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, Unsustainable exploitation 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 21 and 27.

Table 21 Scoring table for La Plata River Basin.

<table>
<thead>
<tr>
<th>GIWA Concern and Issue</th>
<th>Environmental Impacts</th>
<th>Economic Impacts</th>
<th>Health Impacts</th>
<th>Other Community Impacts</th>
<th>Overall Score**</th>
<th>Priority***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater shortage</td>
<td>1.4*</td>
<td>2.0</td>
<td>1.6</td>
<td>1.9</td>
<td>1.8</td>
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</tr>
<tr>
<td>Modification of stream flow</td>
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<td></td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollution of existing supplies</td>
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<td></td>
<td>1.6</td>
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<tr>
<td>Changes in the water table</td>
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</tr>
<tr>
<td>Pollution</td>
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<td>2.3</td>
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<tr>
<td>Microbiological pollution</td>
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<tr>
<td>Eutrophication</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Chemical</td>
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</tr>
<tr>
<td>Suspended solids</td>
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<tr>
<td>Solid waste</td>
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<tr>
<td>Thermal</td>
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<tr>
<td>Radionuclide</td>
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<tr>
<td>Spills</td>
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<td></td>
</tr>
<tr>
<td>Habitat and community modification</td>
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<tr>
<td>Loss of ecosystems</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Modification of ecosystems</td>
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<td></td>
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<tr>
<td>Unsustainable exploitation of fish</td>
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<td>2.2</td>
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<tr>
<td>Overexploitation</td>
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<td>Excessive by-catch and discards</td>
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<td>Destructive fishing practices</td>
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<td>Decreased viability of stock</td>
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<tr>
<td>Impact on biological and genetic diversity</td>
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<td>Global change</td>
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<tr>
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<tr>
<td>Sea level change</td>
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<tr>
<td>Increased UV-B radiation</td>
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<tr>
<td>Changes in ocean CO2 source/sink function</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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.
La Plata River Basin

Freshwater shortage

The impacts of freshwater shortage are moderate in the La Plata River Basin. Although the available freshwater resources in the La Plata River Basin easily exceed the current total demand, uneven temporal and spatial distribution of water flow in the basin headwaters and degradation of water sources are causing freshwater shortages in some areas.

There is evidence of significant decreases in discharge in localised areas due to intensive water extraction in shared basins, which will probably increase in the future. Changes in low water flow and also, to some extent, in high water flow have occurred in the international stretch of the Paraná River system (Argentina, Brazil and Paraguay) because of land use changes and the construction and operation of reservoirs. As a result of reports of fish kills, extended bacteriological contamination due to raw sewage discharges and high pollution levels in some urban and industrial areas, including toxic substances close to rivers with different transboundary status, pollution of freshwater sources was considered the most significant cause of freshwater shortage.

In addition, sub-national and multi-national aquifers that are used as urban and industrial water supplies are contaminated by domestic and industrial pollution and intensive agriculture and cattle raising activities. Also, there is evidence that water tables are receding and, as a result, wells have been deepened, and that overexploitation of aquifers has caused salinisation in some hot spots in Brazil, Uruguay and Argentina (Buenos Aires Metropolitan Region).

Socio-economic issues are more significant than environmental issues in terms of their potential to cause conflicts at sub-national and regional levels.

Environmental impacts

Modification of stream flow

In the Upper Paraná River Basin, stream flows have increased by 20 to 45% in several tributaries upstream of the Itaipú Reservoir compared with those recorded during the 1960-1970s (Müller et al. 1998). Similar trends were found in the Uruguay and the Paraguay River Basins (Figure 12) where, despite only minor increases in rainfall, there has been a considerable increase in the water level of the rivers since 1970 (Collishonn et al. 2001). In addition, other factors, such as changes in land use and land cover, have increased terrestrial run-off and have also contributed to the increased stream flows observed in these rivers (Müller et al. 1998).

Taking into account the history of river discharges, it is possible to identify three periods within the Middle and Lower Paraná River Basin. The first period, from the beginning of 1900 up to 1930 river flows generally increased, while in the second period, between 1930 and 1970, the lowest flows of the century were recorded. Finally, the last period from 1970 to 1998, was characterised by increased stream flow and more frequent outstanding peak flows (Giacosa et al. 2000).

Although lack of information indicating the contribution of climate changes and seasonal anomalies to changes in stream flow makes it difficult to assess the influence of human activities on these issues, the environment of these basins has been modified by changing land uses and the construction of reservoirs and dams for hydropower.
generation and irrigation. Dam operation changes the hydrological regime downstream since it causes either a decrease in peak flows and/or an increase in minimum flows. Figure 13 shows changes in the mean daily minimum discharges and mean annual discharges of the Paraná River (Paraná-Santa Fe cities, Argentina) from 1970.

Notwithstanding the history of water supply and irrigation demands within the La Plata River Basin, at present, in some areas, urban water supply and irrigation compete for available water, especially during periods of low flow, when the demand for water increases (Arcelus 1999, ANA 2001). In the Uruguay River Basin, there is a private rice production development. Irrigation occurs mainly along the Ibiucú River in Brazil and the Cuareim River, which is shared by Uruguay and Brazil, both tributaries of the Uruguay River. In these areas, there are conflicts between the demand for water for human consumption and the demand for irrigation during the dry months (Tucci & Clarke 1998).

In several areas within Tietê River Basin and Grande River Basin in São Paulo state (Brazil), irrigation cannot be expanded since there are conflicts between domestic water supply and irrigation due to freshwater shortage. Similar conflicts between industrial and domestic water supply have occurred in Baxio Pardo-Mogi (São Paulo) where sugar cane and alcohol industries are responsible for about 22% of the industrial water consumption (Tucci 2001).

**Pollution of existing supplies**

Pollution of surface and groundwater bodies is becoming an extended problem with growing trends in the Basin. Consequently, the costs of treatment have increased and there is a need to find alternative sources to cope with growing demand and increasing shortages of water.

The Pilcomayo and Bermejo rivers and their tributaries are important sources of domestic water in Bolivia. Water quality is good except in the vicinity of human settlements. However, additional pre-treatment of the water is required because of the increase in turbidity due to large sediment loads carried by these systems during the summer rainy season. The Water Monitoring Programme in the Department of Tarija (Bolivia) have detected higher concentration levels of arsenic, lead, cadmium, nickel, zinc, manganese, cyanide, phosphorous, iron and boron than permitted under Bolivian environmental legislation.

Additionally, incidental pollution events have been recorded, such as a mining spill at Porco in the Upper Pilcomayo River in 1996 and a hydrocarbon spill at Bloque de los Monos, which affected the Pilcomayo River 5 km upstream of Villamontes in 1998. These events illustrate the risks to humans resulting from consumption of untreated water and the problems associated with the accumulation of pollutants in biota (Centro de Análisis y Desarrollo de la Universidad Juan Saracho 2001, Instituto de Tecnología de Alimentos 2002).

In the Upper Paraguay River, the main sources of pollution are mining (Mato Grosso, Brazil), sediment loads from erosion due to soil fragility and overgrazing, mainly in the Taquari River Basin (Mato Grosso do Sul, Brazil), and untreated discharges. In general, water quality is good except near the cities.

Figure 14 shows graphically the results of a short-term assessment of water quality at selected stations associated with international river reaches in the Brazilian area of the La Plata River Basin. The graphs are based on water quality index parameters over a one-year period.

The Upper Paraná Basin in Brazil supports a population of 46.7 million and covers 1 million km², five states and the Federal District (see Figure 11). A major part of the industries and many of the greatest cities of the La Plata Basin are located in this region. Organic matter discharge is estimated at 730 000 tonnes BOD per year. Pollution of water supplies is a common but localised problem in many urban settlements (CETESB 2001).
The metropolitan area of São Paulo located in the Upper Tietê River Basin has 18 million inhabitants (Figure 15) which require about 60 m$^3$/s of safe drinking water. At present, 33 m$^3$/s are imported from neighbouring basins since the Tietê system lacks high quality water (Tucci & Clarke 1998). Water pollution is a significant concern, as untreated domestic and industrial effluents are discharged in the rivers and reservoirs. The Tamanduatei and Pinheiros rivers (upper metropolitan zone of São Paulo) have a high pollution load with extremely low or even zero dissolved oxygen levels (CETESB 2000). The Cantareira system supplies around 50% of the metropolitan area’s requirement, while the Billings-Guarapiranga Reservoir system, mainly to the southern part of São Paulo Metropolitan Region, supplies an additional 20%. According to the Water Quality Report of Inland Waters in São Paulo state (CETESB 2001), the concentration of phosphorous and chlorophyll a indicate that both reservoirs exhibit generalised eutrophic conditions and that, since 1999, these levels have increased in the Guarapiranga Reservoir.

A similar stress on water sources is found in Curitiba, in the Upper Iguazú River, where the water quality in general is good (ANEEL 2001). However, there are local cases of high pollution, such as the main reach of the Iguazú River and Iraí Reservoir, that cause water supply problems, mainly due to increasing eutrophication (ANEEL 2001). In the Iguazú River, sewage is discharged without prior treatment. The potential pollution load is about 140 tonnes BOD, per day. Only 29% of the urban population is connected to sewage network.

Nitrate and coliform bacteria has been found in wells indicating that some groundwater sources are polluted. Groundwater vulnerability studies identify Ribeirao Preto/Franca, Bauru, Campinhas and the recharge zone of the Guaraní Aquifer in Brazil as the main areas of environmental concern (CETESB 2001).

Run-off from rural and urban areas is another source of pollution. This region has accelerated agricultural growth which is replacing forests with intensive mechanised agricultural areas. This process has resulted in significant consumption of natural resources that has caused serious erosion problems resulting in increased turbidity in water withdrawn for domestic purposes and, as a consequence, a higher degree of purification is needed (Merten 1989).

In the Lower Paraná River near Rosario city, the algal concentration is about 15 000 to 300 000 cells per litre and turbidity is about 30-230 NTU (Nephelometric Turbidity Unit). Although conventional water treatment plants guarantee the absence of pathogens in the treated water, they cannot guarantee the absence of algae, even with the improvements carried out in several treatment steps. Consequently, there are operative problems, possible increase in trihalomethane (THM) and nutrients, such as organic matter, which might enable microorganisms to grow in the water supply network (Vazquez et al. 1997, Cepero 2000).

Intense urban and industrial water uses and poor water quality causes severe impacts in a large inshore coastal area of the La Plata River that is associated with the Buenos Aires Metropolitan Area, although the concentrations of pollutants decline rapidly away from the shore. Oxygen demands (BOD and COD) show high values between the Riachuelo River and Punta Colorada. Dissolved oxygen reaches the lowest values near the coast and the maximum about 3 km offshore. High concentrations of ammonium, nitrates and phosphates, as well as heavy metals, agrochemicals and biphenyl poly-chlorines have also been found. The highest bacterial concentrations occur within 500 m from the coast, and decreases beyond 3 km. Microbiological parameters such as total coliforms and faecal coliforms exceed the values recommended by the Environmental Protection Agency of the United States. In 1997, a geometric mean of about 12 000 faecal coliforms/100 ml were detected in the Riachuelo River (Consejo Permanente para el Monitoreo para la Calidad del Agua de la Franja Costera Sur del Río de la Plata 1997).

In the Buenos Aires Metropolitan Area, leaching from illegal landfills impact on water availability for human consumption (Aguas Argentinas 1997, Virgone 1998). In addition, Buenos Aires and Rosario (the third urban area of Argentina) discharge untreated sewage and other waste directly into the La Plata and Paraná rivers, respectively. Further, even when waste treatment is carried out, as in La Plata City, only a minor fraction of collected sewage water is purified (CEPIS & OPS 2000).

Severe pollution problems have been identified in several water supplies in Uruguay. In the Santa Lucía River Basin, which supplies water to 60% of the country’s population and in the Laguna del Sauce basin...
Basin, eutrophication reduces the quality of water to unacceptable levels causing water shortages for Maldonado and Punta del Este cities (OEA et al. 1992).

Changes in water table
Information about quantity, availability and exploitation of groundwater in La Plata Basin is still incomplete and variable. However, groundwater overexploitation for domestic water supply has been observed in the urban belt of Buenos Aires City, the most densely inhabited area in Argentina, with about 12 million inhabitants. It extends from Zárate City to La Plata City (Figure 16). In La Plata for example, groundwater was overexploited before 1950 (Banco Mundial 2000). During the 1970s, the salt intrusion rate was 70 m per year, but the trend has now decreased as many wells have been abandoned and others have reduced the extraction. At the same time, the intensive exploitation resulted in a decrease of the hydraulic potential of the good quality semi-confined aquifer which supplies the city, favouring the downward flow of water polluted with nitrates from the upper aquifer (CYTED 2000).

Nowadays, in the aquifer supplying Buenos Aires Metropolitan Region, there is an increase in water availability, mainly due to: (i) rainfall increase in the aquifer recharge area; (ii) a decrease of industrial activity and water use; and (iii) substitution of groundwater by surface water supply. In the Buenos Aires urban belt, 55% of the population receives freshwater from the network, while only 33% is served by sewage collection systems (Unidad Ejecutora de Programas para el Conurbano Bonaerense 1996).

In the northwestern part of Buenos Aires province, irrigation and domestic water supply compete for the same groundwater sources. Salinisation processes due to a lowering of the mean water table makes this conflict more serious by reducing water availability, particularly during the summer months when domestic and crop requirements are higher (Gonzalez & Hernández 1998).

Preliminary studies of the Guarani Aquifer System (Figure 8) have found no evidence of overexploitation at regional level. However, at local level, mainly in recharge areas or natural spring areas with urban development, there is evidence of overexploitation and risk of pollution from human activities (Gregoraschuk 2001).

In the state of São Paulo, Brazil, groundwater sources are not highly exploited. The extraction rate is about 60 m$^3$/s, representing only 18% of the available recharge, estimated at 336 m$^3$/s. However, in local areas such as do Pardo (Ribeirão Preto); Turvo/Grande (São José do Rio Preto); Paraiso do Sul (São José dos Campos); and Tietê/Jacaré (Bauru), overexploitation has resulted in a lowering of the water table (CETESB 2001).

In the Upper Tietê River Basin, extraction rates from the sedimentary aquifer are higher than the recharge rates. This negative balance is due to losses from freshwater and sewage networks. In addition, lower levels in the water table due to aquifer overexploitation are inverting the natural underground flow from the River towards the aquifer, reducing the basic discharge of the River (CETESB 2001).

Socio-economic impacts
Economic impacts
Contamination of water supplies was identified as the most important cause of economic impacts. This results from the loss of drinking water supply, which leads to increased costs in water treatment or the incorporation of alternative supply sources. The loss of surface and groundwater water supply sources for urban settlements in large metropolitan areas, such as São Paulo, Buenos Aires and other important cities in Argentina like Rosario, Santa Fe, Resistencia, Posadas or La Plata, affects millions of people and many industries, increasing provision service costs.

A good approach for evaluating the problem is based on the percentages of the population with access to drinking water and sewage system. Table 10 shows the urban and total percentage of the population with access to water and are serviced by a sewage system in the countries sharing the La Plata Basin. It illustrates that a greater percentage of the population in cities are supplied with water and are connected to a sewage system. In addition, during the late 1990s, there has been an increase in coverage in all countries and urban areas within the La Plata Basin (CEPI&S & OPS 2000).
In all the countries the lack of sanitary services coincides with the location of poor housing areas and consequently, poverty. According to the CEPIS & OPS's report analysing the five great cities in La Plata River Basin, Curitiba has the highest percentage of population in marginal settlements, followed by the Buenos Aires Metropolitan Area, Montevideo, São Paulo and Asunción (CEPIS & OPS 2000).

The percentage of treated effluent varies between a maximum of 76% in Uruguay and a minimum of 8% in Paraguay. Values for Argentina and Brazil are at the lower end, with only 10% treated in each country. Bolivia treats approximately 30% of its effluent (CEPIS & OPS 2000).

In the Upper Paraná system, problems associated with the supply of drinking water in the São Paulo Metropolitan Area are related to the pollution of the Tietê River. In addition to high water treatment costs, the treatment of sewage has required considerable investment in sanitation measures. The Tietê Project, an integrated sanitation plan (SABESP 2002, CEPIS & OPS 2000) and the “Projeto de Despoluição do Rio Tietê” (SABESP 2002) aims to completely clean the Tietê River in approximately 20 years. During its first stage, which finished in 1999, the sewage network was extended and effluent treatment capacity increased from 20 to 60%. It is calculated that approximately 80 tonnes of untreated effluent was prevented from being discharged into the Pinheiros River (Tietê tributary) during 1995-1999.

