et al. 1999a and b	Slightly impacted: 10-30 mg/l, Highly impacted: > 100 mg/l.

Report Sheet 12: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39c São Francisco River Basin/Concern: POLLUTION/Issue: SUSPENDED SOLIDS/Score: 3							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Total suspended solids (mg/l)	PhD thesis	Lower SFRB and river mouth (200 km)	2001-2002 Monthly sampling	High	Public access	Medeiros 2003	Significant reduction of suspended solids to a range of 2-10 mg/l due to the construction of dams.
Submerged sand bank in the river	Report	Lower basin and river mouth 200 km	1999-2001	High	Public access	Segundo 2001	Reduction of sand bank migration and stagnation of sand transport due to reduced river flow and elimination of flood flow conditions by the Xingó Dam, 170 km from the river mouth. Modification of fish habitats.
High turbidity	Report	Tributary of the Upper São Francisco basin 2 000 km^2	1994 –1998	High	Public access	IGAM 2001	Increasing turbidity associated to mining and agriculture.
Sediment critical load (%)	Report	Sao Francisco River mouth	1986 and 2003	High	Public access	Jimenez & Maia 1999, Bezerra 1996, Valentini 1996, Medeiros 2003	Delivery of sediments is about 10-50% of critical load. Erosion of adjacent beaches already evident. Total load about 10 billion tonnes/year. Decreased in time down to the present value due to suspended matter retaining in dams.

Report Sheet 13: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: POLLUTION/Issue: SPILLS/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Registration of spills (number of events)	Papers	São Sebastião Channel, São Paulo littoral	Several	Medium	Public access	Weber & Bícego 1991, Poffo et al. 1996	The DTCS oil terminal has been operating since 1967. Between 1985 and 1994, 145 accidents occurred. The worst case occurred with the Brazilian Marina tanker in 1978, when 6 000 m^3 of oil spilled into the Channel.
Total hydrocarbons in water (µg/l of Carmópolis oil equivalents)	Report, paper	São Sebastião Channel, São Paulo state littoral	Nov 1985 to Aug 1986	High	Public access	Weber & Bícego 1991,Zanardi et al. 1999b	0.19 to 8.52 µg/l of petroleum hydrocarbons have been found between Nov 1985 to Aug 1986 (Weber and Bícego 1991) in the Sao Sebastião Channel and adjacent areas. 0.15-4.9 µg/l Carmópolis oil equivalents were found between October 93 to April 95 (Zanardi et al. 1999b).
Oil spills (tonnes)	Report	São Paulo state littoral (400 km)	1996	High	Public access	UNEP 2000	18 200 tonnes of oil were spilled in the coasts of São Paulo state between 1974 and 1994.
Oil spills (number of events)	Report	Sao Sebastião Channel, in São Paulo state littoral	1985-1994	High	Public access	Poffo et al. 1996	In São Paulo coast, where the DTCS oil terminal is located 145 accidents were registred during the period of 1985-1994.
Event of oil spill (litres)	NGOs website	Oil Terminal in São Francisco do Sul, Santa Catarina state	Set 1997	Medium	Public access	IWC 2003	Flooting pipes of the oil terminal from a offshore platform caused the spill of 100 000 litres of petrolium.
Spill (event) nafta	Report	Paranaguá Bay, Santa Catarina 3 000 m^2 affected	18 Oct 2001	High	Public access	IBAMA 2002	392 000 litres of nafta spilled from the ship Norma (Petrobrás), after an accident in the littoral of Paraná state.
Spill (event) oil	Report	São Francisco do Sul in Santa Catarina state	5 Oct 2001	High	Public access	IBAMA 2002	150 000 litres of petrol spilled at 8 km of the coast of Santa Catarina state.
Spill (event)	Report	Paraná state	16 Feb 2001	High	Public access	IBAMA 2002	4 000 litres of diesel oil spilled from a broken pipe (Petrobrás) in Caninana reach, tributary of Nhundiaquara River. Impacts on mangrove, contamination of animals were registered. Fishing was suspended during one month.
Spill (event)	Report	Littoral of Sao Paulo state	Nov 2000	High	Public access	IBAMA 2002	86 000 litres of oil spilled from a cargo (Petrobrás); pollution reached the beaches of Sao Sebastião and Bela Island in Sao Paulo.
Spill (event)	Report	Littoral of Sao Paulo state	16 Mar 2000	High	Public access	IBAMA 2002	7 250 litres of oil spilled from the ship Mafra (Petrobrás) in the São Sebastião channel, littoral of São Paulo.
Spill (event)	Report	Rio Grande do Sul littoral (3 km of Jardim do Eden beach affected)	11 Mar 2000	High	Public access	IBAMA 2002	18 000 litres of crude oil spilled in Tramandaí during transfer from the ship to the terminal Tedut of Petrobrás.
Accidents/spills with large proportions	Report	Brazilian littoral	1975-1992 compared to 1993-2001	High	Public access	IBAMA 2002	1975-1992: 2 spills of large proportions (6 000 tonnes of oil in Guanabara Bay in 1975 and 3 million litres of oil in Bertioga in 1983), 1993-2001: 35 spills of large proportions.

Report Sheet 14: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: POLLUTION/Issue: SPILLS/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Oil spills due to anthropogenic activities	MSc Thesis	Japaratuba River and inner estuary, Sergipe state(4 000 km^2)	Unknown	Medium	Restricted	Souza 1993	High concentrations of oil and grease, surface oil slicks due to frequent discharge of oil.
Oil spills due to anthropogenic activities	MSc Thesis	Sergipe River and inner estuary, Sergipe state(3 800 km^2)	1995 bimonthly	Medium	Restricted	Souza 1993	High concentrations of oil and grease, surface oil slicks due to frequent discharge of oil.
Surface film (oil slick) presence	Text	Sergipe state shoreline (150 km^2)	Unknown	High	Public access	Regional TV news, M.F.L. Souza pers. comm.	Crude oil spills are frequently observed due to exploration and transport by PETROBRAS; tar balls commonly found over and inside sand beach.
Surface film (oil slick), fish kills	National newspaper	Bahia state littoral, from Morro de São Paulo to Ilhéus (100 km)	March 2001	Medium	Public access	Several national newspapers	Crude oil spill of unknown source covered the beaches with tar balls; the spill probably occurred far from the coast (presence of newly established barnacles in the surface of tar balls).
Bivalvia tellinidae as a bioindicator of chronic environmental pollution	Scientific paper	Todos os Santos Bay, Bahia state	1993-1994	High	Public access	Peso-Aguilar and Verani 1995	Detection of contamination by petroleum in Todos os Santos Bay.
Spill (event) natural gas	Report	Salvador, Bahia 150 m of mangrove affected	20 Sep 2001	High	Public access	IBAMA 2002	150 m of mangrove area affected by the natural gas that scaped from a station in Salvador, Bahia state.
Spill (event)	Report	30 km of Bahia littoral affected	05 Oct 2001	High	Public access	IBAMA 2002	Oil from an Arabic ship spilled (amount not informed) affecting the littoral between Buraquinho and Coasta do Sauípe.
Oil run-off and spills (tonnes/day)	Report	Guanabara Bay, Rio de Janeiro littoral	1981-1990	High	Public access	Ferreira 1995	About 18 tonnes/day of which, 84% come from urban run-off and effluent discharge. Oil spills account for 0.2 tonnes/day.
Oil concentration in water, sediments and registration of spills	Governm. Report	Sepetiba Bay, Rio de Janeiro littoral	Several	High	Public access	MMA 1996, Melges-Figueiredo 1993,1999	Evidences of oil released by the Nuclear Power Plant Almirante Alvaro Alberto, oil terminals and pipelines and oil tanker's anchorage at the Port of Sepetiba (MMA 1996); sediments contaminated by hydrocarbons (Melges-Figueiredo 1999).
Oil spills (number of events)	Indexed Book	Ilha Grande Bay and Sepetiba Bay, Rio de Janeiro state littoral	1981-1990	High	Public access	Lamardo et al. 2000	2 543 oil tankers shipped in Ilha Grande Bay and Septiba Bay and 53 oil spills were registred.
Oil spill	Report	Guanabara Bay (40 km^2 affected)	18 Jan 2000	High	Public access	IBAMA 2002	1.3 million litres of oil spilled after the pipe that connected Duque de Caxias refinery to the Ilha d'Água Terminal was broken.

Report Sheet 16: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: POLLUTION/Issue: SOLID WASTE/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Litter including plastic materials (unmeasured)	Visual observation	Cachoeira River and estuary, Bahia state (3 700 km^2)	Unknown	Medium	Restricted	M.F.L. Souza pers. comm.	Presence of a large amount of solid wastes generated by the Itabuna population and dumped in the remnant riparian vegetation.
Dumpsite area	Visual observation	Mangrove at Cururupe River, Bahia state	Unknown	Medium	Restricted	M.F.L. Souza pers. comm.	Ilhéus dumpsite has received municipal, industrial and medical waste.
Disposal of solid wastes (tonnes/day)	Report	Paraiba do Sul River basin	2000	Medium	Public access	IBGE 2000	About 136 000 tonnes/day of solid wastes in the basin is disposed in open dumps.
Disposal of solid wastes (%)	Report	Upper Paraiba do Sul River basin, São Paulo state	1997-1998	Medium	Public access	SIGRH-SP 1999	Increase from 12-21% of solid wastes with inadequate final disposal.
Landfills control and monitoring	Report	15 landfills in the middle and lower PSRB, Rio de Janeiro state portion	2002	High	Free public access	COPPE-UFRJ 2002	15 landfills investigated were considered inappropriate from an environmental point of view.
Destruction of 1 million m^2 of mangrove area due to the construction of the metopolitan landfill of Gramacho	Paper	1 million m^2 of mangrove area at Guanabara Bay, Duque de Caxias Municipality, Rio de Janeiro	1970 - 2003	High	Public access	Marques 1995	The operation of the Gramacho metropolitan landfill (no bottom liner, no leachate or gas collection) started about 30 years ago in Duque de Caxias municipality on top of a mangrove area. Currently it receives about 7 000 tonnes of solid waste per day generated by 4 municipalities of Rio de Janeiro state. In 1995, a leachate collection and treatment system was installed. Over the years, the site received both municipal as well industrial and hazardous wastes. There are indications that during this period the Guanabara Bay has received hazardous substances leaching from the landfill.

Report Sheet 17: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: POLLUTION								
	Socio-economic proxy indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Economic impacts Score: 3	Investments made by the industry for pollution abatement (USD)	Report	Cubatão industrial complex in Sao Paulo littoral	1983-1996	High	Public access	CETESB 1999 in Lamardo et al. 2000	Investments for industrial pollution abatement: The Cubatão Pollution Control Project implemented by the industries of Cubatão, São Paulo (mostly air pollution, water pollution and suspended particles) costed approximately 550 million USD in investments during the period of 1983-1996.
	Penalty due to spill of oil	Report	São Sebastião channel, São Paulo	16 Mar 2002	High	Public access	IBAMA 2002	The state environmental protection agency of São Paulo-CETESB charged Petrobrás with a penalty of about 31 000 USD for the spill of 7 250 litres of oil in São Paulo littoral.
	Costs with dredging activities as a consequence of erosion and silting	MSc Thesis	Patos Lagoon	Activities carried out in Mar-Aug 1998	High	Public access	Torre 2000	Between March and August 1998, 3 million m^3 of sediments were dredged from Patos Lagoon. By the end of 1995 it was estimated that 1.2 million m^3 of sediments were deposited into the estuary every year, originated from 2.0 million m^3 of sediments delivered by the basin.
Health impacts Score: 2	Evaluation of the potential risk associated to the occurrence of toxic algae in reservoirs for water supply related to eutrophication	Paper	Several regions in Brazil, including South/Southeast and East Atlantic Basins	Not given	High	Public access	Azevedo 1996, Costa & Azevedo 1994	Health risk due to occurrence of toxic algal blooms in reservoirs: Potential risk to human health associated to the presence of hepatotoxin due to eutrophication and the occurrence of toxic cyanobacteria in freshwater, particularly in reservoirs for water supply (Azevedo 1996). Laboratory investigations have confirmed the presence of toxic algae in the water supply reservoirs, artificial lakes, lagoons and rivers in the states of Pernambuco, Bahia, Minas Gerais, Rio de Janeiro (39b), and São Paulo and Paraná (39a). Aproximately 75% of the isolated bacteria had toxic effects when tested in bioassays. Some bacteria produced neurotoxins and some others, hepatotoxins (Costa & Azevedo 1994).
	Report on okadaic acid (diarrhetic toxin) associated to algal blooms in aquaculture tanks	Paper	Areas of aquaculture in Santa Catarina state	1990-1995	High	Public access	Proença et al. 1996	Health impacts associated to eutrophication related to aquaculture: In Santa Catarina state, aquaculture has been stimulated by the government, causing a rapid increase in mussel production (about 200% in five years) and the occurrence of toxic algal blooms. Recently, in the shellfish aquaculture region, the occurrence of the okadaic acid (diarrhetic toxin) was registred (Proença et al. 1996) probably produced by *Dinophysis* sp. Cases of human intoxication due to the toxin were registred in the nearby area during one bloom event.

Report Sheet 18: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS
Region 39b East Atlantic Basins/Concern: POLLUTION

	Socio-economic proxy indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Economic impacts Score: 3	Penalty against industry due to the transboundary accident with hazardous wastewater	National news paper	Pomba River (MG) tributary of the Paraiba do Sul River	April 2003	High	Public access	O Globo 2003a and b	About 17 million USD in penalty against the paper-pulp factory Cataguazes in Minas Gerais state due to the spill of 1.2 billion litres of hazardous wastewater discharged into Pomba River after the storage dam was broken, causing death of animals and suspension of water supply in several municipalities in the northern Rio de Janeiro state.
	Economic losses due to flooding events	Report	Doce River basin	Two main events: in 1979 and 1997	High	Public access	Sistema de Meteorologia e Recurso Hídricos de Minas Gerais 2003	Two main events of flooding occurred as a consequence of improper land use, causing erosion, reduction of soil infiltration and river siltation: the 1979 event destroyed 4 424 houses and left 47 776 people with no home; the 1997 event destroyed 7 225 houses and left 57 705 people with no home.
	Penalty of about 2.5 million USD	Official Report	Port of Tubarão, Espírito Santo state	One event in 1999	High	Public access	Ministério Público Federal 1999	A legal action against the Ocean Lines Company Ltd established a penalty of 2.5 million USD due to the spill of 1 500 liters of oil from one ship in the Port of Tubarão, Espírito Santo state.
	Economic losses due to the interruption of the hydropower generation plus maintenance costs	Reports	Funil Hydropower Plant, Rio de Janeiro state	1985-1990	High	Public access	COPPE /UFRJ 2002	Economic losses due to eutrophication in reservoir: In 1984, after 14 years of operation, 3 units of the Funil hydropower plant needed maintenance (COPPE/UFRJ 2002). The disassembling of these units was carried out during 1976. The hydropower operation was interrupted during 1 176 days. The energy that stopped being produced during this period was equivalent to 35.3 million USD or 28 USD/MWh. The maintenance costs were comparatively low: 2.2 million USD. The total economic impact was 37.5 million USD. The diagnosis was corrosion of several parts of the system, mostly due to the eutrophication and the sediments accumulated in the reservoir, coming from the portion of the Paraiba do Sul River basin located in São Paulo state, upstream Rio de Janeiro.
	Pollution mitigation costs	Report	Paraiba do Sul River basin	2001	High	Public access	Freitas 2003	In 2001, the National Agency of Water ANA made available about 9 million USD for investments in the construction of municipal wastewater treatment plants.
	Pollution mitigation costs	Report	Paraiba do Sul River basin	1997	High	Public access	COPPE/UFRJ 2002	Investment for mitigation and contingency plan of sewage collection, solid waste disposal and urban drainage in the PSRB. Total cost: 900 million USD.
	Investment for pollution abatement and water treatment	Report	Guanabara Bay, Rio de Janeiro state	1996-2003	High	Public access	Marques 1995	During the period of 1996-2003, the Government of Rio de Janeiro invested 850 million USD in sanitation projects with the loan from the Interamerican Development Bank IDB and the Japanese Overseas Economic Cooperation Fund OECF. The investments were mostly for construction of sewage collection and wastewater treatment plants in the basin of Guanabara Bay.
	Penalty due to oil spill	National news paper	Guanabara Bay, Rio de Janeiro state littoral	Jan 2000	High	Public access	Luiz Monteiro 2000	A penalty fee of about 26 million USD (equivalent to 750 USD per ha affected) was imposed by the Ministry of Environment due to the spill of 1.3 million litres of oil spilled in January 18, 2000 resulting from the accident at Petrobras's refinery in Guanabara Bay. Environmental impacts included: marine animals and fish kills and other impacts on the coastal ecosystems (e.g. 14 000 ha of mangrove in an environmental protected area). Economic impacts affected at least 600 fishermen (suspension of fishing during 60 days after the accident, damage to boats and fishing equipment, etc).
Health impacts Score: 2	Cases of intoxication and deaths related to dialysis with polluted water	PAHO Report	Bahia state	1988	High	Public Access	Teixeira et al. 1993	Intoxication/deaths and eutrophication in reservoirs: Strong evidence of correlation between bloom of bacteria in Itaparica reservoir (Bahia state) and 88 deaths, among 200 intoxicated people, due to dialysis in a clinic using contaminated water between March and April 1988 (Teixeira et al. 1993).
	Infectious and parasitic diseases (%)	Report	Paraiba do Sul River basin	1999	Low	Public access	COPPE/UFRJ 2002, IBGE 2000	Infectious and parasitic diseases are the main causes of diseases among children (less than 1 year old). Hospital records in several municipalities in the upper São Paulo, middle Minas Gerais and northeasteastern Rio de Janeiro attain 15 %, 33% and 48 %, respectively. Hospitalisation of the total population is less than 20% for the entire basin and 2.6 to 5% at urban centers.
	Waterborne diseases (% total deaths)	Report	Upper Paraiba do Sul River basin, São Paulo state	1995	High	Public access		Cases of waterborne diseases such as Leptospirosis and Schistosomiasis. Both diseases are common among poors that live in areas with no sewage collection and flooding events. Death among the total population varies from 0.3-2.0%.
	Child mortality (deaths per 1 000 live births)	Report	Paraiba do Sul River basin	1998	Very Low	Public access		The rate of children mortality, presents a trend for increasing from the upper portion (20 deaths/1 000 inhabitants) to the lower portion of the basin (30 deaths/1 000 inhabitants). The highest mortality rates are found in the coastal plains in Rio de Janeiro.