Additionally, the intensive use of natural resources, which has caused serious erosion problems, has economic implications for agriculture and the environment. For example, the increase of turbidity has resulted in increased costs for water purification operations (Merten 1989). Within Brazil, water shortages are reducing the capacity to generate hydropower, which affects large economic sectors and the population as a whole.

**Health impacts**

Although reliable epidemiological records to quantitatively assess water-related diseases are not available, water pollution is known to be the cause of many health problems, particularly in urban populations in marginal tropical areas that lack safe water supply. In addition to the impacts caused by domestic and industrial pollution, the health of the population is also affected by contamination of water supplies by microbes, nitrates and even toxic metals.

In Brazil, about 65% of hospitalised people suffer from water-related diseases which affects especially low-income populations that do not have either freshwater supply or sewage infrastructure.

The rural and urban population in marginal areas is the worst affected by water shortages. In tropical regions, with high temperatures, there are health problems, particularly in low-income populations with greater water demands.

The presence of nitrates in the groundwater on the outskirts of Buenos Aires Metropolitan Area may affect populations not served by sewage systems. In the Pilcomayo River Basin, it can be assumed that indigenous people may have health problems related to the consumption of the fish Sábalo that have accumulated heavy metals (lead) in their tissues.

**Other social and community impacts**

Social and community impacts include the increase in potential upstream-downstream conflicts due to reservoir management which, in some cases, have transboundary implications.

There are also conflicts due to differences in regulations regarding the physical-chemical and bacteriological parameters of water quality in Argentina and Brazil. Table 22 shows the main parameters of water quality measured in the transboundary reaches of the Brazilian rivers. Brazilian guidelines describing the physical-chemical and bacteriological standards of water quality that should be met through conventional treatment are different from Argentinean guidelines. Brazilian guidelines take into account water uses together with aquatic life supporting variables, while Argentina treats these separately.

In the Pilcomayo River, high heavy metal concentrations in sediments, originating from mining activities, deleteriously affects water and fishing for human consumption. The dramatic reduction of artisanal fishing and a decrease of economic resources induce migration of indigenous people to the urban centres of Bolivia (e.g. Yacuiba and Santa Cruz) and Argentina.

Losses in recreational uses due to water shortage in extreme low flow situations have been considered. Although the critical period only lasts for about two months, this issue is very significant in Uruguay where the river integrates culture and traditional lifestyle. As the crops of small farmers located next to the riverbanks become affected, social problems arise as a result of the reduction of cultivated areas and the increasing size of settlements.

**Conclusions and future outlook**

It is difficult to assess the relative contribution of human activities and climate change to impacts associated with freshwater shortage because of the lack of historical information describing climatic trends and seasonal anomalies. Although pollution of freshwater sources is
moderate, the present environmental impacts of freshwater shortage as a whole are slight, while the socio-economic impacts are moderate.

Importantly, there was no comparable information for the five countries of the La Plata River Basin, and only scarce information about groundwater exploitation for different uses. As a consequence, it is recommended that further regional studies on groundwater availability, exploitation and management should be conducted.

The economic consequences of pollution are reflected in the source changes, which take place in the main cities, increased water treatment costs, and the restoration of supply sources. However, pollution control, particularly at an industrial level and within major urban settlements, will improve. Population growth, urban concentration and economic limitations may restrict the possibility of drastically improving the very low percentage of wastewater that is currently treated. Thus, water sources will continue to be degraded, while water demands will naturally be greater. Health problems associated with the lack of safe water will increase and consequently, social and community impact will increase. The economic and health impact is expected to increase during the next decade and then decline in the long-term. Therefore, the impacts of freshwater shortage are not expected to increase in the future due to implementation of quality controls in the countries within the Basin and are predicted to remain moderate.

## Pollution

The general lack of sewage treatment in the La Plata River Basin has had a negative impact on the water quality of many rivers, mainly in the vicinity of cities. Industrial contamination as a result of the limited treatment of industrial waste and revamping of industrial processes is particularly important. Heavy metal pollution is ubiquitous in the La Plata River Basin and is the main chemical pollution stress. Waste discharges from mining activities in the Upper Pilcomayo River Basin have transboundary consequences for Argentina and Bolivia downstream.

Inadequate treatment of domestic sewage is demonstrated by numerous instances of bacteriological contamination. Usually, the impacts resulting from microbial contamination of rivers are restricted to sub-national levels but, in some cases, the impacts extend beyond national frontiers, as seen in the Bermejo River (Argentina and Bolivia), Pilcomayo River (Argentina, Bolivia and Paraguay) and Uruguay River (Argentina, Brazil and Uruguay).

Large amounts of suspended sediments can be found in particular rivers, e.g. the Bermejo and Pilcomayo rivers, but most of the suspended material originates from natural landslides and soil erosion. However, there are indications of increased turbidity in some rivers due to changes in land use and unsustainable agricultural practices. This is occurring mainly in humid and semi-arid areas that have been subjected to extensive deforestation, such as the Upper Paraná, Paraguay and Uruguay basins in Brazil, which have exerted impacts downstream in Argentina, Paraguay and Uruguay.
Eutrophication is mainly a localised problem but can cause major economic loss, since algal blooms affect the operation of dams and require increased water treatment. Accidental oil spills and heavy metal contamination from mining activities occur regularly and often has transboundary implications. Accidental spills have also caused major economic loss in terms of emergency and remediation costs.

There is no impact from radionuclide pollution due to the absence of radionuclide sources in the region. Slight impact was assigned to thermal pollution because of the effects of water discharges of open cooling systems of major thermoelectric facilities located next to the Paraná River in the cities of Rosario and San Nicolas. In the La Plata River in Buenos Aires City water discharges are quite limited without transboundary effects.

Health impacts related to pollution mainly concerns water-related diseases. Cholera epidemics have occurred in all countries of the La Plata River Basin, except in Uruguay, during the 1990s, and diarrhoea is a significant disease affecting children.

Overall, pollution is considered to have a moderate impact in the La Plata River Basin.

**Environmental impacts**

**Microbiological pollution**

There is a generalised lack of sewage treatment in the La Plata River Basin that impacts on the water quality of many rivers, mainly in the vicinity of cities. In the Upper Uruguay, Peixe, Cuareim and Lower Uruguay rivers microbiological pollution can be considered severe and, in the Upper Paraguay River, it is moderate due to the dilution capacity of the River.

In the São Paulo Metropolitan Region (Brazil), the Upper Tietê River system is anoxic due to discharge of untreated industrial effluents and sewage. The absence of fish and the emission of disagreeable odours for most of the year have turned it into a sewage dump. It receives permanent wastewater discharges, at a rate of about 40 m$^3$/s, which represents 60% of the river’s mean dry-weather flow. This pollution affects 8 million people and it is the cause of water quality deterioration in the reservoirs downstream (IDB 1995). The Paranoa Lake receives treated effluents from Brasilia City and exhibits water quality problems (Figure 17) (CAESB 2002).

The “Guidelines of Water Quality for La Plata River Basin” proposed by Argentina recommend a maximum number of faecal coliforms of 200/100 ml for leisure activities with direct contact and 1 000/100 ml for water for human consumption with conventional treatment. In the Middle Paraná River, faecal coliforms measured in 1994 showed an average number of 609/100 ml and a median of 210/100 ml, exceeding the standard for leisure activities. The same situation occurs in the Paraguay River, with an average and median of 651/100 ml and 218/100 ml, respectively. Although in the Lower Uruguay River the average and median of faecal coliform concentrations measured have been below the guidelines, there are values in the range of 4-480/100 ml which has had a significant influence on the type of recreational activities allowed in the coastal areas (DNPCyDH & SSRH 1999).

In the La Plata River and its southern shoreline during 1994-1995, the average faecal coliform concentration ranged between 13-630 957/100 ml, significantly exceeding acceptable standards. The highest bacteria concentrations occur within 500 m of the coast. In 1997, a geometric mean of about 12 000/100 ml faecal coliforms was detected in the Riachuelo River. Consequently, recreational activities resulting in direct contact were prohibited in many areas along the coast (Consejo Permanente para el Monitoreo para la Calidad del Agua de la Franja Costera Sur del Río de la Plata 1997).

**Eutrophication**

Eutrophication is present in localised areas of the large reservoirs in the transboundary rivers but is more common in a number of water bodies in their tributaries. In all cases, eutrophication affects water treatment.
In the Brazilian territory of the Paraná River Basin, serious problems in water treatment affects the water supply of São Paulo from the Billings-Guarapiranga Reservoir system due to excessive algal blooms (Beyruth 2000). The series of reservoirs in the Middle Tietê River, Brazil, receive input from sugar cane processing plants and upstream discharges from São Paulo City (CETESB 2002b).

In the Negro River Basin (Uruguay), deterioration of the water quality in reservoirs became evident through increased nutrient levels (mesotrophic-eutrophic) and toxic algal blooms, particularly of nanoplanktonic phytoflagellates, diatoms (*Aulacoseira*) and cyanobacteria (*Microcystis* accompanied by *Anabaena*) (Gorga et al. 2001).

In the south coastal fringe of the La Plata River, nutrients originate from different sources, such as industries and domestic effluents. The most affected zone extends 500 m offshore. The phytoplanktonic species found are characteristic of freshwater environment, with a predominance of mesosaprobic and eutrophic species (Gómez & Bauer 1998).

**Chemical pollution**

Chemical pollution, due to its broad spatial and temporal scale, is the main aspect of pollution. In the Paraná River, heavy metal concentrations in the São Paulo metropolitan zone have been found to exceed Brazilian guidelines (CONAMA 1986) for “Freshwater Aquatic Life”. Persistent organic pollutants such as DDT and hexachlorocyclohexane have been detected in fish from the Paraná River (ENAPRENA 1995). In the Tietê River registered the highest nickel levels (0.07 mg/l) (CETESB 2002b).

The Upper Paraguay River Basin has been subject to intensive gold mining and agricultural exploitation. Mercury pollution from mining operations is particularly significant in the state of Mato Grosso, Brazil (Banks 1991). Agro-chemicals such as fertilisers, herbicides and insecticides, constitute another significant problem, as they are washed into streams.

Agriculture and industry are the major threats concerning the Paraguay River in Paraguay. Traces of heavy metals and pesticides have been found. Lead, chromium, cadmium, iron and mercury concentrations (1988-1995, Pilcomayo and Formosa ports) exceed international water quality guidelines for freshwater aquatic wildlife. Concentrations of chromium and zinc in sediments at different points at Asunción Bay exceeded those reported for moderately polluted world rivers (chromium: 103 mg/kg versus 16-27 mg/kg; zinc: 163.2 mg/kg versus 26-99 mg/kg) (ENAPRENA 1995).

 Persistent organic pollutants such as DDT and hexachlorocyclohexane have been detected in fish (ENAPRENA 1995) also in the Paraguay River. Heavy metal contamination of sediments in the Pilcomayo River system is particularly problematic since the predominant fish species are detritivorous organisms (Sandi 1998). High concentrations of lead, arsenic, copper, mercury, zinc and silver in sediments were found at Misión La Paz (Salta, Argentina) (Comisión Trinacional para el Desarrollo de la Cuenca del Río Pilcomayo 1999). At Potosí (Bolivia), lead, cadmium and zinc concentrations were sufficiently high to declare the water supply unacceptable for human consumption and for recreational use with direct contact.

The Uruguay River receives organic pollutants from agricultural exploitation. These inputs are generally associated with pesticides and aromatic and aliphatic hydrocarbons from urban activities. In addition, phenol concentrations that exceeded the Environmental National Council (CONAMA) (Conselho Nacional do Meio Ambiente) guidelines were found (1993-1998, Iraí station, Brazil). A similar situation was observed at Monte Caseros (Argentina, Uruguay) where the concentration of phenol exceeds the Administrative Commission for the Uruguay River (CARU) (Comisión Administradora del Río Uruguay) guidelines for freshwater aquatic life (INA 1999).

Critical metal concentrations of lead, iron, cadmium and, especially, mercury have been recorded at El Soberbio (Brazil and Argentina). The latter may be referred to an industrial discharge point (INA 1999).

Organic pollutants also affect water quality in the southern reach of the Uruguay River. The heavy use of agro-chemicals is a consequence of agricultural exploitation. High concentrations of pp’DDT and aldrin exceeding the CARU guidelines have been found at Monte Caseros (INA 1999).

Water samples taken in the Iguazú River (Iguazú National Park station, 1998) exhibited high concentrations of cadmium and lead exceeding CONAMA guidelines. Significant phenol levels were reported between 1993 and 1997, also exceeding the above guidelines (ANEEL et al. 1999).

The La Plata River system receives either directly or through its tributaries, urban and industrial wastes that flow through agricultural areas. Some records of chromium and lead concentrations exceed water
quality guidelines. Metal concentrations in sediments, bivalves and in suspended particulate matter are comparable with those reported for other moderately polluted world rivers. The chromium concentration in suspended particulate matter is relatively high; the highest value is double that of the maximum concentration recorded for the Rhine/Meuse estuary (Bilos et al. 1997).

Persistent organic pollutants (POPs) are widely distributed and concentrated in sediment and biota. Despite its considerable dimensions, POPs affect the entire La Plata River coastal ecosystem. These pollutants concentrate in organic sediments and in detritivorous organisms such as Sábalo (Prochilodus lineatus), a fatty fish that is an efficient accumulator of POPs (Colombo et al. 2000).

**Suspended solids**

Erosion due to changes in land use and unsustainable farming practices have caused an increase in water turbidity, mainly in areas subject to deforestation for agricultural use in both humid and semi-arid areas of the La Plata River Basin. The development of agriculture and urban settlements has resulted in extensive deforestation in the Upper Paraná, Paraguay and Uruguay basins in Brazil. Table 23 shows changes in original cover in the states of Paraná and São Paulo, Brazil, both of which are within the Paraná River Basin (Tucci & Clarke 1998).

In the state of Rio Grande do Sul (Brazil), forest cover at the beginning of this century was about 40% of the total area of the state. Today, it is estimated to cover only about 2.6% (Tucci & Clarke 1998). Since 1970, there has been a change in land use within the Upper Paraná, Uruguay and Paraguay River basins. In the Brazilian sector, annual crops such as corn and soya, have replaced the main perennial coffee crop.

The rate of erosion in the Upper Paraguay Basin is about 4 tonnes/ha/year. In the Middle Paraná River, erosion rate is less than 10 tonnes/ha/year, while in the Lower Paraná River it varies between 18 tonnes/ha/year, when agriculture and cattle raising are rotated on an annual basis, and 28 tonnes/ha/year when agricultural production is continuous. In the Upper Uruguay Basin, the rate of erosion is ranges between 16 and 32 tonnes/ha/year and in the Bermejo River Basin it is between 390 and 2 000 tonnes/ha/year (FECIC 1988, Tucci & Clarke 1998, Brea et al. 1999).

The amount of sediment carried by the Bermejo and Pilcomayo rivers is usually high. Sediment discharged by the Bermejo River represents about 70% of the total suspended solids of the Paraná River at Corrientes (Argentina). During the last 20 years, it has constituted 80% of the total sediment load. The construction and operation of reservoirs upstream in the Paraná and Iguazú basins may explain the increase in the discharge of suspended solids (Brea et al. 1999).

The amount of sediment carried by the Upper Pilcomayo Basin is about 84 million tonnes per year with mean suspended solid concentrations as high as 12 g/l (Villamontes, Bolivia). The large amount of sediment deposited along the River in the Chaco Plain is reducing flow rates and increasing the rate of deposition upstream in the Argentinean and Paraguay territory. The rate of recession was estimated at about 5 km per year between 1940 and 1975, and up to 40 km per year in recent years (CONAPIBE 1994).

The production and transport of sediment in the Upper Paraguay Basin is of great concern. In the Planalto, there has been a dramatic increase of the areas planted with annual crops since the 1970s, which has resulted in a significant increase of soil erosion and sediment transport into the Pantanal. At the same time, the short-term increase of annual rainfall in the upper part of the Basin has caused soil losses in the Planalto with deposition in some reaches and, in the Pantanal, greater deposition of sediment and reduced channel conveyance (Tucci 2002, Collischonn et al. 2001). In the Salto Grande Reservoir (Lower Uruguay River), the deposition rate, originally estimated at 330 m³/year, is now about 1 130 m³/year, due to changes in land use in the upper basin as well as stream flow. The above increase was measured between the years 1980 to 1992 (Irigoyen et al. 1998). Normal reservoir operation causes bank erosion downstream with an increase in water turbidity.

**Solid waste**

The impact of solid waste is negligible in surface waters and has a local impact on groundwater in large metropolitan areas within the region. Nevertheless, attention should be given to the increasing development of unregulated disposal of municipal and industrial waste in urban areas, linked to the declining socio-economic status of the Mercosur countries.