Other Social and Community impacts Score: 2	Per capita income: proxy indicator of pollution due to low sanitation coverage	Report	Paraiba do Sul River basin	1991 and 1999	Medium	Public access	IBGE 2000, COPPE/ UFRJ 2002	Income distribution along Paraiba do Sul River basin: The number of minimum wages per capita along the main river course decreased from the upper portion (state of São Paulo) down to the lower portion and coastal plain in the state of Rio de Janeiro, from a range of 1-3 times the minimum wage to 0.76-1.5 times the minimum wage, respectively. However, in manifold systems characterised by rural activities, the minimum wage per capita is lower, particularly in the Northwestern Rio de Janeiro (0-0.75 times the minimum wage). Some municipalities of the middle and upper basin also abide to these conditions.
	Differences of income per capita between Industrialised and non-industrialised cities	Reports	Paraiba do Sul River basin	1991,1999	Medium	Public access	IBGE 2000, COPPE/ UFRJ 2002	The basin presents discrepancies regarding the per capita income between highly industrialised and non-industrialised urban centers, along the main river course of the basin: the Paraíba do Sul River. In 1999, the industrialised cities of São José dos Campos (São Paulo state), Juiz de Fora (Minas Gerais state) and Volta Redonda (Rio de Janeiro state) exhibited respectively an average income per capita of 4.9, 3.3 and 2.6 times the minimum wage. In contrast, the non-industrialised smaller cities of Cunha (SP), Mare de Espanha (MG) and São João da Barra (RJ) exhibited an average income per capita of 1.4, 1.5 and 1.5 times the minimum wage.
	Reduction of the family per capita income (minimum wages/capita)	Report	Paraiba do Sul River basin	1970, 1980, 1991, 2000	High	Public access	IBGE 2000	Reduction of the family per capita income as a result of migration of rural population to urban areas, which increased the unemployment rate of the cities. This trend is more intense in the states of Rio de Janeiro and Minas Gerais, than in São Paulo.
	Poverty status (% of population classified as poor)	Report	Paraiba do Sul River basin	1970-1991	Medium	Public access	IBGE 2000	Increasing poverty in most of the municipalities of the basin occurred between 1970 and 1991. The percentage of the population considered poor varies among the municipalities. In 1991, it varied from 1% to 50% at the upper sector of the basin (São Paulo state). In the middle sector of the basin (Minas Gerais and Rio de Janeiro states) it varied from 25% to 75 %. In the lower portion of the basin (northestern Rio de Janeiro state) it varied from 50% to 75%.
	Interruption of water supply due to an accident with discharge of industrial wastewater into the existing water supply system	National news papers, TV news, Govern mental Reports	Pombas River (Tributary of PSRB in the Minas Gerais portion) and the downstream portion in Rio de Janeiro state	April 2003	High	Public access	FEEMA 2003a and b O Globo a and b	Industrial wastewater discharged in a tributary of PSRB with environmental and socio-economic impacts downstream in Rio de Janeiro state. Transboundary conflict between Minas Gerais and Rio de Janeiro. About 1.2 billion litres of hazardous wastewater entered into Pomba River coming from the pulp-paper industry Cataguazes Papeis Ltd. This hazardous effluent was transported downstream to Rio de Janeiro state and caused the death of many animals and the interruption of the water supply for 8 municipalities in northern and northwestern Rio de Janeiro, affecting 600 000 inhabitants. Irrigation, water supply, fisheries and tourism were the main economic sectors affected.
	1) Presence of *Anabaena* sp. in the reservoir for water supply 2) Very low water level in the reservoir after a long dry period 3) Smell in the water due to the presence of geosmine (substance produced by algaes) 4) Increasing consumption of mineral water indicated by the disappearance of the stocks from the supermarkets in several municipalities	National and regional news papers, TV news in TV channels, from Nov 16 to Dec 20, 2001.	Part of Rio de Janeiro state, Baixada Fluminense and Paraíba do Sul cities (39b) and Três Rios representing a total of more than 3 million inhabitants affected	Nov 2001	Medium	Public Access	Diário do Vale 2001	Eutrophication in reservoirs/Increase in mineral water consumption: During Nov-Dec 2001 (summer) more than 3 million inhabitants of different municipalities in Rio de Janeiro noted a strong smell in the water coming from the tap. After many attempts to explain this problem, the State Secretary of Environment - based on the diagnosis made by the Environmental Protection Agency FEEMA - officially declared that the smell was due to the presence of algal biomass in the Funil reservoir, which was released to the water distribution system. Previous events of algal blooms have been reported in the reservoir. The smell felt at the tap was probably caused by the presence of geosmine, an organoclorate substance produced by cyanobacteriaa (O Globo, 19 November 2001). One possible explanation why the biomass has never reached the distribution system before is that the algal biomass usually occupies the upper part of the water column and the water for energy generation and supply is taken from an outlet close to the bottom. During this particular summer, after a unusually drought period, the reservoir was filled with only 5% of its capacity. Intensive rainfall occurred after the long drought period. The biomass, once in the bottom was transported to the turbines and then, to the water supply system. Another possible source of algal biomass entering into the system before the water is treated and distributed (Amador in O Globo, 19 Nov 2001) are 80 artificial eutrophied lakes formed due to mining activities along the basin and the connection between them and the river after the intense rainfall events.