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**Table 23**  Deforestation evolution in São Paulo and Paraná states (Brazil) and in eastern Paraguay.

<table>
<thead>
<tr>
<th>Year</th>
<th>Original forest cover of Paraná state (%)</th>
<th>Year</th>
<th>Original forest cover of São Paulo state (%)</th>
<th>Year</th>
<th>Original forest cover of eastern Paraguay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1890</td>
<td>83.4</td>
<td>&lt;1886</td>
<td>83.8</td>
<td>1945</td>
<td>55</td>
</tr>
<tr>
<td>1890</td>
<td>83.4</td>
<td>1886</td>
<td>70.5</td>
<td>1960</td>
<td>45</td>
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<td>1930</td>
<td>64.1</td>
<td>1907</td>
<td>58.0</td>
<td>1970</td>
<td>35</td>
</tr>
<tr>
<td>1937</td>
<td>58.7</td>
<td>1935</td>
<td>26.2</td>
<td>1980</td>
<td>25</td>
</tr>
<tr>
<td>1950</td>
<td>30.7</td>
<td>1952</td>
<td>18.2</td>
<td>1990</td>
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</tr>
<tr>
<td>1965</td>
<td>23.9</td>
<td>1962</td>
<td>13.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>11.9</td>
<td>1973</td>
<td>8.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Tucci & Clarke 1998)
The Pilcomayo River receives solid waste from different human activities in Bolivian territory. This is a result of urban growth and unsustainable solid waste disposal along streets and rivers and in open dump sites. Final disposal of solid waste is around 50% in controlled landfills, and 50% in open dump sites (Acurio et al. 1998).

The estimated generation of solid waste in Paraguay is around 3.3 tonnes per day; less than 20% is collected and disposed of in a controlled manner (BiD et al. 2001). Some hazardous solid waste containing heavy metals and toxic organic compounds is dumped in the environment with industrial wastewaters or goes into landfills as solid waste.

The Upper Paraná River, in Brazil, receives a significant load of solid waste and wastewater from human activities in riparian cities and urban shanty towns, which affect the quality of the watercourse. For example, in São Paulo’s Metropolitan Area the quantity of solid waste generated is 22 100 tonnes per day with 1.3 kg per inhabitant per day (Acurio et al. 1998).

The La Plata River receives solid waste from the coastal cities Montevideo and Colonia in Uruguay and Buenos Aires Metropolitan Area in Argentina. In Montevideo City, one of the most important environmental problems is the dumping of waste in watercourses due to a malfunctioning sewage collection system. The dumping is performed by solid waste scavengers (hurgadores) concentrating the waste near the river shores or on open dump sites, leading to disease and uncontrolled plague (Acurio et al. 1998).

The Buenos Aires Metropolitan Area generates 10 500 tonnes per day of solid waste. In 1994, on the outskirts of Buenos Aires City more than 100 open dump sites were detected affecting 400 ha of soil with 1.2 million tonnes of urban and industrial solid waste. Recently, the percentage of solid waste that receives some kind of controlled final disposal has declined, increasing the number of open dump sites (Virgone 1998).

Spills
Occasional major oil spills occur in the La Plata and Iguazú rivers, with significant impact at local levels. The La Plata River has seen four such spills. In 1996, in the access channel to Buenos Aires port, two ships collided and lost 2 400 m³ of fuel oil, contaminating 40 km of the coastal area (BRECHA Newspaper). In 1997, a ship breached 20 miles from Punta del Este (Uruguay) and spilled 2 000 to 3 000 tonnes of crude oil. The spill of raw petroleum reached the beaches of Uruguay and affected 20 km of coastline and the Sea Wolves Island. In 1999, two ships collided in the La Plata River near Magdalena’s coast, Argentina. The spill of 4 600 m³ affected 20 km of the Buenos Aires coast (Villalonga 2000). In 2000, a ship spilled 3 000 litres of crude oil in the La Plata River near the Berisso coast, Buenos Aires. Contingency operations were hampered by bad weather conditions, allowing hydrocarbon waste to reach the coast (Villalonga 2000).

In the Iguazú River Basin, in 2000, a spill of 4 000 m³ of petroleum from a refinery, occurred in Curitiba (Paraná state, Brazil). The estimated amount of oil that reached the River was 1 300 m³. Volatile lineal and aromatic hydrocarbons (BTEX), and polycyclic aromatic hydrocarbons (PAH) were however not detected in dissolved and particulate phases (INÁ 2002).

A heavy metal spill from the tailings pond of the COMSUR Mine has had a significant impact. In the Upper Pilcomayo River Basin (Porco, Bolivia) in 1996, 235 000 m³ of mine tailings containing high concentrations of heavy metals were spilled because of a ruptured dike (Vargas Ballester 1996). Concentrations of heavy metals and suspended solids exceeded Bolivian standards. Immediate remediation measures were performed along a 10 km reach of the River. The load of heavy metals was transported along the entire basin through particles, limiting heavy metal bioavailability. Today a Mining Residues Recovery Programme is carried out in Bolivia.

In the Bermejo River Basin (Argentina), incipient contamination from oil residues originating from oil exploration wells were reported in 2001. A spill from a breaking mine tailings pond was also reported in this basin (Aguilar Mine). Issues related to water quality and quantity are of a high concern in the Bermejo River Basin due to increasing and diversified water uses.

In 1992, a truck-tank transporting liquefied phenol crashed (Caieiras, São Paulo), spilling 22 m³ on the roadside. Part of this spilled material entered the road drainage system and eventually ended up in Juquerí River (Paraná tributary). After this accident, the phenol concentration in the Juquerí River exceeded its mean value by 20 times; contaminating water for a two-month period (Haddad & Aventurato 1994).

Socio-economic impacts
Economic impacts
The polluted state of the Tietê River requires great investments in water treatment and sanitation in São Paulo (Brazil). Sanitation measures have been carried out by the Drainage Company of São Paulo state (SABES) (Companhia de Saneamento Básico do Estado do São Paulo). Algal blooms in the Guarapiranga Reservoir have affected dam operations due to their resistance to algaecide and consequently, have cause an
increase in water treatment costs (Beyruth 2000). In the São Paulo state (Brazil), emergency and remediation operation costs of an accidental spill in the Juquerí River system (1992) was estimated at about 150 000 USD (Haddad & Aventurato 1994).

Problems related to suspended solids of anthropogenic origin were detected in Paraná state (Brazil), where erosion caused by land use changes produced a considerable increase in river turbidity in water supplied to more than 200 cities, which caused an increase in water treatment costs (Merten 1993).

Several activities in the Pantanal have been seriously impacted resulting in higher maintenance costs for navigation in the Paraguay River and significant economic loss to commercial and sport fishing (Moiragh de Pérez 2000). Sediment progressively fills channels and riverbeds, increasing overflow and flooding. This has a negative economic impact on cattle raising and land values (Tucci 1996).

Due to successive mining accidents in the Pilcomayo River system, environmental actions were started. The World Bank, the Swedish International Development Cooperation Agency (Sida), and the Bolivian Mining Corporation (COMIBOL) (Corporación Minera de Bolivia) assigned 3 million USD for mitigation and prevention actions (Veneros 1998). In the Lower Pilcomayo River (Argentina), it is necessary to remove heavy metals present in suspended solids and to treat water for human and agricultural uses (Lopardo 1998).

As a consequence of the spills in Magdalena on the La Plata River coast (Argentina), the Government and affected people have filed indemnity claims against the companies responsible for the spills.

Until 1976, the water intake for the Buenos Aires Metropolitan Area was located some 600-700 m from the coast. Because of the high pollution levels, the intake was moved to 1,050 m from the coast. The cost of this is directly associated with the negative impact of pollution. Despite this change, the water intake point continues to receive discharge from the Reconquista River (one of most contaminated rivers in the Buenos Aires Metropolitan Area), which may lead to increased water treatment costs (World Bank 1995).

Health impacts
Despite the absence of information to explicitly link morbidity and mortality with water pollution, there are reports that indicate the existence of water-related diseases in each country. In Argentina, the most frequent diseases are gastrointestinal disease, paratyphoid, typhoid fever, intestinal parasites and methemoglobinemia (CEPIS & OPS 2000). Between 1992 and 1996, cholera epidemics were reported, which affected principally the indigenous communities of the Salta province (CEPIS & OPS 2000). The most important epidemic centres were cities within the Bermejo and Pilcomayo river systems, with a peak of 2,080 cases (6.5 per 100,000 inhabitants) and a mortality rate of 1.6% in 1993 (OPS & OMS 1998). There were also reports of disease outbreaks in the province of Chaco (Norte Newspaper 1997).

In Brazil, the most problematic water-related diseases are schistosomiasis, malaria and dengue fever. In addition, there are a few cases of yellow fever and filariosis. It is estimated that there are approximately 10 million people affected with schistosomiasis (a disease caused by water contact) (CEPIS & OPS 2000). Information from 1995 indicates that diarrhoea was the second biggest reason for hospitalisation and the third largest cause of mortality among 1-year-olds. An epidemic of cholera was also registered in the early 1990s (OPS-OMS 1998), but the majority of cases were located outside the Patagonian Shelf region.

In Paraguay, diarrhoea is the most common water-related disease and the second biggest cause of mortality among children between the age of 0 and 5 (CEPIS & OPS 2000). The regional cholera epidemic that occurred in the 1990s also involved Paraguay, although the number of registered cases was relatively few (seven in 1993 and four in 1996). Although there are no studies that associate the occurrence of infectious and parasitic diseases with solid waste pollution, it is possible to associate the 1999 dengue epidemic with poor waste management (BID et al. 2001).

In Uruguay, there have not been any cases of diseases produced by vectors (schistosomiasis, malaria and dengue). Intestinal infections in children under the age of one are the second largest reason for consultation in public hospitals, while in 1995, severe diarrhoea was the 8th most common cause of infant mortality. No cholera cases were registered during the 1990 epidemic (OPS & OMS 1998).

Finally, in Bolivia, diarrhoea is the most significant water-related disease and accounts for 64% of all registered cases of water-related diseases (PLAMACH-BOL 1996). Despite the lack of statistical information, studies link the occurrence of diarrhoea in urban areas with microbiological pollution and deficiency in sanitary services (Barrera Arraya 1996). This is also common among indigenous populations, where diarrhoea is the primary cause of infant mortality. The regional cholera epidemic reached a maximum peak in 1996, with 2,634 registered cases and a mortality rate of 2.4% (OPS & OMS 1998), concentrated in La Paz and Potosí departments.
Serious problems affect the water supply of São Paulo from Billings-Guarapiranga Reservoir system due to excessive algal blooms. Massive applications of copper sulphate in the dam to control algal growth are becoming less efficient and hazardous to human health (Beiruth 2001).

Phenol spills in the surroundings of the Juquerí River (Upper Paraná system) caused an interruption of the water supply service during several days, which placed the local population in a risk situation (Haddad & Aventurato 1994). In the Pilcomayo River Basin, the population’s health is considered at risk due to pollution caused by mining residues and effluents discharged by Sucre, Potosí and other cities (Arce et al. 1998). In Potosí and Chuquisaca departments (Upper Pilcomayo River Basin), cases of lead poisoning have been registered (Sandi 1998).

In the Paraguayan tributaries of the Upper Paraná system, pollutants from agro-chemical origin have been detected (Azodrín 400, Apadrín 60), and have been related to cases of poisoning (Gobierno de la República del Paraguay 2000).

In the La Plata River, some municipalities of Buenos Aires Metropolitan Area are at high sanitary risk due to water pollution from biological (leptospirosis and diverse parasites) and chemical origin (metahemoglobinemia). These diseases together with the above mentioned severe effect of diarrhoea are related to deficient sanitary services, especially in deprived settlements (CEPIS & OPS 2000). The leptospirosis cases are related to water recreational uses such as bathing in rivers and ditches and coastal fishing. Cases of metahemoglobinemia are related to anthropogenic aquifer pollution (Aguas Argentinas 1997).

**Other social and community impacts**

In the Upper Paraná system, severe pollution of the Tietê River has affected the urban landscape (Secretaria Estadual do Meio Ambiente 2002). At Guarapiranga Basin, landscape degradation, loss of vegetable and animal species and loss of ecosystem ecological functions have been observed (CETESB 1997). In the Guarapiranga Reservoir’s beaches, microbiological pollution impacts recreational use (CETESB 2002a).

High concentrations of cadmium and lead and significant phenol levels in the Iguazú River at Iguazú National Park is a priority concern, not only because Iguazú National Park is a major international tourist resort, but because this area is an important habitat for the conservation of local biodiversity (ANEEL & SRH/MMA 2000).

The negative impact of pollution in Pilcomayo River on the economy of indigenous communities has caused migration towards urban centres, both in Bolivia and Argentina. There is, however, a lack of quantitative information, which makes it difficult to evaluate the magnitude of the problem. It is estimated that forced migration jeopardises the survival of the communities, through loss of identity, communal disintegration and loss of native language (Castro Arze 1998). The accident in the Porco Mine temporarily aggravated the process of migration (Condori 1997). In 1996, at the Group of Work of Indigenous Peoples assembled in Ginebra, the death of three indigenous farmers due to polluted drinking water was denounced (Más sobre el Río Pilcomayo 2002).

The oil spill near Punta del Este (Uruguay) affected tourist beaches in high summer season, as well as other places such as the Sea Wolves Island, an important habitat of birds and marine mammals (Villalonga 2000). The spill near the coast of Magdalena, Argentina, degraded the coastal landscape and affected recreational activities (INA 2000). These spills have direct and indirect consequences on human health and there are claims from people affected.

**Conclusions and future outlook**

Present environmental impact of pollution in the region is moderate, although microbiological and chemical pollution is severe at local levels. Solid waste, thermal and radionuclides have lesser impact. Nevertheless, the economic impact is severe, although there are no quantitative regional data. Health and other social and community impacts are moderate.

In the long-term, a slight improvement is expected due to governmental action, the influence of environmental NGOs, enhanced community awareness and commitment and increased self-regulation of industry (ISO standards). There is a trend towards reducing organic pollution in Argentina and Brazil, and it is considered that an improvement and more effective enforcement of the regulatory framework to control pollution should take place in the Basin. Most effort should be devoted to cope with large pollution sources, mainly represented by industrial facilities and large urban settlements.

Improvements in pollution control will require major investments by the private and public sectors and, as a consequence, improvements in the condition of the environment will come with increased economic costs. In the future, the economic impacts of pollution will remain severe, but it is anticipated that impacts on the health of the population and other social and community impacts will be slightly reduced as a consequence of better environmental conditions.
Habitat and community modification

The major part of the population and annual gross national production of Argentina, Bolivia, Brazil, Paraguay, and Uruguay is located in the La Plata River Basin. A major loss or transformation of aquatic fluvial and riparian ecosystems has taken place within this basin as a consequence of the construction of reservoirs for hydropower generation as well as the settlement of large urban areas.

The construction of a large number of reservoirs in the main reaches and their tributaries has caused the transformation of fluvial lotic systems into lentic or almost lentic ecosystems. Riparian river ecotones have been turned into lake ecotones and the impoundment has turned terrestrial habitats into aquatic littoral habitats. These losses affect more than 30% of the internationally shared portion of the river. As many of these reservoirs are bi-national developments, the ecosystem loss has impacted on the territories of the countries involved.

In the Paraná River, the construction of polders has resulted in the disruption of natural delta habitats. The development of large urban settlements along the river shores, such as São Paulo (Brazil), Posadas (Argentina) and Encarnación (Paraguay), the coastal belt of the Lower Paraná River and the La Plata River in Argentina has destroyed riparian habitats.

Reservoir cascades built on internationally shared rivers and their tributaries, such as the Paraná River (Argentina, Brazil and Paraguay), have altered the habitats and interrupted system continuity, affecting community structure and the population dynamics of migratory species of biological and commercial value. Their impact is important at international and sub-national level.

Accidentally introduced alien species of Asiatic origin, such as Golden mussel (*Limpnoperna fortunei*) and Asian clam (*Corbicula fluminea*), have spread in a great part of the La Plata Basin with evidence of substitution and displacement of native benthic species in the Pantanal, inner and medium La Plata River, Paraná, Paranapanema, Iguazú and Uruguay rivers. The great area that these species have invaded (in Argentina, Brazil, Paraguay and Uruguay) has resulted in severe impact with transboundary consequences.

It is evident that there is an increasing abundance of carp in the inner La Plata River, Paraná and Uruguay rivers. Wide distribution of alien tilapia is well known in reservoirs and lakes in the sub-tropical areas of the Basin. As a consequence, the ecosystems exhibit species exclusion and changes in the food web.