Report Sheet 19: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS Region 39c São Francisco River Basin/Concern: POLLUTION								
	Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Economic impacts Score: 2	Significant reduction of fluvial navigation as a transport option	Report	1 000 km along the São Francisco River	1993-2002	High	Public access	Ministério dos Transportes 2002	Serious restriction in the fluvial navigation due to damming and siltation of the river channel, in a river that was once considered the "river of the national integration" due to its intensive use for transport of goods between the southeast and the northeast of Brazil in the past.
Health impacts Score: 2	Number of intoxication cases and number of deaths associated to the hemodialysis in a clinic	Conference paper; scientific journal	Caruaru city in Pernambuco state	1996	High	Public Access	Azevedo 1996 and 1998, Carmichael et al. 1996	Cases of intoxication and deaths associated to eutrophication in reservoirs: In the beginning of 1996, 123 patients with chronic renal disfunction presented clinical symptoms compatible to severe hepatoxicosis after being submitted to hemodialysis section in a clinic in Caruaru. Among them, 54 died within five months after the appearance of the symptoms. The clinic was supplied with water from a regional reservoir. Previous events of algal blooms in the reservoir led to the hypothesis that the water used in the hemodialysis was contaminated by hepatoxines. The presence of microcystin in the coal filter used in the water purification system in the clinic was confirmed in laboratory tests by Prof. Wayne W. Carmichael, Wright State University, Ohio, USA, as well as in blood and liver tissue from intoxicated patients (Azevedo 1996, Carmichael et al. 1996). In the reservoir that supplied the city, it was found a predominance of cyanobacteria.
	Waterborne diseases	Report	Lower SFRB	2000	High	Public access	FUNASA 2000	16 786 persons examined in the Lower-São Francisco basin. 10% of them were infected with Schistosomiasis and 45% with other verm diseases.
	Mortality due to polluted water	Report	SRFB	1980	High	Public access	Ministério da Saúde 1983	503 deaths were registered in 1980 form infection by schistosomiasis in the São Francisco basin.

Report Sheet 20: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern:HABITAT AND COMMUNITY MODIFICATION/Issue: ECOSYSTEM MODIFICATION/Score: 3							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Alteration in the mangrove ecosystem structure	Report	Santos estuary, São Paulo state	Unknown	High	Public access	Lamparelli et al. 1993	Alteration of mangrove due to heavy metals contamination, solid waste, frequent oil spills and discharge of industrial and domestic effluents.
Laboratory demonstration of mutagenic effect caused by sediments and dredged material on *Salmonella typhirurium*; impared embryo development of sea urchin *Lytechinus* sp.	Report	Cubatão River basin in Santos estuary	1998 laboratory tests	High	Public Access	Prósperi et al. 1998	As a consequence of intensified harbour activities, more than 500 tonnes of sediments are dredged every year. This material has been disposed of in the ocean. The sediments are contaminated mainly with PAHs, particularly benzo(a)pyrene and metals, such as Hg, Ni, Cu, Pb and Zn. The mutagenic effect of these sediments was demonstrated in laboratory scale with bioindicators.
Decline of shark stocks (% decline in a 20-year period)	Scientific paper	Patos Lagoon estuary	20-year process	High	Public access	Haimovici et al. 1997, 1998	A decline of 90% in the viviparous shark's abundance (*Rhinobathos horkelii, Galeorhinus galeus*) at the Patos Lagoon estuary during a 20-year period associated to the loss of habitat and disturbances in the food web.
Wetland area loss (%)	Report	Patos Lagoon estuary	1997	High	Public access	Seeliger & Costa 1997, Seeliger et al.1997	10% of the marsh area was lost during a 40-year period (1956-1996), corresponding to an annual loss rate of 0.25% of marsh area at the estuary.
Seagrass loss	Report	Patos Lagoon estuary	Along years	High	Public access	Seeliger & Costa 1997, Seeliger et al. 1997	The filling of intertidal and shallow water flats in the lower estuary for port, residential, and more recently, industrial development has decreased or destroyed seagrass.
Fishery stocks and biological productivity threshold levels (%)	Report	Patos Lagoon system (10 000 km^2)	1993	High	Public access	Montu & Gloeden 1982	Change in zooplankton community structure and anatomic anomalies were described. Overexploitation of *Netuma* spp. is described.
Artisanal fishing: Reduction (tonnes/year) of teleosteos species	Scientific Paper	Patos Lagoon and the adjacent marine region	1972-1989 1998-2001	High	Public access	Reis 1994, Haimovici et al. 1998, IBAMA 2002	The artisanal fishing represented 42.6% of the total fish landing in Rio Grande do Sul state during the 1970s. Since them, this percentage declined to become a subsistence activity. From 1972 to 1989: the artisanal fishing declined from 43 705 tonnes down to 13 121 tonnes. From 1998 to 2001 the average was 8 396 tonnes/year.
Introduction of alien species with ballast water	Report	Guaíba Lagoon, Rio Grande do Sul state	Unknown (detected in April 2001)	High	Public access	IBAMA 2002	Introduction of the bivalve *Limnoperna fortunei*, which became one of the most severe environmental problems causing severe economic losses in reservoirs in southern Brazil.

Report Sheet 21: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: HABITAT AND COMMUNITY MODIFICATION/Issue: ECOSYSTEM MODIFICATION/Score:3							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Coral bleaching associated to temperature rise	Paper	Abrolhos archipelago coral reefs, Bahia state	Two events described in Bahia littoral	High	Public access	Leão 1999	Two occurrences of coral bleaching are registered to be related to a rise of the sea surface temperature (Leão 1999). The first one occurred due to a sea surface temperature anomaly during the summer 1994 when 51% to 88% of colonies of the genus *Mussismilia* were affected (Castro & Pires 1999). The second one is related to the ENSO event that begun by the end of 1997 in the Pacific Ocean and caused a rise of the sea surface temperature in some regions of the eastern coast of Brazil. The most affected species were *Porites branneri* and *Mussismilia hispida*, both with more than 80% of their colonies totally bleached, *M. harttii* with an average of 75% of its colonies affected, and *Porites asteroides* with all colonies with some signal of bleaching (Kikichi in Leão 1999). Although the species *Agaricia agaricites* did not show totally bleached colonies, more than 90% of them had a pale colour.
Introduction of alien species	Report	Todos os Santos Bay and Guanabara Bay (Rio de Janeiro state littoral)	Unknown	High	Public access	IBAMA 2002	Introduction through ballast water of the crab *Charybdis hellerii* found in Todos os Santos Bay and Guanabara Bay.
Impacts on coral reefs	Papers	Abrolhos Archipelago coral reefs, Bahia state	Continuous	Medium	Public access	Amado Filho et al. 1997, Coutinho et al. 1993, Leão 1996, 1999	The papers describe the impacts on coral reefs due to coastal zone development, tourism, overexploitation of natural resources and pollution from urbanisation and industrial activities particularly the exploitation of fossil fuels in deep waters.
Mangrove and dunes alteration	Scientific paper	Paraiba do Sul River delta, Rio de Janeiro state	Unknown	High	Public access	Salomão et al. 2001, Dias & Silva 1984	Due to the sediments and particles trapped in the basin caused by damming and the water diversion for human supply, an extensive erosion of the coastline has been observed causing destruction of fringes of mangroves forest, dunes and small villages in the Paraíba do Sul River delta.
Decline in the fish stocks and biological productivity characterised by threshold levels (%)	Report	Sepetiba Bay (400 km^2)	1993	High	Public access	Lacerda 1993a, Magro et al. 2000	Fish stocks in Sepetiba Bay had a general decrease of 20% during the last decade (2 000 tonnes of sustainable annual catches). Specific severe decrease in some species (e.g. sardine) and loss of habitat along the southestern Brazilian coast.
Introduction of alien species with ballast water	Report	Ilha Grande Bay, Sepetiba Bay, Lakes region	Unknown	High	Public access	IBAMA 2002	Introduction of the bivalve Isognomon bicolour; coral *Nephthea curvata* and *Tubastraea coxima* with the ballast water.
Classification of biodiversity hot spots. Criteria: degree of endemism among freshwater fishes associated to the Atlantic Rainforest	Report	Freshwater fish species associated to the Atlantic Forest (basically the entire Brazil Current region)	2000	High	Public access	MMA 2000	The Atlantic Rainforest in the Brazil Current region has the highest importance in terms of biodiversity, including freshwater fish biodiversity. The reason of the extremely high endemism found in the forest aquatic system is related to isolation from other basins during the evolution. Additionally, inside the Brazil Current region, the rivers Paraiba do Sul, Doce, Jequitinhonha and Mucuri are transboundary waters classified within the category of biologically extremely important, according to the criteria applied in the Ministry of Environment report (MMA 2000). All these basins have been profoundly impacted by anthropogenic activities.