There are also habitat modifications due to heavy pollution, such as in the Tietê and Riachuelo rivers with sub-national transboundary impact in Brazil and Argentina respectively.

There is no indication of direct impact on human health as a result of habitat losses, even with the creation of lentic littoral ecotones (as a result of reservoir water impoundments, areas with a tendency to harbour tropical diseases, like schistosomiasis, yellow fever, etc. are increased).

Consequently, habitat and community modification in the La Plata River Basin is moderate, although there are frequent cases of severe local impact.

Environmental impacts

Loss of ecosystems and ecotones

Although quantitative indicators reflecting the degree of transformation have not yet been published, it is possible to state, based on the compilation of graphic and written data, that over 35% of the total length of the Paraná River, about 2,570 km, has been altered by the creation of large reservoirs, such as the Ilha Solteira, Jupia and Porto Primavera (Brazil), Itaipú (Brazil-Paraguay) and Yacyretá (Argentina-Paraguay). Likewise, the riparian zones have been transformed into urban settlements built along the riverbanks, mainly in the urban and industrial belt of the Lower Paraná River in Argentina. For example, Rosario, Zárate and Campana each occupy stretches of the River more than 100 km long.

In addition, a large number of reservoirs have been built on the tributaries of the Paraná River in Brazilian territory. A considerable proportion of the lotic environments have been transformed into lentic and semi-lentic habitats. Along the Uruguay River about 10% of the lotic environments have been transformed, while in the Tietê, Iguazú, Grande and Paranapanema rivers, 36%, 46%, 48% and 64% have been transformed respectively. Also, the expansion of large metropolitan regions of São Paulo and Curitiba has resulted in substantial losses of natural riparian ecosystems in the Tietê and Iguazú systems respectively.

The fauna of reservoirs is poorer than the fauna of the rivers due to the decrease in flow velocity and the formation of a great pelagic area.

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1 A lentic system is a non-flowing or standing body of freshwater, such as a lake, swamp, marsh or pond and a lotic system is a flowing body of freshwater, such as a river or stream (National Weather Service 1997). 2 IARH, based on data of original river lengths from ANEEL 2000 and 2001, SSRH 2002 and Castellanos 1975 and data of modified river lengths by reservoir building calculated on GIS (information provided by ANEEL 2000 and CIAT 1998). 3 IARH, based on data of original river lengths from SSRH 2002 and Castellanos 1975 and data of urban coast calculated on GIS (information provided by CIAT 1998).
For example, in the Itaipú Reservoir, several studies have described the changes in the fauna after the river closure. Prior to the construction of the reservoir (1978-1981), there were 113 species of fish upstream of Saltos de Guayra while only 83 species were found after the construction of the reservoir (Agostinho et al. 1994).

The creation of a reservoir transforms fluvial riparian ecosystems into lake type ecosystems, notably increasing their longitudinal development, as well as changing terrestrial ecosystems into aquatic ones. The sum of reservoir areas by sub-basin is a proxy indicator of the latter which, in the case of reservoirs on the Paraná River, amounts to about 6 800 km$^2$. The total area of the main reservoirs in the Paraná system, including major tributaries, is over 16 000 km$^2$, which amounts to about 1% of its basin (Figure 18). The Salto Grande Reservoir (Argentina and Uruguay) has modified almost 8% of the length of the Uruguay River, including a development situated on the shoreline that occupies over 500 km$^2$.

In the Iguazú River, mainly in its middle zone, several reservoirs devoted to hydropower generation have been built changing the physical, chemical and biological features of the River. The cascade of reservoirs has transformed about 36% of lotic environments into lentic and semi-lentic habitats, and over 40% with Salto Caxias in operation (Agostinho & Gomes 1997). Before the Segredo Reservoir started to operate, rooted aquatic plants characterised the aquatic vegetation of this reach of the Iguazú River, while floating plants were extremely rare. Today, in a lentic environment, aquatic macrophytes and floating plants dominate. In addition, there have been changes in the trophic web among aquatic fauna. Such changes might have important consequences for biodiversity, not only because there are fewer species in the Iguazú River but also because of their high endemism. However, the fish community was already affected by Foz do Areira Reservoir, located upstream (Agostinho & Gomes 1997).

Another interesting indicator of transformation is the increase in average annual residence time in the various water sub-systems. Table 24 illustrates the situation before and after the construction of the reservoirs, revealing significant transformations imposed on the natural fluvial environment.

In the Salado River Basin, province of Buenos Aires, negative impact on the ecosystems has resulted from the construction of drainage canals, especially in the Samborombón Bay, which is a Ramsar Site. In 1997, Channel 15 was made deeper and wider and, as it takes all the water from the Salado River except during floods, some downstream reaches have become lentic as a consequence of such interruption (Miretzki et al. 2002).
Modification of habitats or communities

The main human impact comes from overexploitation of fish, pollution and eutrophication, as well as the building and operation of reservoirs. Fish mortality resulting from agro-chemical discharge, organic discharge, hydrocarbon pollution, and gas oversaturation due to dam operations has influenced structural and community dynamics (DRIyA 2002). The death of around 120,000 fish, mainly demersal species, due to gas oversaturated water (bubble illness) as a result of the floodgate operation of Yacyretá Reservoir has caused ecological damage to the trophic web (Jacobo et al. 1994).

Habitat modification, mainly due to reservoir building, has a direct impact on the aquatic wildlife and biodiversity (Agostinho et al. 1997). Of the 10 most frequently occurring species in the Itaipú River before the construction of the dam, only the “Corvine” (Plagioscion squamosissimus, an alien species imported from the Paranaíba River) remained after the River was closed (Figure 19). During the first stages of the river closure and impoundment, there was high production of plankton, other invertebrates and small fish, with a significant increase in abundance of the fauna that preyed on these food sources (Canevari et al. 1999). “Curimbata” (Prochilodus scrofa), the dominant fish prior to the construction and of high commercial value, suffered a reduction of around 25% after damming. The abundance of Piranhas (Serrasalmus marginatus) increased significantly in the upper reaches of the reservoir farthest from the dam.

Analysis of fish communities with similar food habits revealed that detritivorous fish were more abundant before the impoundment amounting to 57% of the catch and that, in the following six years, this figure decreased to between 8.6% and 19.7%. Insectivores have proliferated in the reservoir area and, together with piscivorous species, they are the predominant group in the community. The number of carnivorous species remained stable, but changes in their specific composition have been observed (Agostinho et al. 1997).

Reservoir developments have reduced spawning and reproduction areas. For example, in the Itupararanga Reservoir in the Sorocaba River (tributary of the Tietê River), fish biodiversity may have diminished due to the decrease and species, such as Apareiodon cf. piracicabae, “Sábalo” (Prochilodus lineatus) and “Tabarana” (Salminus hilarii) which are present in unaffected reaches, may have become extinct in the reservoir (Smith & Petrere 2001).

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The ichthyofauna has been largely affected by the construction of large reservoirs in the Upper Paraná River and its tributaries. Due to lack of fish ladders aiding the passage of migratory species, vital functions, Table 24  Mean annual residence time of water in river sub-systems of La Plata River Basin.

<table>
<thead>
<tr>
<th>River sub-system</th>
<th>Residence time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>Reservoir</td>
</tr>
<tr>
<td>Grande</td>
<td>15</td>
</tr>
<tr>
<td>Paranába</td>
<td>14</td>
</tr>
<tr>
<td>Tietê</td>
<td>12</td>
</tr>
<tr>
<td>Parapancia</td>
<td>8</td>
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<tr>
<td>Iguazu</td>
<td>15</td>
</tr>
<tr>
<td>Paraná</td>
<td>30</td>
</tr>
</tbody>
</table>

Notes: 1. Reference values assuming a mean velocity of 1 m/s. 2. Calculated on the basis of reservoir maximum total volume and mean annual discharges. (Source: Values specially calculated by IARH for the GIWA Project. Based on ANEEL 1999 and 2001, SSRH 2002)

Figure 19  Relative frequency of species in Itaipú River. (Source: Agostinho et al. 1994)

Figure 20  Percentage of species transferred in Yacyretá Reservoir (Argentina-Paraguay). (Source: Bajgún & Oldani 2001)
such as reproduction, or spawning that occurred in upstream reaches of the rivers, were retarded. Furthermore, where fish ladders have been constructed, they have not functioned properly or have not been able to mitigate the negative impacts of the reservoir development on the environment (Canevari et al. 1998). The fish ladders built in Yacyretá (Figure 20), have not facilitated the migration of important species that constitute the basis of regional fisheries (Baigun & Oldani 2001). Instead, they have really only helped the transfer of small species, such as Yellow catfish (*Pimelodus clarias*) and “Armados” (*Pterodoras granulosus*), that are ubiquitous and have little importance to fishing. Among the important migratory species, Sábalo was the most abundant in the fish ladders but only represented 2.5% of all fish migrating through the transfer facilities. However, experimental examination of the fish community downstream of the reservoir revealed that Sábalo comprised 30% of the community. This suggests that fish reach the bottom of the dam but do not enter the fish ladders. The efficiency of transfer mechanisms of the dam is too low; only 1.9% of the total migratory species reach the reservoir and the efficiency is as low as 0.6% taking into account only the most valuable species (Fundación Proteger 2001). Similar impact on migratory species has been found in the Salto Grande Reservoir in the Uruguay River (Canevari et al. 1998).

In addition, the regulation of stream flow by the reservoir has affected species that use downstream floodplains for spawning. The most affected species was the Sábalo with a reduction of about 50% of the stock in the Upper Paraná River (Agostinho & Gomes 2002).

Impact has also been recorded in the community structure and dynamics due to pollution from point and diffuse sources. In the Lower Uruguay River, pollution concentrations above the Uruguay River Administrating Committee aquatic living standards have been found.

In the Upper Pilcomayo River so-called “tailings” or toxic mud from mining activity in the Potosí department have negatively impacted several tributaries. There is a high concentration of heavy metals in water and sediments and a sharp decrease has been observed in the benthic fauna, as well as fish extinction in some reaches where water cannot be used even for irrigation (Medina Hoyos 1996).

In the La Plata River, the major source of pollution is the urban belt from Riachuelo (Figure 21) to Berazategui because of its high industrial and population concentration. Persistent organic pollutants (POPs) are widely spread and concentrated mainly in sediments and bioaccumulated in detritivorous organisms such as Sábalo. Organochlorate agro-chemicals as well as PCBs are accumulated in the fat tissue of fish (Canevari et al. 1998).

The introduction of alien species, such as carp (*Cyprinus carpio*), negatively affects the community structure and dynamics at higher trophic levels. As a consequence, the ecosystems exhibit species exclusion and changes in the food web (DRlyA 2002).

In lower trophic levels, Asian molluscs have been introduced by international shipping. Among them, Asian clam (*Corbicula fluminea* and *C. largillerti*) and the mytilidae *Limpnoperna fortunei* have spread widely in the La Plata River, Lower and Middle Paraná River and Uruguay River causing significant ecological impacts. Autochthonous benthic species have disappeared as a result of these invasive molluscs (Canevari et al. 1998). In addition, the introduction of these molluscs has modified the food web mainly for ox-eyed cackerel, catfish and atherine, all of them economically important species (CARU 2002). Also, because these molluscs are filter feeders they can increase the clarity of the water by as much as 200 times and, as a consequence, the ecosystem can be dramatically modified.

*Limpnoperna fortunei*, which was presumably introduced via shipping traffic between Hong Kong and Argentina, maintains large populations in estuarine habitats. This mollusc species has spread from La Plata River where it has established a stable population as dense as 80 000 per m² in littoral areas of the River (Dress 1996) reaching up to the Yacyretá Reservoir. It has also reached Brazilian waters and occurs in the Itaipú Reservoir (Paraná River), the Salto Osorio and Salto Santiago (Iguazu River), Mato Grosso (Pantanal), the Paranapanema River and the water supply in Foz do Iguazu City.

Serious ecosystem impact due to accidental spills has already been reported under Pollution. In Magdalena town, province of Buenos Aires, spills of raw oil has affected mainly the riparian ecosystem. Although the impact on the fish community is low, invertebrate, amphibian, mammal and bird habitats have been seriously affected.

![Figure 21 Riachuelo River in Buenos Aires (Argentina).](Photo: Strategic Planning Website for Buenos Aires)
According to an assessment carried out by a United Nations specialist, the restoration of the damaged ecosystem will take at least 10 years (Morton 1999). In 1996, at Porco in the Upper Pilcomayo River, a dam containing mine tailings broke causing a widespread impacts on the ecosystem due to high concentrations of heavy metals (Preston 1998).

Finally, selective fishing practices in local areas in the La Plata Basin may cause changes in the community structure and dynamics, since the most valuable sport and commercial species are the main target. There are many indications of overexploitation of different species in the Paraná, Paraguay, Upper Pilcomayo and Middle and Lower Paraná rivers. Such overexploitation by fisheries is strongly linked to the Unsustainable exploitation of fish and other living resources in the La Plata River Basin.

**Socio-economic impacts**

**Economic impacts**

Considering the present economic situation, the economic impact of habitat destruction and modification is moderate. It becomes evident mainly in relation to decrease in fishing and the decline of commercially important species in communities dependent on them for food or trade. Consequently, there is a greater impact on regional economies and fishing, sporting and tourism activities. For example, in the Itaipú Reservoir, the fishing effort has increased and is now above the optimal recommended rate, while the Catch per Effort Unit (CPUE) has been decreasing (FUEM et al. 1999, Okada 2001).

The cost of controlling invasive species, habitat restoration, loss of educational and scientific values and fundamentally, generational inequity, should be added. The invasion of *Limnoperna fortunei* causes significant socio-economic impact due to the obstruction of filters in water supply pipes, acceleration of corrosive processes in all metallic components of ships, tanks, etc. In the Itaipú Dam alone, losses of nearly 1 million USD per day occur due to operational standstills for cleaning purposes, with consequent lack of hydropower generation (Agencia Brasil 2003).

**Other social and community impacts**

A number of communities, riparian or directly related to water systems that depend on the characteristics, goods and services provided by the ecosystems and shoreline ecotones, have been affected. Many of these communities carry out crafts of great social, economic and cultural significance at local level. The decrease in fish stocks due to overexploitation could have serious impact on communities that depend on this resource. Experts believe that if Sábalo resources decrease, between 300 000 and 500 000 people who rely on subsistence fishing would move to the cities, resulting in impoverishment (Dario El Litoral 2002).

In the Middle Iguazu River, due to the modification of the ecosystem by reservoir building, the riparian fishing communities had to change their fishing practices. The adaptation to such new fishing practices is considered to be an important social impact resulting from the reservoir building (Agostinho & Gomes 1997). The lack of conservation and the systematic destruction of the ecosystem may damage traditional ways of life which, in many cases, are merely of subsistence character. These changes in traditional ways of living generate economic as well as cultural losses, inducing migration.

**Conclusions and future outlook**

The present impact of environmental issues related to habitat and community modification is severe. The loss of ecosystems or ecotones is serious as it transforms fluvial lotic systems into lentic or semi-lentic ecosystems in a large number of reservoirs in the main reaches and its tributaries.

Although dam construction and reservoir development is expected to decrease in the next decades, the loss and modification of ecosystems already caused by existing dams and reservoirs will not change. Nevertheless, in the future, the dam construction process will be longer and will take into consideration environmental, social and health issues. The process will be based on option assessments and multi-stakeholder participation, thus minimising impact, through the selection of less impacting options and improved mitigation measures.

Though the long-term impacts of alien species introduced either deliberately or accidentally is unknown, a social awareness about water resources to stop degradation is emerging. As regards continental habitats and ecosystems, new nature conservation areas are being created, but it is generally expected that there will be an increase in the pressure on natural resources and environment, while no restoration is taking place in areas that are already degraded. Consequently, the degradation of the environment will continue and the impacts resulting from the most likely future scenario until 2020 will remain severe.

Despite efforts and improvements carried out by the various sectors of society towards environmental protection and restoration, it is anticipated that habitat and community structures will continue to be modified and, as a result, it is expected that economic and social impacts, directly associated with ecosystem degradation will increase, but will remain moderate.
Unsustainable exploitation of fish and other living resources

The La Plata River Basin is the primary focus of the continental fishery, both from a commercial and recreational point of view. Sustainability of fisheries is at risk due to the inadequate management of aquatic resources. Building and operation of reservoirs, mainly in Brazil, is the main cause of human impact on fisheries, with transboundary consequences at multinational and sub-national level.

There are important fisheries in all Brazilian basins, and the species composition shows an important spatial and temporal heterogeneity. Species present in the rivers within the Paraná Basin are generally migratory with a great predominance of Spotted sorubim (*Pseudoplatystoma corruscans*) and "Dorado" (*Salminus maxillosus*). In the Itaipú Reservoir (Paraná River), landings are composed of around 50 species, five of which contribute 78% of the annual yield (1 600 tonnes). Fisheries in the Paraguay River are mostly commercial and sporting and include large migratory species. Between 1999 and 2002, the continental fishery in Brazil showed a moderate increase in total catch.

In the Paraná River in Argentina, some 220 species can be found, 20 of which are valuable either commercially or as food. Among them the Sábalo (*Prochilodus lineatus*) is the key species of the ecosystem due to its role in the trophic chain; 70% of the chain depends on it and it also affects other fishing resources such as "Surubi" (*Pseudoplatystoma* sp.) and Dorado. In Victoria City (Entre Ríos province), there is evidence of an alarming increase in the exploitation of Sábalo in the Lower Paraná over the past few years. The fishery in the Paraná is mainly commercial and for recreational sport. There are also subsistence fishers, but there is limited information available on their activities. There is no data confirming that fishery is at risk in the medium and lower sections of the Paraná, although the opinions of local experts differ.

Most fishing activities in the upper Paraná and Paraguay rivers are by trawling, while long lines with several fishhooks and gill nets are used in the lower Paraná and Uruguay rivers. Exploitation of stocks in these rivers has transboundary impacts as many species are migratory.

There is evidence of a decreased viability of fish stocks due to pollution at local level, but the effects are not significant at regional level. The introduction of alien species could have a detrimental effect on community structure and dynamics in the rivers of the La Plata Basin, such as species exclusion and changes in the food web, with transboundary impact.

Although the fishing sector is small, impacts on the national economy and social impacts are significant. In addition, fishing is an important subsistence activity. Human health issues are not more important than environmental issues in terms of their impact on potential conflicts at sub-national and regional level.

Overall, the impacts of Unsustainable exploitation of fish and other living resources are moderate in the La Plata River Basin.

Environmental impacts

Overexploitation

Latin-American rivers show a remarkable fish biodiversity comprising migratory species of economic importance such as Sábalo, ray-finned fish (*Leporinus*), "Pati" (*Luciopimelodus*) and Surubi. Their migratory cycles have a great influence over the trophic structure of the fish community. The Sábalo is one of the system key species since its eggs and larvae are the base of the food web (Oldani 1990).

There are indications of overexploitation of "Pacú" (*Paractus mesopotamicus*) and "Manguruyu" (*Paulicea lüetkeni*) in the Brazilian areas of the Paraná River and Paraguay River basins (Ministério do Meio Ambiente y Programa Nacional do Meio Ambiente II 2001). Quiro’s (1990) suggests that the decrease of Pacú in the lower sector of the Paraná and Uruguay rivers is due to deforestation.

In the Upper Paraná River, there has been a reduction in the catfish *Rhinelepis aspera* stock, and the catch has decreased by 70%. Overexploitation of granulated catfish (*Pterodoras granulosus*), Manguruyu and Spotted sorubim has been reported in the Itaipú Reservoir (FUEM et al. 1999). In this reservoir, fishing effort was 67.5 days in 1987, 120 days in 1993 and 106.5 days in 1998. The optimal recommended rate is 95.5 days per year (FUEM et al. 1999). Catch per Effort Unit has been decreasing; 21.7 kg per day in 1987, 15.5 kg per day in 1992 and 11.5 kg per day in 1998 (Okada 2001).

There is evidence of Sábalo exploitation in the Middle Paraná River since its capture rate is now twice or three times higher than previously. Of 200 recorded species, about 20 feed on Sábalo, its loss might therefore cause the extinction of many valuable species (Fundación Proteger 2002). In the San Javier river area, the catch is frequently comprised of fish under four years old and smaller than the legal minimum size, affecting the probability of Sábalo population recuperation (Oldani et al. 2001).

There is also evidence of a decrease in the catches of fish species downstream the Santa Fe-Paraná axis, such as catfish and Pacú.
Some local experts attribute these decreases to overexploitation, stating that the mean size of fish, such as Sábalo and Dorado, has decreased. Catches of “Armado chancho” (Oxydoras kneri), silverside (Odontesthes bonariensis), salmon (Brycon orbignyanus), Manguruyu and “Tres Puntos” (Hemisorubin platyrhynchus) have also dramatically declined, and some species have not been registered for years. These declines are attributed to a variety of factors by local experts, such as overexploitation, environmental impact of dams on migration, loss of habitat for reproduction, deforestation and pollution.

In the Upper Pilcomayo River, high inter-annual variations in the capture of valuable species have been reported. The catches of Sábalo illustrate the decline with average landings decreasing from over 1 000 tonnes per year between 1980-1989 to 400 tonnes per year between 1990-1998 and, in some years, as low as 100 tonnes per year (Smolders 2001). The Bolivian Red Book of vertebrates has classified Sábalo as a vulnerable species (Correo del Sur 2002). Although the decrease in stream flow of the Pilcomayo River in the 1990s may have affected Sábalo landings, the decreasing catch rate may also be due to overexploitation together with river receding in the Lower Pilcomayo, which has isolated upstream populations making them more vulnerable (Smolders 2001).

Finally, selective fishing practices in local areas in the La Plata Basin may produce changes in the community structure and dynamics, since the most valuable sport and commercial species like Surubi and Dorado are the main target.

**Excessive by-catch and discards**

In rivers of the La Plata Basin in Argentina, by-catches involve non-migratory species. In the Uruguay and Paraná Rivers by-catch by entanglement is negligible.

Lake conditions in Itaipú Reservoir have caused a depletion of large piscivores and an increased density of piranhas. This compels fishers to use gill nets, increasing both the number of species exploited and the amount of by-catch but reducing overall profitability.

**Destructive fishing practices**

The lack of definite policies or changes in sustainable practices has made fisheries management difficult and has generated conflicts. Some existing resources are threatened or continue to be managed inadequately (Baigún 2003). Although there a few land-based subsistence fishers that use lines with several fishhooks or nets, trawling is the most common fishing practice (Agosthino & Gomes 1997).

Commercial fishing in the Pilcomayo River, carried out by Argentinean, Bolivian and Paraguayan fishermen, particularly indigenous people, includes different practices such as traps, nets and explosives (Correo del Sur 2002).

**Decreased viability of stocks through pollution and disease**

There are records of fish mortality due to different causes such as agro-chemical and organic discharge, high temperatures, pollution by hydrocarbons, and gas oversaturation due to dam operations, which affect structure and community dynamics. There is evidence of decreased viability of stocks due to deforestation, pollution and disease, in the most polluted areas.

Heavy metal pollution in the Pilcomayo River poses hazards to both human and other biota. Bioaccumulation of these toxins in fish fat and muscles is a major problem. Detritivorous fish, such as Sábalo, are particularly affected and, because of its commercial importance as a primary source of income, there are economic impacts resulting from the contamination of these species. In the Upper Pilcomayo Basin, the main water quality impact associated with the presence of heavy metals from mining effluents and spills is closely related to the impact on edible fish species such as Sábalo, Long-whiskered catfish (Pimelodus albicans) and Tiger fish (Hoplias malabaricus).

In the Brazilian Pantanal, the use of mercury in mining can be detected and quantified in sediment core chronologies and biological tissues, although species at different trophic levels show dissimilar impact. Mechanisms involved in mercury magnification along food chains deserve more attention, particularly in tropical regions where the threat of chronic exposure to this neurotoxin may have the greatest implications for biodiversity (Leady & Gottgens 2001).

Persistent organic pollutants are also degrading the water quality of the southern reaches of the Uruguay River. Heavy agro-chemical use is likely, as agricultural exploitation is a major economic activity in Uruguay. Organic pollution is regarded as an important cause of decline in the population of migratory fish species in the upper and middle course of the Uruguay River, posing negative commercial impact (FAO 2003).

**Impact on biological and genetic diversity**

The introduction of alien species generally has a negative effect on community structure and dynamics and, as a result, ecosystems exhibit species exclusion and changes in the food web. The introduction of carp (Cyprinus carpio) in the entire La Plata River Basin could seriously threaten native species such as silverside, catfish and Sábalo, although its effect has not been demonstrated. Similar effects could be produced...
by the introduction of South American silver croaker (*Plagioscion squamosissimus*) and tilapia (*Oreochromis* sp.) in the Upper Paraná River, and sturgeon (*Asciencer baeri*) in the Lower Uruguay River and in the Middle and Lower Paraná River (DRyA 2002).

Two Amazon predators are captured in Itaipú Reservoir, South American silver croaker and ray-finned fish (*Cichla monoculus*), which came from upstream reservoirs. In 1997, an accidental introduction of alien species from an aquatic farm occurred in the Parapanema River due to an extraordinary flood. In addition to the many alien species spread in the River after the accident, the parasite *Laernea cyprinacea* was also introduced (Agostinho & Gomes 2002).

**Socio-economic impacts**

**Economic impacts**

Economic impact is moderate in relation to decreased catches of commercially valuable species in communities relying on fishing for food and trade.

The Sábalo fisheries have both an economic and social value in the Upper Pilcomayo Basin, mainly in Villamontes (Tarija, Bolivia), where a decrease in catch since the late 1980s (Smolders 1998), has affected the regional economy. More than 3 000 families in Villamontes (90 % of the total employment) depend on fishing income during five month of the year. Fishing of Sábalo is the only subsistence for the “matacos”, indigenous of the region (Correo del Sur 2002).

In the Upper Paraná River, a closed fishing season from November 1 to January 31 has been established in order to ensure the migration of migratory species to spawning areas. Although the impact on fisheries has not yet been assessed, such prohibition produces social and economical problems due to a lack of income for many fishermen to support their families during those three months (Agostinho & Gomes 2002).

**Social and community impacts**

A large proportion of the population along more than 3 000 km of the Paraná River, from Mato Grosso up to the delta, relies on this water resource for their livelihood. Due to the high rate of unemployment and the hard economic situation in Argentina, many people practice subsistence fishing as a way to feed their families and obtain some income by selling fish.

Decreasing fish populations due to overexploitation could have a serious impact on the communities depending on this resource. Some experts believe that if the catch of Sábalo decreases, many people who practice subsistence fishing will move to the cities, resulting in impoverishment (Diario El Litoral 2002).

In the Upper Paraná River, during the closed season, fishers have no income to support their families. Thus, many engage in illegal activities such as car thefts and drug trafficking across the Brazil-Paraguay border (Agostinho & Gomes 2002). During this period, Argentinean Provincial governmental bodies offer a subsidy or some form of aid (e.g. food) to fishermen.

In the Middle Iguazú River the adaptation of riparian fishing communities from using fish line and fishhook to waiting nets, due to the modification caused by the construction of reservoirs, is considered an important social impact of the construction of the reservoirs (Agostinho & Gomes 1997). These changes have generated economic and cultural loss, inducing migrations.

**Conclusions and future outlook**

Environmental issues relating to the unsustainable exploitation of fish and other living resources are of major concern and have a moderate impact, although overexploitation in some sectors of the La Plata Basin is severe. In the future, a moderate negative change is foreseen in the development of this concern. It is thought that the exploitation of fishery resources will remain stable in areas where regulations have been instituted, but will tend to deteriorate in other areas. The unsustainable exploitation of fish is strongly linked to habitat and community modification since it is evident that it affects population and community structure.

Economic, social and community impacts of overexploitation of fish and other living resources are moderate at present. A slight increase in the severity of these impacts can be expected as a result of continued unsustainable exploitation of fish and the environmental impact associated with these practices.

Impacts to the health of the population of the sub-system are negligible because of the relative low fish consumption in the region. It is likely that the proportion of fish in the diet of people living in the basin will not increase and, as a consequence, the future impacts of overexploitation of fish and other living resources on health will remain negligible.

Differing opinions from local experts have been observed regarding overexploitation in the Argentinean Paraná River. Future research efforts in the whole basin are considered a priority. At present, it is not possible to describe the actual situation due to lack of reliable information.
Global change

In 1996, the Second Assessment Report of the IPCC concluded that the balance of evidence suggested that there was a discernible human influence on the global climate. Nevertheless, there was an array of uncertainties concerning the real magnitude of that influence on global warming and other effects of global climate change. The Third Assessment Report of the International Panel on Climate Change (IPCC 2001a) partially resolved these uncertainties, concluding that the best agreement between model simulations and observations over the last 140 years has been found when both the anthropogenic and the natural factors were combined. Simulations of the response to natural forcing alone do not explain the warming in the second half of the 20th century, but they may have contributed to the observed warming in the first half of the 20th century (IPCC 2001a).

The La Plata Basin has been permanently influenced by the climatic variability with consequent variations in river level. Fluctuations have reached extremes, which produces frequent high and low water conditions.

Even though it is still uncertain how global warming may affect frequency and intensity of extreme events, extraordinary combinations of hydrological and climatic conditions have historically produced disasters in some parts of the La Plata River Basin. To this natural variability must be added the possible impact in the Basin of global change produced by human activities. Cities and other settlements developed on the banks of the big rivers within the Basin have suffered flooding, especially in northeastern Argentina. Consequently, the economic impact is severe.

An increase in frequency and magnitude of extreme events associated with El Niño phenomena, like flooding, is expected. The La Plata River Basin is one of the most sensitive regions to El Niño signals.

There is no evidence of change in the sea level, increase in UV-B radiation or changes in the ocean function as a CO2 source/sink.

Consequently, the impacts of climate change are moderate in the La Plata River Basin considering variations in the rainfall and stream flow patterns mainly due to El Niño phenomena.

Environmental impacts

Changes in the hydrological cycle and ocean circulation

Precipitation is the main driver of variability in water balance over space and time, and changes in precipitation have very important consequences for hydrology and water resources. Flood frequency is affected by changes in the year-to-year variability in precipitation and by changes in short-term properties. The frequency of low or drought flows are affected primarily by changes in the seasonal distribution of rainfalls and year-to-year variability, and the occurrence of prolonged droughts.

Since 1960, significant increases in annual precipitation has been recorded in the eastern and central regions of Argentina, southern Brazil and Uruguay. The greater values go as far as 50%, which indicates exceptional change (Barros 2002).

Stream flow in the La Plata Basin (especially in the Paraguay, Paraná and Uruguay rivers) showed a negative trend from 1901 to 1970, but reversed after this period. Variability over decades is also observed in discharge. Moreover, there are written reports of alternating flood and drought periods during the 16th and 18th centuries, indicating high natural variability. In sub-tropical Argentina, Paraguay and Brazil, rainfall exhibits a long-term change, with a sharp increase between 1956 and 1990, after a drier period during 1921-1955. There is a positive precipitation trend in the period 1890-1984 in the Argentinean plains. This increase in annual precipitation was accompanied by a relative increase in rainfall during spring and summer (IPCC 2001b).

Impact assessments of climate change obtained from the General Circulation Model (GCM) vary depending on the latitude and longitude considered in the La Plata Basin. There is a case study of one application of GCM approach to assess the impact of climate change in the Uruguay River Basin (Tucci & Damiani 1994). US NASA Goddard Institute for Space Sciences (GISS), US National Oceanic and Atmospheric Administration Geophysical Fluids Dynamic Laboratory (GFDL), and the United Kingdom Meteorological Office (UKMO) which simulate the percentage increase of temperature and rainfall, produced different results. The GISS scenario predicts a reduction in the maximum and annual mean stream flow of 9 to 14%, although stream flow increases in February-March. The GFDL’s scenario, on the other hand, anticipates an increase of 14 to 33%, with the largest increase in October, which is consistent with warmer sea surface temperature in the tropical Pacific at a time of year when connections with the climate in southeastern South America are strongest. The UKMO’s scenario predicts increases of 5 to 21%. Minimum stream flows were shown to decrease in all cases. Nevertheless, the models are still not consistent with each other, and regional precipitation is not accurately simulated for present climate conditions (Baetghen et al. 2001).

In several cities of southern and southeastern Brazil, studies of long-term trends in air temperatures, from the beginning of the 20th century,
have indicated a general warming. These trends could be attributable to increase in urbanisation or systematic warming observed in the South Atlantic since the beginning of the 1950s. In southern tropical Argentina, warming is only observed during the autumn season and in the Argentinean humid plains, warming is a result of increased urbanisation (IPCC 2001b). Changes have been detected in the zonal air circulation over Paraguay, Brazil, Uruguay and northeast Argentina. In this area, the air circulation associated with the sub-tropical Atlantic anticyclone increased after 1954.