Report Sheet 22: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39c São Francisco River Basin/Concern: HABITAT AND COMMUNITY MODIFICATION/Issue: ECOSYSTEM MODIFICATION / Score: 3							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Extinction of migratory fish and shrimp in some areas	Report	Lower-SFRB 250 km	1993-2002	High	Public access	Instituto Xingó 2002	The construction of a cascade of dams in the river has caused obstruction of fish migration.
Isolation of marginal lakes used as reproductive habitat	Report	Lower-SFRB 100 km	1993-2002	High	Public access	Instituto Xingó 2002	The flow regulation extinguished flooding, inducing the loss of the marginal lakes.
Introduction of alien species	Report	SFRB 2 700 km	1999-2002	High	Public access	Instituto Xingó 2002	The Amazon fish Tucunaré thrives on fish eggs and larvae from others species. *Tilapia* sp. has been introduced as an alternative food source in aquaculture projects.
Loss of seasonality and decline of biological production	Report	Lower SFRB 200 km	1990-2001	High	Public access	Instituto de Biologia/UFBa 2002	The plankton production and density in the river and estuary shows a total absence of seasonal patterns. Before the construction of a cascade of dams, the river flow, nutrients and plankton biomass exhibited seasonal unimodal trends. Loss of productivity by plankton and fish yields.

Report Sheet 23: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS
Region 39b East Atlantic Basins/Concern: HABITAT AND COMMUNITY MODIFICATION

	Environmental impact indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Economic impacts. Score: 2	Reduction of agriculture areas (%)	Report	Paraiba do Sul River basin	1985-1995	High	Public access	COPPE/UFRJ 2002	The agriculture sector suffered a significant reduction in its productive area from 1985 to 1995 in all municipalities of the basin. After significant replacement of the original vegetation cover by agriculture fields, agricultural lands were reduced about 46% in São Paulo, 35% in Minas Gerais, and 41% in Rio de Janeiro.
	Degraded pasture areas (%)	Report	PSRB	2000	High	Public access	COPPE/UFRJ 2002	The natural vegetation cover was replaced by pasture for livestocks. Intense degradation occurred along the entire basin, mainly in higher relief areas, some of which have been abandoned. Frequent fires and accelerated erosion have been described. At present, the pasture lands form 67.4% of the basins area, including active pasture and abandoned areas. In total, a 17% reduction of the pasture area occurred.
Other social and community impacts Score: 2	Rural exodus rate	Report	Some PSRB cities	1970-2000	High	Public access	IBGE 2000	An agricultural exodus since 1970 has occurred with the rate of 16 000 inhabitants per year or 1.2 % per year.
	Increasing aquaculture development	Report	Lower-middle PSRB	1980-2000	High	Public access	Valenti et al. 2000, COPPE/UFRJ 2002	In contrast to the reduction of fish stocks in the river, aquaculture has become an alternative economic activity. Over the last 20 years the sector grew rapidly, now amounting to about 70% of the total freshwater fisheries. Trout, carp and tilapia are the main species groups. An adverse impact, however, has been the introduction of alien species, either from abroad or from other Brazilian freshwater basins.
	Number of fishermen associations	Report	Paraíba do Sul River coast	2000	High	Public access	COPPE/UFRJ 2002	Five professional fishermen colonies existed in the region. Nowadays, only two remain.
	Urban floods associated to habitats/ ecosystem changes	Report	Paraiba do Sul River basin	Analysis based on 20 years of recurrence of floods	High	Public access	COPPE/UFRJ 2002	Floods occur annually at risk sites, but at different intensities. They induce damage or loss to private and industrial properties. The high risk areas are the wider floodplains of the river and the steeper mountain flanks subject to uncontrolled demographic expansion by the low income population, causing landslides and increased erosion. The floods registered during 1997 and 2000, affected directly and indirectly 60 000 and 300 000 inhabitants, respectively, in the states of Minas Gerais and Rio de Janeiro.
	Sugar cane production (ha)	Report	Lower PSRB, Rio de Janeiro	1995/1996	High	Public access	COPPE/UFRJ 2002	About 220 000 ha of land are used for sugar cane plantations. Of these, 170 000 ha are temporary with 144 500 ha allotted to the sugar cane industry. Clear burning, soil acidification, pesticide and fertiliser use are the main consequences and impacts.
	Excessive use of pesticides (kg/ha)	Report	Paty do Alferes, Rio de Janeiro, PSRB	1990	High	Public access	COPPE/UFRJ 2002	92.3% of the local agriculture make use of 33 active ingredients of pesticides at elevated levels, with a total consumption of 6 885 kg, or 12.9 kg/ha. The impacts are not properly measured. Insecticides (organo-phosphorate compounds) account for 2 488 kg and fungicides (dithiocarbamates) for 2 131 kg.
	Freshwater fish (tonnes)	Report	Paraiba do Sul River basin	1951-1999	High	Public access	COPPE/UFRJ 2002, CIDE 2001, Hillsdorf & Petrere 2002	During the 1950s, the Paraíba do Sul River basin had an extensive fishing activity and exhibited high fish biodiversity. Since then, the productivity and the number of species were drastically reduced due to pollution and changes in the stream flow. Current catches in the lower and middle sectors of the River amount to 1 500 tonnes per year. The water quality bio-indicator "piabanha" (*Brycon insignis*), which was an important economic species is now nearly extinct.
	Estuarine and marine fish catch (tonnes)	Report	Estuary and coastal waters of Paraiba do Sul River	1985-1989 compared to 1990-1994	High	Public access	Hillsdorf & Petrére 2002, CIDE 2001, Paiva 1997	One proxy indicator of the reduction of the estuarine and coastal fish stocks is the total catch at the Rio de Janeiro coastal zone, since the local statistics for the estuary are scant. Average artisanal and industrial catches from 1985 to 1989 were 60 000 and 132 000 tonnes per year, respectively. From 1990 to 1994, the values were much less: 24 000 and 35 000 tonnes per year, respectively. In 1999, the direct landing of marine fish catches in São João da Barra (estuarine portion of PSRB) was 4 500 tonnes per year.

Report Sheet 24: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS
Region 39c São Francisco River Basin/Concern: HABITAT AND COMMUNITY MODIFICATION

	Environmental impact indicator (unit)	Format	Extent or area covered	Duration and frequency	Reli-ability	Avail-ability	Source	Explanation or justification how the indicator supports the conclusion made in the Assessment
Economic impacts Score: 2	Reduction of fisheries sector	Report	240 km along the lower-SFRB	1974-1999	High	Public access	Todaro 2001	Fisheries yield reduced by 86.4% in the last 25 years.
Health impacts Score: 2	Proliferation of rodents	Personal communication	240 km along the lower SFRB	2002	Medium	Un-published	Lúcio 2000	The flow regulation and the elimination of the flooding of the rivers margins induced the proliferation of rodents, which has affected human health and rice cultivation.
Other social and community impacts Score: 2	Population migration	Map	200 km along the estuarine zone of São Francisco River	1990-1997	Medium	Public access	IBGE 2000	Interruption of fishing activity along the coastal zone and migration of the fisher families to the cities.

Report Sheet 25: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39a South/Southeast Atlantic Basins/Concern: FRESHWATER SHORTAGE/Issue: MODIFICATION OF STREAM FLOW/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Increment in water demand for industrial and domestic use over the last 35 years (km^3/year)	Report	Catchment basin of the Patos Lagoon (200 000 km^2)	1997	High	Public Access	Seeliger & Costa 1997	Average annual increase of the water demand during a 35 year-period of 0.46-0.76 km^3/year (total increase of 16.1-26.6 km^3 during 35 years).
Increment in water demand for irrigated rice cultivation over the last 35 years (km^3/year)	Report	Catchment basin of the Patos Lagoon (200 000 km^2)	1997	High	Public Access	Seeliger & Costa 1997	Average annual increase of 3.89-9.31 km^3/year (total increase of 136-326 km^3 in a 35 year-period).

Report Sheet 26: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: FRESHWATER SHORTAGE/Issue: MODIFICATION OF STREAM FLOW/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Stream flow changes due to dam construction (% in m^3/s)	PhD thesis	Paraiba do Sul River basin	1934-1999	Public access	Public access	Souza 2002	A number of dams constructed since the 1950s caused 25% reduction in the average flow, from 940 m^3/s during the period 1934-1943, to 700 m^3/s (1990-1999). A slight dampening of seasonal unimodal cycle was also observed.
Stream flow changes (m^3/s)	Report Data table and map	Doce River basin	1939-1998 daily observations	Public access	Public access	DNAEE 1990, SRH/MG 2003, Souza 2002	Run-off: Heterogeneous pattern due to physiography and climate. The southwest and west basin has a run-off ranging from 15-30 l/s/km^2 and the lower-middle and lower Doce River basin exhibit an average run-off of 10-15 l/s/km^2. The northern region presents the smallest run-off with 5-10 l/s/km^2. However, both the rivers sources/springs in the highlands and northern sections of the basin are now more frequently drying up, a matter of concern for the local populations. Deforestation and erosion has affected the recharge zones. River flow: The average annual river flow for the period 1939-1948 was 1 300 m^3/s and for 1989-1998 it was reduced to 800 m^3/s. The seasonal unimodal pattern of river flow was not affected.

Report Sheet 27: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: FRESHWATER SHORTAGE/Issue: CHANGES IN GROUNDWATER/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Aquifer overexploitation (m^3/s)	Report	Caçapava Aquifer, Paraiba do Sul River basin	2000	Low	Free public access	SIH/ANEEL 1999	An aquifer deficit of 84% or 1 200 m^3/s (difference between consumption and recharge) was observed.

Report Sheet 28: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39c São Francisco River Basin/Concern: FRESHWATER SHORTAGE/Issue: MODIFICATION OF STREAM FLOW/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Flow regulation by dams (m^3/s)	Report	Lower-SFRB Xingó dam (170 km from rivers mouth)	1993-2001	High	Free public access	FUNDEPES 2001	Uniform flow pattern regulated by the dam at 2 060 m^3/s. Elimination of flooding and as a consequence, the fertilisation of the rivers margin and marginal lakes.
Low productivity at the estuary due to dam construction	Report	Lower-SFRB Xingó dam (170 km from rivers mouth)	1993-2002	High	Free public access	UFAL 2002, Medeiros 2003	The large reservoir (70 billion m^3) retains most of the rivers fine sediments, organic matter and nutrients. Dams constructed upstream the Xingó Dam already retain a large fraction of the basins materials.
Erosion of river banks	Report	Middle-lower SFRB and lower SFRB (1 000 km along the main river)	1993-2002	High	Free public access	Ministério dos Transportes 2002	Uniform river flow regulation induced significant erosion of the river banks.
Ichthyofauna production (kg/year), Itraipú River in São Francisco River basin	Report	Middle-lower São Francisco	1974-1999	High	Free public access	Machmann Oliveira et al. 2003	Significant reduction during the studied period (1974-1999).
Ichthyofauna production (kg/year), estuary of São Francisco River basin	Report	Lower São Francisco River	1998-2000	High	Free public access	Machmann Oliveira et al. 2003	Significant reduction during the studied period (1998-2000).

Report Sheet 29: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39c São Francisco River Basin/Concern: FRESHWATER SHORTAGE/Issue: POLLUTION OF EXISTING SUPPLIES/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Groundwater contamination by arsenic	Report	Tributary in the upper SFRB (2 000 km^2)	1999-2000	High	Free public access	IGAM 2001	Presence of arsenic in the groundwater wells.

Report Sheet 30: Description of indicators substantiating ENVIRONMENTAL IMPACTS Region 39b East Atlantic Basins/Concern: FRESHWATER SHORTAGE/Issue: CHANGES IN THE WATERTABLE/Score: 2							
Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Experimental demonstration of sinking of water table level	Report	Experimental irrigation project (100 km^2)	2000-2002	High	Public access	UFBA 2002	In an experimental irrigated area of 100 km^2, which was representative of other aquifers in the São Francisco River basin, in a 2-year period, the water table sank about 10 m.

Report Sheet 31: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS Region 39b East Atlantic Basins/Concern: FRESHWATER SHORTAGE								
	Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Economic impacts Score: 2	Economic losses due to floods in urban areas	Report	Paraiba do Sul River basin	Floods of 20-year recurrency period	High	Public access	COPPE/ UFRJ 2002	Economic impacts due to floods: Many municipalities/urban centres along the entire river course are significantly affected by floods, which are caused by inappropriate land use and modification of stream flow. In the states of Rio de Janeiro and Minas Gerais, 60 000 inhabitants are directly affected and 300 000 are indirectly affected by annual floods with a 20-year recurrence period. The report states that no quantitative cost assessment has been made available. Severe events occurred particularly in 1997 and 2000.
Other social and community impacts Score: 2	Proxy indicator of pollution impacts: change of urban and rural population and migration	Report	Paraiba do Sul River basin	1970- 2000	High	Public access	IBGE 2000	The agriculture sector has been reduced to a large extent. The urban and rural population changed as follow: 2.7 million and 1.3 million inhabitants respectively (1970) to 6.8 million and 0.8 million inhabitants respectively (2000). Urbanisation rate of 132 000 inhabitants per year (or 4.9 % per year). Rural population decreasing of 16 000 inhabitants per year or 1.2 % per year). The figures indicate migration to the large cities and urban expansion also increased industrialisation. The increasing urbanisation is a proxy indicator of pollution due to wastewater and waste generation.
	Proxy indicator of pollution impacts: demographic expansion rates (inhabitants/year)	Report	Paraiba do Sul River basin	1970- 2000	High	Public access	IBGE 2000	The average annual growth rate of the total population of the basin for the 31 year period is nearly 116 000 inhabitants per year.

Report Sheet 32: Description of indicators substantiating SOCIO-ECONOMIC IMPACTS Region 39c São Francisco River Basin/Concern: FRESHWATER SHORTAGE								
	Environmental impact indicator (unit)	**Format**	**Extent or area covered**	**Duration and frequency**	**Reli-ability**	**Avail-ability**	**Source**	**Explanation or justification how the indicator supports the conclusion made in the Assessment**
Economic impacts Score: 2	Limitation in the agricultural productivity	Report	All semi-arid portion of SFRB	2000-2002	High	Public access	UFBA 2002	Limited water resources impose limitations to agriculture expansion.
Health impacts Score: 2	Salinisation of drink water associated to droughts	Report	SFRB 300 000 km^2	1903-1994	Medium	Public access	SUDENE 1994	Water quality decay in small reservoirs in the São Francisco River basin due to salinisation that occurs during frequent droughts.
Other social and community impacts Score: 3	Population migration	Report	SFRB 300 000 km^2	1990-1997	Medium	Public access	IBGE 2000	Regional migration due to increase of droughts, particularly in the sector within the "Drought Polygon" (mostly semi-arid climate).

Annex IV
List of important water-related programmes and assessments in the region