Climate variability can influence water levels in the La Plata River. Even though it is still uncertain how global warming is linked to the behaviour of the El Niño phenomenon in this region, there is evidence of increasing flow anomalies in the La Plata River Basin during the last El Niño events. The discharge of Paraná River increased its maximum monthly values between two and six times above normal values during El Niño events that occurred in 1982-1983, 1992, 1994 and 1997-1998 (Moyano 2001). During previous El Niño events (1902-1977), the Paraná river flow was between one and two times above its normal maximum monthly values. Despite the fact that the impact of the El Niño phenomenon varies in magnitude, it was suggested that the frequency has increased in the last years.

**Socio-economic impacts**

**Economic impacts**

Economic sectors affected by flooding and water table elevation in the Basin are considerable. Damage to public and private property, loss of agricultural production and long-lasting change in agricultural, fishery and forestry productivity is significant (IPCC 2001b).

Argentina has been permanently affected by extreme flood or water shortage events. There are still doubts as to whether climate change or environmental degradation is the main cause, or whether random natural processes are to blame (World Bank 2000). The frequency of extreme events is high and the rehabilitation period is over 10 years. However, 11 events have taken place since 1957, on average one every four years, causing several deaths, infrastructure and agricultural losses, as well as serious social and economic impact (Mugetti 2002). The 1982/1983 El Niño event flooded 4 million ha and caused economic losses of about 1 800 million USD (World Bank 2000).

Together with changes in land use in the upper basin, the increase in frequency of extreme events since 1970 might be related to El Niño phenomena. Table 25 shows the relationship between peak flows and affected surface and losses in Argentina (Mugetti 2002).

Several studies in Argentina, Uruguay and Brazil, based on general circulation models and crop models project decreased yields for several crops (maize, wheat, barley), even when the direct effect of CO$_2$ fertilisation and the implementation of moderate adaptation measures at farm level are considered.

In Brazil, the drier conditions in major plantation states such as Minas Gerais, Paraná and São Paulo, that are likely to result from global warming and/or reduced water vapour transportation from the Amazon forest can be expected to reduce silvicultural yields (IPCC 2001b).

**Health impacts**

The risk to human health increases, particularly in relation to tropical and water-related diseases. Climatic change increases the viability of certain disease vectors and the propagation of existing ones. Extremes in the hydrological cycle, such as water shortage and flooding, could increase the risk of diarrhoea. Water shortages cause diarrhoea through poor hygiene, and flooding can pollute drinking water from watershed run-off or sewage overflow.

There is good evidence that the El Niño Southern Oscillation (ENSO) cycle is associated with increased risk of certain diseases and can affect distribution, reproduction and mortality of disease vectors. Several studies have speculated that the cholera outbreak in the early 1990s was linked with the 1992-1993 El Niño event (IPCC 2001b).

**Other social and community impacts**

The size of the community affected is moderate to large, since the whole population in the fluvial littoral zone in the Basin is involved. The inhabitants of the large areas affected by water table increase should also be considered. The degree of severity is quite high where people have been forced to migrate, and moderate when they are subject to temporary relocations. More often, the most vulnerable segments of the society are affected by the events.

---

**Table 25** Major floods in northeast Argentina. Affected surface and economic losses.

<table>
<thead>
<tr>
<th>Year</th>
<th>Paraná river flow at Posadas (m$^3$/s)</th>
<th>Affected surface (millions of ha)</th>
<th>Economic losses (million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>37 885</td>
<td>ND</td>
<td>751</td>
</tr>
<tr>
<td>1977</td>
<td>30 081</td>
<td>ND</td>
<td>265</td>
</tr>
<tr>
<td>1982-1983</td>
<td>50 882</td>
<td>4.0</td>
<td>1 790</td>
</tr>
<tr>
<td>1992</td>
<td>48 790</td>
<td>3.0</td>
<td>905</td>
</tr>
<tr>
<td>1997-1998</td>
<td>33 000</td>
<td>18.5$^1$</td>
<td>17 502</td>
</tr>
</tbody>
</table>

Notes: ND = No Data. $^1$Subsecretaría de Recursos Hídricos. $^2$Subunidad Central de Coordinación para la Emergencia. (Source: GWP 2000)
The number of people evacuated, auto-evacuated or isolated is another good indicator of the severity of the event (Mugetti 2002). Table 26 shows the number of people in each of these categories for three different events in Argentina.

### Table 26 Number of people evacuated, auto-evacuated and isolated during three major floods in northeast Argentina.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of people affected</td>
<td>177 035</td>
<td>133 106</td>
<td>121 348</td>
</tr>
</tbody>
</table>

(Source: Mugetti 2002)

### Conclusions and future outlook

The IPCC Report on climate change indicates that warming will accelerate as an increase of +0.6°C in the mean annual world temperature is expected during the present century (IPCC 2001a). Even if the Kyoto Protocol is signed and effectively implemented by all participating countries, the situation will worsen. According to forecasts, climate evolution in the La Plata River Basin will be negative. Although small modifications in the total annual precipitation are expected, precipitation intensities and distribution will change, and climatic variability will increase.

Considering that the environmental impact of global change is likely to increase in the near future, an increase in costs, health problems and social and community impact is expected. It is also predicted that, as a consequence of climate changes, tropical and sub-tropical disease vectors will increase expanding to areas where the population is neither prepared nor resistant to their effects. Therefore, the future impact will be severe.

It is also recommended that regional studies should be carried out to assess and predict impact due to climate variability, through a deeper knowledge of climate and hydrological factors that define flood and drought frequency in the La Plata River Basin.
### South Atlantic Drainage System

#### Table 27  Scoring table for South Atlantic Drainage System.

<table>
<thead>
<tr>
<th>Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter)</th>
<th>The arrow indicates the likely direction of future changes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No known impacts</td>
<td>Increased impact</td>
</tr>
<tr>
<td>Slight impacts</td>
<td>No changes</td>
</tr>
<tr>
<td>Severe impacts</td>
<td>Decreased impact</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>South Atlantic Drainage System</th>
<th>Environmental impacts</th>
<th>Economic impacts</th>
<th>Health impacts</th>
<th>Other community impacts</th>
<th>Overall Score**</th>
<th>Priority***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater shortage</td>
<td>1.0*</td>
<td>2.3</td>
<td>0</td>
<td>2.3</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Modification of stream flow</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollution of existing supplies</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in the water table</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollution</td>
<td>1.4*</td>
<td>2.3</td>
<td>2.0</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Microbiological pollution</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eutrophication</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid waste</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radionuclide</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spills</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat and community modification</td>
<td>2.0*</td>
<td>2.3</td>
<td>0</td>
<td>2.0</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Loss of ecosystems</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification of ecosystems</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsustainable exploitation of fish</td>
<td>1.8*</td>
<td>2.3</td>
<td>0</td>
<td>2.2</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Overexploitation</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excessive by-catch and discards</td>
<td>2</td>
<td>2.2</td>
<td>0</td>
<td>2.2</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Destructive fishing practices</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decreased viability of stock</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact on biological and genetic diversity</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global change</td>
<td>0.2*</td>
<td>1.4</td>
<td>0</td>
<td>1.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Changes in hydrological cycle</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea level change</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased UV-B radiation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in ocean CO(_2) source/sink function</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 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

The impacts of freshwater shortage in the South Atlantic Drainage System were assessed as moderate. Water shortages are common features in the arid and semi-arid zones within this system. However, a decrease of spring water areas has been observed in some parts of the system and there is evidence of salinity change in some coastal lagoons. The construction and operation of reservoirs in the Limay, Neuquén and Lower Chubut rivers (inter-jurisdictional rivers) have resulted in changes in the seasonal flow pattern, which have affected the drainage of irrigated land, caused water tables to rise and become contaminated with salt and impaired the use of groundwater as a rural freshwater source. At some monitoring stations there have been indications of bacteriological contamination, hydrocarbons from oil spills and pollution of groundwater from oil industry activities.

In addition, there is evidence of salinisation at regional level in irrigated areas associated with major inter-jurisdictional rivers (Chubut, Negro, Colorado) due to rising water tables resulting from low irrigation efficiency and insufficient underground drainage capacity. In other areas where water tables are replenished by springs, there are also indications of lowering in water table as a consequence of soil compaction due to sheep overgrazing and trampling in local recharge zones. Water availability in flood meadows (“mallines”) is affected by human intervention. In some places, salinisation processes due to overexploitation are impairing groundwater supply.

Economic impacts are moderate mainly because of increased water treatment costs and effects on agricultural activities. There is no readily available data describing the magnitude of the impact of this concern on human health. Low population density, the intensity of agriculture and land use in the region and the deterioration of water quality have a significant social impact on rural workers who, although not numerous, are severely affected in the long-term.

#### Environmental impacts

**Modification of stream flow**

Modification of stream flow has a slight impact on the system, manifested mainly by a reduction in the surface area of wetlands and changes in annual river flows due to dam construction and operation.

The Colhue Huapi Lake within the Senguerr River Basin is located in the province of Chubut and is suffering desiccation and desertification due to both human and natural causes. The system has become endorheic, characterised by a negative water balance over the second half of the 20th century. Due to progressive reduction in size and increased salt...
concentration, the zooplankton diversity has noticeably diminished. Today, the surface area of the Colhué Huapi Lake is about 1/8 of its original size due to: (i) a decrease in flow of the Senguerr River resulting from declines in the amount of rainfall and melting ice in recent years; and (ii) extraction of large amounts of water mainly for irrigation, domestic water supply and the oil industry. Previously, the Colhué Huapi Lake occasionally discharged water into the Chico River but this has ceased, likely due to the continuous increase in the area of irrigated land together with withdrawal of water for domestic supply and industrial use (Malinow et al. 2001).

Irrigation practices in the Lower Senguerr Basin involves mostly extensive grassland flooding. Controlled irrigation occurs over a considerably smaller area. Such inefficient generalised irrigation practices in the Basin are usually conducted using poor infrastructure (channels, dams, small embankments), favouring the infiltration of large water volumes and causing, as in Colonia Sarmiento, the elevation of the water table and soil salinisation. Similar practices, near the town of Alto Río Senguerr, floods the steppe plains at lower elevations which, in the summer, may represent up to 78% of the mean flow of the Senguerr River (Malinow et al. 2001). These water resource practices results in much lower input into the Colhué Huapi Lake than in the past (Figure 22).

Building and operation of dams in the Limay, Neuquén and Chubut rivers has changed the seasonal pattern of drainage as well as increased evaporation from reservoirs. The first dam in the Limay River was built in 1973 and four more dams have been built since 1983.

Changes in mean discharges, as well as in maximum and minimum discharges, due to reservoir operation are shown in Figures 23 and 24. These figures illustrate the stream flow measured at Paso Córdoba gauge that lies downstream of the confluence of Limay River and Neuquén River before and after the construction of the dam (SSRH 2000). The seasonal variability and the monthly discharge during the year have both decreased with the operation of the dam. Similar changes were observed in the Colorado River at Pichi Mahuida gauge downstream of Casa de Piedra Reservoir, as well as downstream of Florentino Ameghino Reservoir, in the Chubut River.

On the other hand, building and operation of reservoirs has increased water availability, allowing new land to be irrigated in the provinces of Neuquén, Río Negro and Chubut, which has led to an important economic development and improved situation for the farmers. However, the increase in minimum discharges in the regulated rivers has caused an elevation of the water table affecting the lowest areas in the near valleys. Elevated water
tables affect the root zone of irrigated crops (mainly apple and pear trees) by depleting them of oxygen. Some cases of soil salinisation due to poor drainage, capillary ascent and water evaporation has also been caused by the increase in water table.

**Pollution of existing supplies**

In the Colorado River between 1997 and 1999, a detailed assessment was conducted that examined the potential sources of pollution related to the main human activities in the Basin, such as urban discharge, agriculture, oil industry, mining, etc., and their impacts on water quality for different uses. The assessment took into account the aquatic environment in the Grande, Barracas and Colorado rivers, as well as Casa de Piedra Reservoir. Monitoring of polynuclear and aliphatic hydrocarbons, heavy metals and metalloids, agro-chemicals, as well as analysis of riverbed sediments, determined that water quality was not limiting water use. This conclusion was confirmed by complementary studies carried out in 2000 (COIRCO 2000).

In some zones of the Negro River Basin, water treatment for domestic water supply is made complicated by the presence of algae. Similar problems are found in Trelew City downstream of Florentino Ameghino Reservoir in the Chubut River Basin. There are also water treatment problems due to eutrophication in Paso Piedras Reservoir, the water supply for Bahía Blanca City. The reservoir is mesotrophic with recurrent algal blooms (more than 1 million cells/ml, varying from diatoms to filamentous cyanobacteria). Water treatment by disinfectants is not effective and the algae remain in the water supply generating trihalomethanes (THM), unpleasant odours and taste. There are also risks of bacterial re-growth (Marquez 1991).

Some cases of impacted groundwater have been reported in the system. Río Gallegos City, located near the mouth of the Río Gallegos River, is supplied from both groundwater and surface water. The groundwater supply network has 30 wells. Some wells located near the estuary of the river are more affected by seawater and show an increasing chloride/bicarbonate ratio indicating seawater intrusion, and there is an increasing trend for such conditions (Baumann & Castillo 1999). In Mar del Plata City seawater intrusion affects the water supply.

**Changes in water table**

Groundwater is a very important resource in Patagonia since it is the only source of freshwater, for domestic, irrigation and animal (sheep raising) requirements in many areas. However, this important resource is affected by human activities. There is evidence of salinisation, pollution, and changes in water table, both increasing and decreasing.

In the province of Mendoza, 80,000 ha are irrigated by groundwater. In the northern oasis, including Mendoza City, salinisation, due to inefficient irrigation practices, and pollution, due to agro-chemical, industrial and domestic discharge, affected the first layer of the aquifer in the 1970s. The second layer of the aquifer with better water quality was then exploited, but some problems during well construction allowed infiltration from the upper polluted layer, and the wells were abandoned. Today, a third deeper layer of the aquifer is being exploited (DGI 1999).

Inefficient irrigation practices, together with lack of drainage infrastructure and poor soil drainage capacity, have resulted in elevated water tables and started a salinisation process. Such salt accumulation changes the structure and chemical properties of the soil and, as a consequence, affects the normal growth of crops. Affected areas include the lower irrigated valleys of the Colorado, Negro and Chubut rivers.

There is also evidence of lowered water tables in many areas due to overgrazing and changes in physical and chemical properties of the soil, affecting water dynamics in the soil.

Flood meadows or “mallines” are wetlands in arid regions developing in areas where there is water available for extended periods of the year. The deterioration of mallines is basically related to human activities. Quantity and quality of vegetation is decreasing due to overgrazing and increasing run-off towards the central channel of the mallines. Flow increases create a riverbed channel, operating as drainage of the mallín by lowering the water table (Figure 25). In addition, increased salt concentrations have also contributed to the deterioration of the mallines, particularly in eastern Patagonia and the coastal zones (Horne 1999).

Although the groundwater used for domestic water supply in the region is not widely affected, some local areas are affected by pollution from oil industry and overexploitation. In Río Gallegos City, located in the southern part of the province of Santa Cruz, groundwater is a very important source of water supply that has changed its quality since 1982. Overexploitation might have caused seawater intrusion changing water chemistry from bicarbonate type to chloride type indicating declines in water quality (Baumann & Castillo 1999).

**Socio-economic impacts**

**Economic impacts**

Despite large and obvious benefits, the regulation of stream flows has resulted in elevated water tables and, as a consequence, increases in the salinity of groundwater. This is due to more frequent and longer periods...
of low water levels which determine regional drainage and also the construction of the Cerros Colorados dam. The dam acts as sediment trap reducing the quantity of sediment transported downstream. Prior to the construction of the dam, sediment transported by the river was deposited naturally along irrigation channels forming a barrier that retarded seepage of water into the ground and water table adjacent to irrigation channels. Without the natural deposition of sediment, the water has eroded the beds and banks of irrigation channels allowing water to seep into the surrounding ground elevating water tables. In addition, the lower turbidity of water downstream from the dam allows greater light penetration and, as a consequence, enabled algae to proliferate in the irrigation channels. These problems have generated losses in agricultural land use. A large part of the economic sector is affected in terms of productive capacity. Recent studies on the effects of clear water in the High Valley of the Negro River irrigation system estimated economic losses at about 225 million USD due to the absence of sediments in the last 21 years (Landricini et al. 2000).

Since agriculture is responsible of about 75% of all freshwater withdrawal for human use in Argentina, its development has enormous influence on the use of water resources. In developing countries, irrigation is expected to increase by 14% by 2030 (FAO 2002).

The cost of water supply treatment has slightly increased in some local areas related to eutrophication of water sources.

Other social and community impacts
Potential conflicts among sectors (agriculture, industry and urban water supply) may arise relating to diminishing water availability to meet different user requirements, and increasing water treatment costs.