Country/Region (Implementing agency)	Project title	Focal area/Project status	GEF allocation/ Co-financing amount (million USD)
Country projects			
Brazil (UNDP)	Promoting Biodiversity Conservation and Sustainable Use in the Frontier Forests of Northwestern Mato Grosso	Biodiversity / Approved	6.98 / 9.13
Brazil (UNDP)	Climate Change Enabling Activity	Climate Change / Approved	1.50 /
Brazil (UNDP)	Biodiversity Enabling Activity	Biodiversity / Approved	0.94 /
Brazil (World Bank)	Amazon Region Protected Areas Program (ARPA)	Biodiversity / Approved	30.35 / 59
Brazil (UNDP)	Biomass Power Generation: Sugar Cane Bagasse and Trash	Climate Change / Approved	3.75 / 2.77
Brazil (UNEP)	Integrated Management of Land-Based Activities in the São Francisco Basin	International Waters / approved	4.77 / 15.44
Brazil (World Bank)	Energy Efficiency	Climate Change / Approved	20.0 / 180
Brazil (UNDP)	Hydrogen Fuel Cell Buses for Urban Transport	Climate Change / Approved	12.6/
Brazil (World Bank)	Biomass Power Commercial Demonstration	Climate Change / Approved	40.5 / 82
Brazil (UNDP)	Establishment of Private Natural Heritage Reserves in the Brazilian Cerrado	Biodiversity / Approved	0.75 / 0.10
Brazil (World Bank)	National Biodiversity Project	Biodiversity / Approved	10 / 10
Brazil (World Bank)	Brazilian Biodiversity Fund	Biodiversity / Approved	20 / 5
Brazil (UNEP)	Integrated Watershed Management Program for the Pantanal and Upper Paraguay River Basin	International Waters/Approved	6.62 / 9.78
Brazil (UNDP)	Biomass Integrated Gasification / Gas Turbine Project	Climate Change / Approved	8.12 /
Uruguay (UNDP)	Clearing House Mechanism Enabling Activity	Biodiversity / Approved	0.01 /
Uruguay (UNDP)	Enabling Activity: Uruguay's Second National Communication to the UNFCCC: Programs of General Measures and Voluntary Greenhouse Gas Emissions Reduction	Climate Change / Approved	0.60 / 0.29
Uruguay (UNDP)	Climate Change Enabling Activity	Climate Change / Pipeline	0.70
Uruguay (UNDP)	Biodiversity Enabling Activity	Biodiversity / Approved	0.12 /
Uruguay (UNDP	Conservation of Biodiversity in the Eastern Wetlands	Biodiversity / Completed	3.00 /
Uruguay (UNDP)	Consolidation of the Bañados del Este Biosphere Reserve	Biodiversity / Completed	2.50 / 1.50
Uruguay (World Bank)	Landfill Methane Recovery Demonstration Project	Climate Change / Approved	1.0/ 3.09
Regional projects			
Latin America / Caribbean (World Bank / IFC)	Terra Capital Biodiversity Enterprise Fund for Latin America (IFC)	Biodiversity / Approved	5 / 25
Latin America / Caribbean (UNEP	A Participatory Approach to Managing the Environment: An Input to the Inter-American Strategy for Participation (ISP)	Multi Focal Areas / Approved	0.72 / 0.84
Latin America / Caribbean (UNDP / UNEP)	Demonstrations of Innovative Approaches to the Rehabilitation of Heavily Contaminated Bays in the Wider Caribbean	International Waters / Approved	9.41 / 25.85
Latin America / Caribbean (World Bank)	Wider Caribbean Initiative for Ship-Generated Waste	International Waters / Completed	5.50 /
Latin America / Caribbean (UNEP)	Strategic Action Programme for Binational Basin of the Bremejo River	International Waters / Approved	3.22 / 2.74
Latin America / Caribbean (UNDP)	Regional Support for the Conservation and Sustainable Use of Natural Resources in the Amazon	Biodiversity / Approved	4.5 /
Latin America / Caribbean (UNDP)	Action for a Sustainable Amazon	Biodiversity / Cancelled	3.8 /
Regional (Argentina, Uruguay) (UNDP)	Environmental Protection of the Rio de la Plata and Its Maritime Front: Pollution Prevention and Control and Habitat Restoration	International Waters / Approved	6.01 / 4.8
Regional (Chile, Brazil, Mexico) (UNDP)	An Indicator Model for Dryland Ecosystems in Latin America	Biodiversity / approved	0.75 /
Global projects			
Global (UNDP)	Research Programme on Methane Emissions from Rice Fields	Climate Change / Approved	5 /
Global (UNDP)	Monitoring of Greenhouse Gases Including Ozone	Climate Change / Approved	4.8 / 1.2
Global (UNDP)	Global Biodiversity Assessment	Biodiversity / Completed	3.3 / 0.18
Global (UNDP / UNEP / World Bank	GEF Country Workshops	Multiple Focal Areas / Approved	3.51 / 1.11

Global (UNEP)	Regionally-Based Assessment of Persistent Toxic Substances	International Waters / Approved	3 /
Global (UNDP)	Small Grants Programme (Second Phase)	Multiple Focal Areas / Approved	31.62 / 30
Global (UNDP)	Removal of Barriers to the Effective Implementation of the Ballast Water Control and Management in the Developing Countries	International Waters / Approved	7.61 / 3.83
Global (UNEP)	Global Biodiversity Forum Phase II	Biodiversity / Completed	0.75 / 0.9
Global (UNEP)	Directing Investment Decisions to Promote the Transfer of Cleaner and More Climate Friendly Technologies – A Private Sector Clearinghouse	Climate Change / Approved	0.75 / 0.18
Global (UNDP)	Alternatives to Slash and Burn	Climate Change / Approved	3 / 4.5
Global (World Bank / IFC)	Solar Development Corporation	Climate Change / Approved	10 / 40
Global (UNDP / UNEP)	Biodiversity Planning Support Programme	Biodiversity / Approved	3.43 /0.8
Global (UNDP)	Global Change System for Analysis Research and Training (START)	Climate Change / Approved	7 /
Global (UNEP)	Global International Waters Assessment (GIWA)	International Waters / Approved	6.79 /
Global (UNDP)	Small Grants Programme	Multiple Focal Areas / Approved	13 / 3.5
Global (World Bank)	World Water Vision – Water and Nature	International Waters / Completed	0.70 / 13.15
Global (UNDP)	Small Grants Programme	Multiple Focal Areas / Approved	1.94 /
Global (UNDP	Climate Change Capacity Building	Climate Change / Approved	0.90 /
Global (UNEP	Fuel Bus and Distributed Power Generation Market Prospects and Intervention Strategy Options	Climate Change / Approved	0.69
Global (UNDP)	Climate Change Training Phase II – Training Programme to Support the Implementation of the UNFCCC	Climate Change / Approved	2.70 /0.50
Global (World Bank / IFC)	Efficient Lighting Initiative	Climate Change / Approved	15.23 / 35.00
Global (UNDP / UNEP/ World Bank)	Strengthening Capacity for Global Knowledge-Sharing in International Waters	International Waters / Approved	
Global (UNDP)	Small Grants Programme	Multiple Focal Areas / Approved	24 /
Global (UNEP)	Capacity Building and Infrastructure: Participation in the Assessment, Methodology Development, and other Activities of the Intergovernmental Panel on Climate change (IPCC)	Climate Change / Completed	2.8 / 2.9
Global (UNDP)	Regional Oceans Training Programme	International Waters / Completed	2.58 / 2.6
Global (UNEP)	Millennium Ecosystem Assessment	Biodiversity / Approved	7.31 / 17.61
Global (World Bank)	Critical Ecosystems Partnership Fund	Biodiversity / Approved	25 / 75
Global (UNEP)	The Role of the Coastal Ocean in the Disturbed and Undisturbed Nutrient and Carbon Cycles	International Waters / Approved	0.72 / 0.46
Global (World Bank / IFC)	Renewable Energy and Energy Efficiency Fund (IFC)	Climate Change / Approved	30 / 210
Global (UNEP)	Assessments of Impacts and adaptation to Climate Change (AIACC)	Climate Change / Approved	7.85 / 4.61
Global (UNEP)	Technology Transfer Networks, Phase I	Multiple Focal Areas / Approved	1.28 / 1.28
Global (World Bank / IFC	Small and Medium Scale Enterprise Program (IFC, replenishment)	Multiple Focal Areas / Approved	16.50 / 36
Global (World Bank / IFC)	Small and Medium Scale Enterprise Program (IFC)	Multiple Focal Areas / Completed	4.30 / 15.20
Global (UNDP)	Small Grants Program (Second Operational Phase)	Multiple Focal Areas / Approved	22.82 / 24
Global (UNEP)	Development of National Bio-safety Frameworks	Biodiversity / Approved	26.09 / 12.34
Global (UNDP)	Global Alternatives to Slash and Burn Agriculture Phase II	Climate Change / Completed	3.00 / 3.37
Global (UNDP / UNEP)	National Communications Support Programme	Climate Change / Approved	2.16 / 1.10
	Biodiversity Data Management Capacitating in Developing Countries and Networking Biodiversity Information	Biodiversity / Completed	4.00 / 1.39
	Pilot Bio-safety Enabling Activity	Biodiversity / Completed	2.74 /
Global (Brazil, China, Ghana, Guinea, Kenya, Papua New Guinea, Tanzania, Uganda) (UNEP)	People, Land Management, and Environmental Change (PLEC)	Biodiversity / Approved	6.28 / 4.82
Global (Burkina Faso, Mali, Nigeria, Senegal, Egypt, Jordan, Kuwait, Morocco, Syria, Tunisia, Mongolia, Pakistan, Brazil, Jamaica, Mexico) (UNEP)	Promoting Best Practices for Conservation and Sustainable Use of Biodiversity of Global Significance in Arid and Semi-arid Zones	Biodiversity / Approved	0.75 /

Annex V
List of conventions and agreements

Brazil

Part to

Antarctic-Environmental Protocol, Antarctic-Marine Living Resources, Antarctic Seals, Antarctic Treaty, Biodiversity, Climate Change, Climate Change-Kyoto Protocol, Desertification, Endangered Species, Environmental Modification, Hazardous Wastes, Law of the Sea, Marine Dumping, Nuclear Test Ban, Ozone Layer Protection, Ship Pollution, Tropical Timber 83, Tropical Timber 94, Wetlands, Whaling.

Signed but not ratified

None of the selected agreements.

Uruguay

Part to

Antarctic-Environmental Protocol, Antarctic-Marine Living Resources, Antarctic Treaty, Species, Environmental Modification, Hazardous Wastes, Law of the Sea, Ozone Layer Protection, Ship Pollution, Tropical Timber 94, Wetlands.

Signed but not ratified

Marine Dumping, Marine Life Conservation, Nuclear Test Ban.

Specific agreements between Uruguay and Brazil

- Agreement on Fisheries and Preservation of Living Resources (1969).
- Cooperation Agreement for the Use of Natural Resources and the Development of the Quaraí River Basin (1992).
- Agreement on Environmental Issues (1995).
- Treaty for the Development of the Mirim Lagoon.

Activities related to the management of natural resources within the region

Fundação Universidade Rio Grande FURG: Research programmes for the Mirim Lagoon.

PROBIDES: Implementation of a management plan with components of education, preservation and scientific approach within the public area of El Potrerillo. The objective is to guarantee the conservation of the psamophites which have been threatened by the urban expansion around the San Ignacio Lagoon.

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Brazil Current region. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF".*

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: *"GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference*".

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

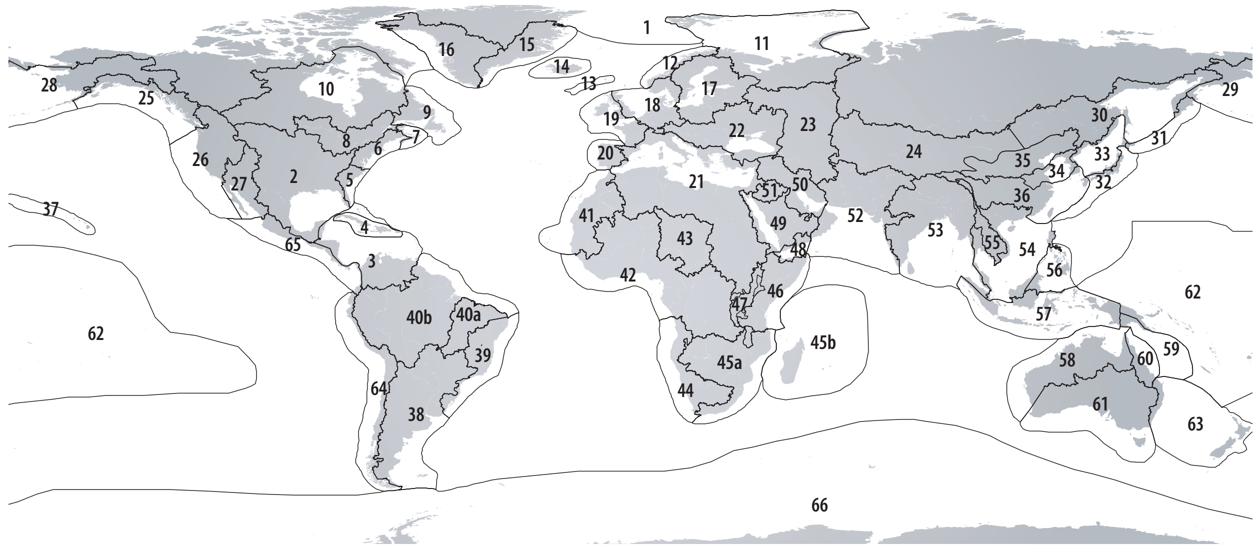
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1 Arctic
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal (LME)
21 Mediterranean Sea (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 East Bering Sea (LME)
29 West Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan/East Sea (LME)
34 Yellow Sea (LME)
35 Bohai Sea
36 East-China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Brazilian Northeast (LME)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
48 Gulf of Aden
49 Red Sea (LME)
50 The Gulf
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal S.E.
54 South China Sea (LME)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Small Island States
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

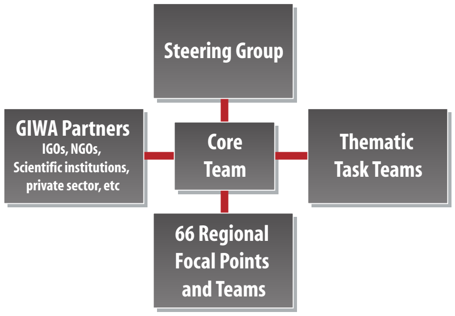


Figure 2 The organisation of the GIWA project.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	**Major concerns**
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO_2 source/sink function	**V Global change**

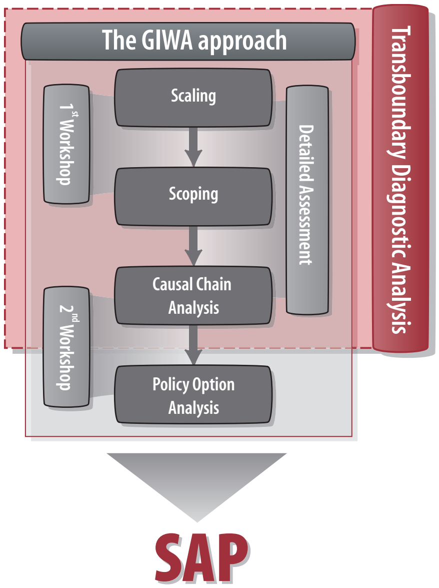

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.*" The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern. In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small 0 1 2 3 Very large	2	50
Degree of severity	Minimum 0 1 2 3 Severe	2	30
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

Global International Waters Assessment

Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/ suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

GIWA

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of all the world's transboundary waters that recognises the inextricable links between freshwater and coastal marine environment and integrates environmental and socio-economic information to determine the impacts of a broad suite of influences on the world's aquatic environment.

Broad Transboundary Approach

The GIWA not only assesses the problems caused by human activities manifested by the physical movement of transboundary waters, but also the impacts of other non-hydrological influences that determine how humans use transboundary waters.

Regional Assessment - Global Perspective

The GIWA provides a global perspective of the world's transboundary waters by assessing 66 regions that encompass all major drainage basins and adjacent large marine ecosystems. The GIWA Assessment of each region incorporates information and expertise from all countries sharing the transboundary water resources.

Global Comparability

In each region, the assessment focuses on 5 broad concerns that are comprised of 22 specific water related issues.

Integration of Information and Ecosystems

The GIWA recognises the inextricable links between freshwater and coastal marine environment and assesses them together as one integrated unit.

The GIWA recognises that the integration of socio-economic and environmental information and expertise is essential to obtain a holistic picture of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

The GIWA indicates priority concerns in each region, determines their societal root causes and develops options to mitigate the impacts of those concerns in the future.

This Report

This report presents the assessment of the GIWA region Brazil Current, including drainage basins and their associated coastal/marine zones. Three separate sub-regions have been assessed within the region: the South/Southeast Atlantic Basins, East Atlantic Basins, and São Francisco River Basin. Increased anthropogenic pressures due to economic development and urbanisation in the coastal area have polluted the water environment and caused severe impact on important ecosystems such as coastal plains and mangrove ecosystems. Significant changes in the suspended solids transport/sedimentation dynamics in the river basins due to unsustainable land use practices associated to intense deforestation and damming has caused increasing erosion of coastal zones, siltation of riverbeds, and modified the stream flows resulting in periods of water scarcity and flooding in some basins. The root causes of pollution and habitat and community modification are identified for the bi-national Mirim Lagoon Basin, a transboundary freshwater body shared between Brazil and Uruguay, and Doce River Basin that hosts biomes of global importance. Potential remedial policy options are presented.

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