Conclusions and future outlook
Modification of stream flows in the South Atlantic Drainage System are mainly explained by a moderate decrease of spring water observed in some zones, as well as building and operation of dams that have changed the stream flow pattern in some rivers.

Biological pollution, due to sewage effluents, and hydrocarbons, due to oil spills, are the main sources of pollution of water supplies in the system. Eutrophication is low but affects almost all the reservoirs to some extent. Both pollution and eutrophication impact on freshwater supplies.

Regarding changes in the water table, there is some evidence of salinisation in the irrigated areas and indications of lowering of water table, associated with springs in the local recharge zones. In some local places, salinisation resulting from overexploitation has degraded the quality of groundwater. However, there is no information on groundwater salinisation or lowering in water table due to overexploitation at regional level. Therefore, it is recommended that studies are conducted at a regional level to generate baseline information describing the extent and impacts of these factors.

It is anticipated that there will be a slight worsening of the present situation concerning freshwater shortage, mainly caused by further pressure on the flood meadows (“mallines”). A productive expansion of these fragile ecosystems is expected. Finally, it is assumed that some progress will be achieved in relation to the environmental regulatory framework.

Considering the predicted slight increases in freshwater shortage during the next decades, it becomes apparent that economic costs associated with increased water treatment and the restoration and replacement of supply sources will increase similarly. However, a more serious increase in health problems is expected due to lack of safe water. Social and community impact will likely also become more severe.

Pollution
The intensive use of pesticides and fertilisers in extensive areas in the South Atlantic Drainage System has impacted on water bodies such as the Nahuel Huapi Lake (shared by the provinces of Neuquén and Río Negro) and the Pellegrini Lake, causing eutrophication of some localised areas with restricted water circulation.
Surface water pollution by oil spills has a transboundary impact at sub-national level. There is also impact on groundwater due to secondary oil recovery in the province of Santa Cruz, and impact on other sectors along the Atlantic coast, where some species have become contaminated or poisoned due to frequent oil spills. There is also evidence of some toxic spills during the transportation of high-risk material.

Discharge of thermal waters has been observed without significant impact, and there is no evidence of radionuclide impact in the South Atlantic Drainage System.

Moderate economic impacts are caused by pollution in the South Atlantic Drainage System mainly because of the increased costs of water treatment.

**Environmental impacts**

**Microbiological pollution**

Microbiological pollution exerts slight transboundary impacts in the South Atlantic Drainage System indicated by the concentration of faecal coliforms and total coliforms in water sources.

During the summer 2000-2001, the microbial content of the water from 36 recreational resorts was surveyed. According to the results, the water of 31 resorts was suitable for direct contact, while water at the remaining five, which are situated near the confluence of the Limay and Neuquén rivers and in the upper reaches of the Negro River (Neuquén and Río Negro provinces), was unsuitable (Autoridad Interjurisdiccional de Cuenca de los Ríos Limay, Neuquén y Negro, 2001). The monitoring was carried out in the framework of the Programme of Bacteriological Control of River Beaches (Secretary of Environmental Management, Interjurisdictional Basin Authority of the Negro River) according to the criteria recommended by the Canadian guidelines on Water Quality. The bacteria *Escherichia coli*, was considered the main indicator.

The main sources of microbiological pollution in the South Atlantic Drainage System are industrial and urban discharges. Mar del Plata, Buenos Aires province, which is the main tourist city in Argentina, and Bahía Blanca city only pre-treat their effluent before it is subsequently discharged into the sea. Many cities of the provinces of Santa Cruz and Chubut, such as Puerto Deseado, Puerto Santa Cruz, Comodante Piedrabuena, Puerto San Julián and Puerto Madryn, have secondary treatment of wastewater before discharge to the sea. Finally, Rio Gallegos and Comodoro Rivadavia cities discharge untreated effluent directly to the sea.

Fundación Patagonia Natural (FPN) has detected pathogens along the Atlantic seashore that have, in some cases, exceeded internationally recommended levels for recreational water use. In the Chubut River outlet, diatoms characteristic of eutrophic environments, such as *Aulacoseira granulata* and *Stephanodiscus* spp., and other harmful pathogens, such as *Alexandrium tamarense* and *Dinophysis acuminata*, and faecal coliforms have been found (Fundación Patagonia Natural 1999).

**Eutrophication**

In the Negro River Basin, the Interjurisdictional Basin Authority has conducted systematic monitoring of water quality since 1998. The presence of algae due to dam building and operation has caused problems in water treatment, since they are not removed by conventional treatment. A similar situation is found in the Chubut River, downstream of the Florentino Ameghino Reservoir, where there are problems in the purification process of water supplied to Trelew City.

According to the monitoring carried out in the Pellegrini Lake (Neuquen) during November 1996, the environment could be characterised as mesotrophic-eutrophic (Amalfi & Verniere 1995). Several records from 1995 indicate cyanobacterial blooms in the summer, with a predominance of *Microcystis aeruginosa* and *Anabaena spiroides* (Amalfi & Verniere 1995).

The Nahuel Huapi Lake (shared by the provinces of Neuquen and Río Negro) has been classified as ultra-oligotrophic because of the low concentrations of nitrogen, phosphorus, chlorophyll a, high transparency of the water and small phytoplankton biomass. However, some areas are characterised by restricted water circulation, presenting a different status with higher nutrient concentrations due to the discharge of point and non-point sources. This allows phytoplankton development, as occurred in summer 2000-2001, near the sewage treatment plant (Pedrozo et al. 1997).

The Ramos Mejía Reservoir in the area of El Chocón village (Neuquen) is characterised as mesotrophic (Labollita and Pedrozo 1997) with periodic algal blooms.

The Ramos Mejía Reservoir in the area of El Chocón village (Neuquen) is characterised as mesotrophic (Labollita and Pedrozo 1997) with periodic algal blooms.

Serious problems of water treatment exist as a result of eutrophication in Paso Piedras Reservoir, which supplies Bahía Blanca city (Buenos Aires province). The Lake is mesotrophic and is characterised by frequent algal blooms (more than 1 million cells/ml, varying from diatoms to filamentous cyanobacteria) (Marquez 1991).
Along the Atlantic seashore, impact from eutrophication has been found in the Nuevo Gulf, since the secondary biological treatment of effluent (aerated lagoons) from Puerto Madryn City is overloaded, inefficient and does not remove nutrients.

Toxic algal blooms together with poisonings that occur through the consumption of contaminated molluscs have serious consequences for public health, and has caused deaths in the Patagonian region where at least two groups of noxious species can be found: Alexandrium tamarense and A. catenell, Pseudonitzschia multiseries, P. pseudodelicatissima and P. australis, and Dinophys acuminata and Prorocentrum lima. It is therefore necessary to implement an adequate monitoring of these groups (Fundación Patagonia Natural 1999).

**Chemical pollution**

Oil and agricultural exploitation affect the Colorado River. In the past, oil refining industries have discharged effluents into this system. Today, farming activities in Neuquén, Río Negro and La Pampa provinces are potential sources of agro-chemical input.

In a study on chemical pollutants carried out in 1987, it was found that copper concentrations in sediments downstream oil refining industries and at the entrance to Casa de Piedra Dam (Río Negro and La Pampa provinces, Colorado River) were clearly higher than those found at other reference stations, suggesting the influence of anthropogenic activities. The same research showed that lead and chromium concentrations in the fine sediment fraction, less than 63 µm, also exceeded guidelines for freshwater organisms. Acenaphthene was detected in 7 out of 12 sampling stations. This contaminant was the only aromatic hydrocarbon that exceeded guidelines for freshwater organisms (CCREM 1987).

This study also found that mercury and selenium concentrations in fish muscle exceeded the National Service of Agro-food Health and Quality (SENASA) (Servicio Nacional de Sanidad y Calidad Agroalimentaria) edible food guidelines for human consumption in all fish species at all sampling stations. The highest mercury concentration in fish tissue was reported in silverside (Odontesthes argentinensis) at Desfiladero Bayo, while the highest selenium fish tissue concentration was recorded in Perca fluviatilis at Río Barrancas (CCREM 1987).

Despite long-term exposure to oil and agricultural exploitation, the Colorado River system is suitable for supplying drinking water, and has no restrictions for human fish consumption or serious risks for aquatic biota (Alcade et al. 1999). Nevertheless, further studies are needed, especially to detect metal residues in fish. Sampling has not been sufficient to assess human consumption recommendations (Alcade et al. 1999).

The Patagonian coastal zone experiences slight to moderate pollution of toxic chemicals. Petrogenic hydrocarbons in sediments have reportedly the highest concentrations in oil shipping locations (Caleta Córdova, Comodoro Rivadavia and Caleta Oliva), where discharges of oil effluents and tanker ballast washing is carried out. This is especially important at Caleta Córdova where hydrocarbon concentrations are increasing. Winds and marine currents are potential transport agents of such persistent pollutants (a situation already reported in Faro Aristazábal) posing environmental risks to vulnerable coasts with great ecological sensitivity.

High concentrations of heavy metals in sediments (lead, zinc and copper) have been registered in San Antonio Bay and in San Matías Gulf. These were the only coastal areas where cadmium was found, affecting local flora and fauna, and threatening migratory species such as the birds Calidris melanotos and Charadrius wilsonia, which cross this zone during seasonal migration. High cadmium concentrations were detected in the kidney and liver of the Commerson’s dolphin (Cephalorhynchus commersonii) and the Dusky dolphin (Lagenorhynchus obscurus), and in kidneys of the Kelp gull (Larus dominicanus). The only halogenated persistent pollutant detected in biota was pp'-DDE, which was found in the Magellanic penguin (Spheniscus magellanicus) and the Kelp gull, although recent studies have found significant quantities of halogenated residues in dead new-born cubs of the Sea lion (Otaria flavescens) suggesting that these residues are transmitted from the parent (Fundación Patagonia Natural 1999).

**Suspended solids**

Mining activities have caused a sharp increase in turbidity in various streams, reservoirs and marine water bodies and has altered the natural vegetation cover of extensive sedimentary areas devoted to sheep raising in southern Patagonia.

In the province of Santa Cruz, the Río Turbio mining industry discharges large quantities of solids generated by mineral carbon treatment which flush into the Gallegos River. Carbon waste at the banks of the San José and Turbio Rivers is carried by pluvial and eolic erosion and discharged into the River. The concentration of suspended solids upstream of the mining complex is 0.05 g/l reaching as high as 15.5 g/l downstream of the mine. The amount of suspended solids in the water affects aquatic life as well as its suitability for human use (Brea & Loschacoff 2000).

Wind and water erosion are additional sources of sediment. About 30% of Patagonia is suffering desertification caused primarily by overgrazing by sheep and cattle. Intensive sheep raising with high animal densities started at the beginning of the 20th century which, together with the
hard climate features of the region, accelerated the degradation process (SAYDS 2003). Reduction in vegetation coverage has increased run-off and soil losses and, in many cases, has affected the water bodies.

On the other hand, a decrease of suspended solids can also affect water resources and cause economic impacts. In the Negro River, there has been a considerable decrease of suspended solids after the building and operation of the Cerros Colorados System in 1978. Before the reservoir was constructed, suspended sediments, mainly clay and mud, coated irrigation channels reducing the infiltration rate and subsequent water loss. Sedimentation in the channels was 2.3 cm per year and sediment accumulation for about 50 years in the irrigated field represented almost 3% of the soil. After the dam was completed, sediments were retained in the reservoir, and the clear water discharged in the irrigation channels increased water infiltration and caused algal growth due to decreased turbidity. Such higher infiltration, which represents about 68 to 74% of the channel inflow, has raised the water table, affecting up to 66% of irrigated land (Landricini et al. 2000).

**Solid waste**

The analysis of information related to the contamination of water resources by solid waste indicates a negligible impact on surface water. Nevertheless, along the Patagonian Atlantic coast interference of solid waste with fishing activities has been observed.

There are some environmental impacts in the coastal area of the South Atlantic Drainage System due to solid waste disposal practices, mainly in urban areas close to the coast, where it is common to dispose solid waste in open dump sites. Some landfills located in harbour areas also receive large quantities of fishing waste, which produce offensive odours, water pollution and negative effects on the coastal landscape, tourism and recreation activities.

Regarding the Negro River, the dumping of solid waste in open sites, riverbanks and lakes generates an environmental and human health impact, mainly due to non-biodegradable waste.

**Spills**

Spills are closely related to chemical pollution in the South Atlantic Drainage System, both according to the nature of the pollution source, the presence of treatment facilities and the frequency of events.

In the Upper Colorado River Basin (Mendoza and Neuquén provinces), significant oil drilling activities are performed (40% of the Argentine oil production comes from this basin) and have been the cause of intermittent oil spills for quite some time. Accidental spill events since 1995, linked to oil drilling, have seriously affected the water quality of this course. One of the most serious accidents happened in early 1997 when an oil spill of 100-300 m³ of petroleum polluted the River. The impact generated by the spill caused the closure of drinking water supply to nearby towns (more than 10,000 inhabitants were affected) and the interrupted of irrigation supply to an area of 5,000 ha. A 10 km coastal stretch was also affected (La Cuenca negra del Colorado 1997, Daniele & Natenzon 1997). Records of relevant oil spills go back to January 1992, when an oil spill (a 30 ha oil plume) from a fracture in a YPF (Yacimientos Petrolíferos Fiscales) oil pipeline at Rincón de los Sauces, affected irrigation water intakes and caused the closure of drinking water supply to Catriel and 25 de Mayo cities. In February 2002, another oil spill occurred due to overflow of two oil ponds containing chemicals, generating an avalanche of mud contaminated with hydrocarbons that entered into the Colorado River.

The Inter-jurisdictional Committee of the Colorado River Basin (COIRCO) (Comité Interjurisdiccional del Río Colorado), together with the Argentine Energy and Mining Secretary and the Oil Enterprises Group, performed a water quality survey (1997-1999) recording the concentration of PAHs (polycyclic aromatic hydrocarbons) in water, sediments and biota, particularly fish, and performing ecotoxicological bioassays (zooplankton, benthos) (COIRCO 2001). The data showed naphthalene concentrations in sediment at Casa de Piedra intakes exceeding international reference standards, and accepted conditions in the remaining sampling locations. Chronic toxicity to the amphipod *Hyalella curvispina* was found at Puesto Hernández, in the oil drilling area. PAHs were detected in the muscle tissue of various species of fish (*Odontesthes bonarensis*, *Oncorhynchus mykiss*, *Percichthys colhuapiensis*, *Percichthys altispinnis*, *Cyprinus carpio* and *Diplomystes viedmensis*) at standard levels in the ng/g order of magnitude at two sampling sites (Desfiladero Bayo in the Colorado River and Casa de Piedra Reservoir). The obtained values indicated that it was not necessary to apply restrictions to human consumption based on the US Environmental Protection Agency risk assessment (COIRCO 2001).

On the Patagonian maritime coast, impact due to accidental spills or daily activities in coastal ports, has been observed. The most relevant accident occurred in September 1995, when approximately 30 tonnes of diesel oil were spilt, affecting 10 km of beach in the surroundings of Puerto Deseado (Santa Cruz province). Another oil spill occurred in 1991, when unidentified hydrocarbon (crude oil or fuel oil) was spilt near Valdés Peninsula (Chubut province). Due to this oil spill, approximately 1100 penguins were covered with oil and died from hypothermia and poisoning (DRyA 2001).
In case of pollution due to harbour activity, beaches remain affected by the presence of tar balls and birds become covered in oil. The incidents are related to operative problems in the ports and the washing of hulls and tanks (DRiAY 2001).

**Socio-economic impacts**

**Economic impacts**

Economic impacts derived from pollution in the South Atlantic Drainage System are mainly related to increased water treatment costs. Algal blooms in reservoirs and oil spills demand major economic investment for contingency measures and water treatment.

Paso Piedras Reservoir, which supplies water to Bahía Blanca, Paso Alto and other cities in the province of Buenos Aires, suffers severe eutrophication. The main problem in the reservoir is the occurrence of algal blooms during autumn and summer (Marquez 1991). Water treatment is not effective and the algae remain in water used for human consumption posing risks of bacterial re-growth and generation of THM.

In the upper basin of the Colorado River there are problems in water supply due to recurrent oil spills. These spills have especially affected irrigated agriculture in the area near Catriel (province of Río Negro) and 25 de Mayo (province of La Pampa) cities. In an area of approximately 48,000 ha, cultivated with vegetables, alfalfa and fruits, 30% was affected by the interruption of irrigation water supply causing considerable economic losses. Spills also affected Rincón de los Sauces, a small town in the province of Neuquén. In this case, local authorities interrupted water distribution and private oil companies assumed the cost of the emergency by distributing thousands of litres of mineral water for human consumption (Daniele & Natenzon 1997).

In the oceanic component of the South Atlantic Drainage System, negative economic impact has been reported by the private sector devoted to exploitation and seafood production, since harvest and commercialisation has been prohibited due to toxic algal blooms.

**Health impacts**

Access to drinking water and sanitation systems are a fairly accurate indication of sanitary conditions in relation to pollution in the South Atlantic Drainage System. According to data from the 1990s, the total population supplied with drinking water was 61.2%, whereas only 31.8% of the population was connected to sewage networks (INDEC 1991). Although the census carried out in 2001 by INDEC did not specifically record the proportion of the total population supplied with drinking water and serviced by sewage networks, the proportion of the urban population with access to drinking water has increased to 79.9%, while 51.6% is connected to sewage networks (ENOHSA 2002).

Due to eutrophication and oil spills, the incidents described under economic impact also present aspects linked to human health. Since 1977, episodes of algal blooms have been commonplace in the Paso Piedras Reservoir. In the summer-autumn of 2000, a significant incident took place resulting from an *Anabaena spiroides* bloom. Between April and May, the crisis reached its maximum. The Health Department of the province of Buenos Aires deemed the water not suitable for drinking and recommended a complete suspension of the water supply (Mancini & Santoro 2000). There was long-term risk for human health due to the appearance of trihalomethanes (THMs), formed by the combination of the algae with chlorine utilised in the water treatment.

Another example of serious impact and risk to human health is the 300,000 tonnes oil spill that occurred in March 1997, which caused the interruption of drinking water supply in Rincón de los Sauces and other cities in the province of Neuquén. Local authorities declared an epidemiological alert (La Cuenca negra del Colorado 1997) due to the possibility of disease related to polluted water, such as diarrhoea. This interruption was mainly caused by hydrocarbons in the water purifying systems, which did not guarantee sanitary conditions (Daniele & Natenzon 1997).

**Other social and community impacts**

Algal blooms in the Paso Piedras Reservoir have caused other impacts associated with the disagreeable smell and taste of the water. The cyanobacteria *Anabaena spiroides* caused a problem due to highly disagreeable taste and smell and greenish-blue coloration of the water and the algae *Ceratium hirundinella* caused problems to the water supply system in 1997-1999, giving a brown colour and high turbidity to the water (Mancini & Santoro 2000).

In the Upper Colorado River Basin, inhabitants and officials of towns affected by successive oil spills led protests and presented lawsuits to the provincial authorities (En Neuquén protestan por los derrames de petróleo 1997). In Rincón de los Sauces, local NGOs and representatives from the Chamber of Commerce took part in the complaint (En Neuquén protestan por los derrames de petróleo 1997). Primary producers, invoking loss in soil quality, pollution of groundwater and decreases in crop yields also led protests (La Nación 1997).

**Conclusions and future outlook**

Pollution is considered to have moderate overall impact in the South Atlantic Drainage System. The highest environmental impact is from
spills and suspended solids. Demographic pressure in the region will continue to be low and therefore the pressure on water resources will not increase significantly.

Action from environmental NGOs and increased community awareness is likely to improve the situation and result in diminished pollution loads. Major investments in the region may be carried out by large enterprise subject to international funding, which would force them to be environmentally friendly and comply with self-regulating ISO standards. Even so, some degradation is expected.

Improvements in pollution control will require major investments by the private and public sectors. Thus, improvement in terms of environmental impact will be offset by an increase of the economic impact. Health problems and other social and community impact will likely improve as a consequence of better environmental conditions.

**Habitat and community modification**

The construction of reservoirs in inter-jurisdictional rivers in the South Atlantic Drainage System to regulate flow and control floods has altered seasonal flow patterns affecting the environmental conditions for most species. This includes the transformation of fast running water courses into lentic reservoir environments with longer residence times, large impounded areas and lengthy lake shores.

Areas with large productive potential, such as flood meadows (‘mallines’) are seriously deteriorating. About 30% of the territory between 41° N and Magallanes Strait, is affected by intense wind and water erosion processes (SAyDS 2003).

Along the ocean environment, mainly on the coast in the province of Buenos Aires, there is evidence of fragmentation of sandy foreshores, the littoral belt system and coastal fringes as a consequence of discrete urban settlements, infrastructure works, fishing and recreational beach facilities. Erosion from human origin also modifies habitats and ecosystems.

Operation of harbours and oil shipping facilities in some areas (Puerto Madryn, Caleta Cordoba, etc.) along the coast has resulted in pollution hot spots that locally affect coastal habitats and attached aquatic communities.

The main cause of community modification is however intensive fish exploitation which, together with incidental captures, discards and fishing practices, has sharply affected aquatic community structure and population dynamics at various trophic levels.

Economic and social and community impacts are moderate. No significant links between health impact and this concern have been identified.

**Environmental impacts**

**Losses of ecosystems and ecotones**

A large number of reservoirs have been built in the South Atlantic Drainage System, mainly in the Neuquén and Limay rivers (Table 28). The construction of reservoirs transforms fluvial riparian ecosystems into lentic systems with long water residence times and changes terrestrial ecosystems into aquatic systems. Approximately 44% of lotic environments along the Limay River have been transformed into lentic and semi-lentic environments.

Other ecosystems at risk due to anthropogenic activities are the flood meadows so called “mallines”. The mallines are wetlands in arid and semi-arid regions. Although they represent only 4% to 8% of the provinces of Rio Negro, Neuquén, Chubut and Santa Cruz, these ecosystems are quite important for the economy since they are an important resource for sheep and cattle raising. The structure and dynamics of the mallines are highly related to water availability. Alteration of the mallines features due to overgrazing, mainly by sheep,

**Table 28** Main reservoirs built in the South Atlantic Drainage System.

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>River</th>
<th>Province</th>
<th>Country</th>
<th>Reservoir feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arroyito</td>
<td>Limay</td>
<td>Neuquén/Río Negro</td>
<td>Argentina</td>
<td>39 0.013</td>
</tr>
<tr>
<td>Piedra del Aguila</td>
<td>Limay</td>
<td>Neuquén/Río Negro</td>
<td>Argentina</td>
<td>292 0.56</td>
</tr>
<tr>
<td>Alicurá</td>
<td>Limay</td>
<td>Neuquén/Río Negro</td>
<td>Argentina</td>
<td>67.5 0.38</td>
</tr>
<tr>
<td>E. Ramos Mexía</td>
<td>Limay</td>
<td>Neuquén/Río Negro</td>
<td>Argentina</td>
<td>816 1.77</td>
</tr>
<tr>
<td>Florentino Ameghino</td>
<td>Chubut</td>
<td>Chubut</td>
<td>Argentina</td>
<td>74 0.82</td>
</tr>
<tr>
<td>El Chiarú</td>
<td>Neuquén</td>
<td>Neuquén</td>
<td>Argentina</td>
<td>10 0.004</td>
</tr>
<tr>
<td>Loma de la Lata</td>
<td>Neuquén</td>
<td>Neuquén</td>
<td>Argentina</td>
<td>409 2.83</td>
</tr>
<tr>
<td>Partezuelo Grande</td>
<td>Neuquén</td>
<td>Neuquén</td>
<td>Argentina</td>
<td>39 0.001</td>
</tr>
<tr>
<td>Planicie Banderita</td>
<td>Neuquén</td>
<td>Neuquén</td>
<td>Argentina</td>
<td>174 1.41</td>
</tr>
<tr>
<td>Casa de Piedra</td>
<td>Colorado</td>
<td>La Pampa/Río Negro</td>
<td>Argentina</td>
<td>360 1.04</td>
</tr>
</tbody>
</table>

(Source: SSRH 1993)
has interrupted a delicate equilibrium causing deterioration and loss of vegetation cover (Horne 1999). Some mallines that were seeded until 1975 have been degraded by overgrazing.

Most beaches on the province of Buenos Aires coast have suffered significant erosion, increased by anthropogenic activity, which has altered the coastline and also negatively affected properties and population activities. Some of these areas (e.g. beaches and coastal dunes) are particularly vulnerable to environmental stress due to the presence of coastal wetlands and their potential for service and activity development. For example, at Mar Chiquita, the beach is receding at a rate of 5 m per year at some points (Bonamy et al. 2002).

The main alteration of the physical environment on the Patagonian coast is a consequence of mining activities, urban and coastal development (harbours and roads), and degradation due to tourism activities (DRyA 2001).

**Modification of habitats or communities**

The Patagonian coast is a highly important component of the Argentine marine shelf, which has a wide variety of environments and a highly productive sea. Marine resources have been under pressure from demographic and industrial growth during the last 15 years. Although such economic development has had a positive impact on provincial livelihood, it has been developed in an uncontrolled way and without infrastructure and coordinated management. Thus, biodiversity as well as sustainable exploitation of the renewable resources are seriously endangered (Fundación Patagonia Natural 1999). As a consequence of human settlement and activities, there is a modification of the marine ecosystems by degradation, fragmentation or loss of habitats (Gray 1997). Although the detrimental impacts are known, there are no quantitative estimates of such habitat modifications.

There is growing pressure on marine resources by human activities due to overextraction and the development of aquaculture activities. There is an impact on the structure of the seashore communities, mortality of fauna, and conflicts among different uses of this resource (tourism, aquaculture and fishing).

The main threats for biodiversity and, as a consequence for communities, in Patagonia are: (i) overexploitation of natural resources, mainly fisheries; (ii) pollution; (iii) introduction of alien species; (iv) loss of habitats; and (v) activities linked to tourism (FUCEMA 1999).

Physical alteration or habitat destruction of marine ecosystems occur mainly in the shallow waters off the shore due to dredging, port building, stabilisation of the coast, fishing methods, the construction of embankments and aquaculture ponds (DRyA 2001). Harbour activities have increased in several areas such as Puerto Deseado, Caleta Olivia, Ushuaia, Comodoro Rivadavia, Bahia Camarones and Puerto Madryn (Fundación Patagonia Natural 1999).

Urban and industrial pollution is a general problem on the Patagonian coast, since liquid wastes either are inadequately treated or not treated at all. These effluents have caused eutrophication in some areas off the shore (Fundación Patagonia Natural 1999). Chemical discharges and other elements such as sediment and solid waste pollute the sea. Commercial fishing and fish industrial waste affect bird communities, benthic organisms and human population due to high BOD discharge (DRyA 2001).

Hydrocarbons derived from petroleum show the highest concentration in the areas of oil transport. An increasing trend has been observed in Caleta Cordova in the province of Chubut. However, negative impacts on the ecosystem affects shores beyond the harbour areas, since currents and wind carry pollutants towards other more ecologically sensitive areas, generating chronic pollution that is difficult to mitigate, such as areas of industrial algal harvest (Fundación Patagonia Natural 1999).

A critical situation due to unsustainable exploitation practices is evident for marine living resources, which are subject to intense fishing activity by Argentina and Uruguay, in the Buenos Aires Coastal Ecosystem and the Argentine-Uruguayan Common Fishing Zone. An indicator of such overexploitation is the decreasing trend of total and reproductive biomass (Pérez 2000), as well as landed catch, integrated to 50% by age-2 juveniles (Renz et al. 1999).

There is little information about the introduction of alien species. Some accidentally introduced species are the brown alga (*Undaria pinnatifida*), Asian clam (*Corbicula fluminea*) and “Dog’s teeth” (*Balanus glandula*). Other intentionally introduced species for aquaculture are Brown trout (*Salmo trutta*), Rainbow trout (*Onchorhynchus mykiss*), Chinook salmon (*O. tshawystcha*), Pacific oyster (*Crassostrea gigas*), Chilean oyster (*Tiostrea chilensis*), and beavers (DRyA 2001).

The brown alga *Undaria pinnatifida*, originally from the Japanese coast, was accidentally introduced in Puerto Madryn in the ballast water of foreign ships and has quickly spread in the Nuevo Gulf area (Casas & Piriz 1996). Sewage discharge, oil spills and waste discharged from ships and boats have probably contributed to this brown alga remaining and developing in this area (Fundación Patagonia Natural 1999).
The Asian clam was probably introduced with ballast water in the Paraná-Uruguay River system in the 1960s. The southernmost area colonised is the Colorado River. South of the Colorado River the water becomes colder which inhibits propagation of the Asian clam (Cazzaniga 1997).

Tourism has also had a negative impact on the ecosystems. Motorcycles and 4x4 trucks disturb feeding and reproductive areas, such as dunes and beaches, along the coast. Such impact is more severe on the coast of the province of Buenos Aires, and only in local areas along the Patagonian coast. Another important impact from tourism is the excessive number of boats engaging in whale observation (DRyA 2001).

Finally, a critical region where significant modification of habitats and communities has occurred is the Buenos Aires coast. This includes the main beach zone of the Atlantic coast, where the most important Buenos Aires tourist activity has developed. The historic lack of planning and territorial ordering has resulted in significant degradation of the coastline with the consequent increase of coastal erosion, which strongly affects tourist income (beach and dunes degradation, urban infrastructure damage). The advance of urbanisation has produced this situation along the coastline. Dunes, forming a natural protection against winds and tides, have been removed and/or fixed. Settlement landslide is frequent, as well as pedestrian and vehicle roadways that require refilling. Many affected municipalities are now designing or executing expensive projects to stop these processes. Another cause of degradation is associated with the unsustainable use of natural resources. In spite of severe erosion problems affecting the coastline, the sand extracting process due to construction continues (Bonamy et al. 2002).

**Socio-economic impacts**

**Economic impacts**

Climate and soil conditions make the Patagonian region extremely dependent on water resources and goods and services provided by aquatic ecosystems. Most of the population is concentrated in urban settlements near the Atlantic coast. A considerable proportion are highly dependent on ocean fisheries or live in river valleys where irrigation provides opportunities for intense economic activity.

Therefore, habitat loss and modification of the aquatic community have significant economic and social impacts on the populations concerned, particularly from the construction of dams and their influence on water tables and the availability of water for irrigation and also the exploitation of fish. Economic losses and elevated costs associated with this concern affect both public and private sectors; the latter mainly comprising small enterprise, cooperatives and individuals being the most vulnerable.

Decrease in fish yield has resulted in serious economic loss to local fishermen inducing the authorities to establish catch limits and controls to allow recovery of stocks of major commercial species. Social and community impacts are even larger due to the vulnerability of the affected sector (see Unsustainable exploitation of fish, Socio-economic impacts).

**Other social and community impacts**

Habitat and community modification, mainly due to overexploitation of fish, has resulted in significant social and economic problems due to the loss of employment and closing of fishing enterprises, with quite strong impact on the local community. The more the resource becomes affected, the higher likelihood of conflict among different sectors.

The loss of agricultural productivity is particularly important because it affects labour resources and results in many ranches being abandoned and the occupants emigrating to urban settlements. The effect of tourist activities also contributes to this phenomenon.

**Conclusions and future outlook**

Habitat and community modification is considered to have a moderate impact, having the same impact as loss of ecosystems and ecotones, and modification of structure or communities. The impact of this concern is expected to increase in the future. Although the recent trend of creating protected areas is expected to continue, degradation in other areas will continue and even increase.

Based on the expected slightly negative trend toward further habitat and community structure modification and despite efforts and improvements by the various sectors of society towards protection and restoration of the environment, it is considered that economic and social impacts directly associated with ecosystem degradation will increase. A very slight increase was predicted for both issues, while health impact was difficult to assess and not considered significant.

**Unsustainable exploitation of fish and other living resources**

Hake (*Merluccius hubbsi*) is the main resource exploited in the oceanic component of the South Atlantic Drainage System. This resource is seriously affected, as it has been exploited beyond safe biological limits. In addition, incidental by-catch and discards comprises between 30 and 60% of the total catch caught in the hake fishery. Only sport fishing is carried out in inland waters.
Fishing activity generates a series of threats to biological marine diversity. Most important are overexploitation of resources, incidental by-catch and discard of organisms without commercial value (DRIyA 2001). Destructive fishing practices result from intensive trawling on the continental shelf where the sea floor is often trawled more than 10 times per fishing operation, seriously affecting the habitat. The introduction of carp and trout (of great economic importance for the region) in rivers and the cultivation of algae for the extraction of thickening agents in the Nuevo Gulf have not changed community structure.

Economic impacts were based mainly on hake overexploitation and its effects on all sectors involved in fishing activity. There are no indications of major impacts on the population as a consequence of disease or pollution. No significant links between health impacts and this concern were identified.

Environmental impacts
Overexploitation
Recent studies have found that overexploitation of fish has not only affected the Argentine hake stock, which is almost completely exhausted, but has also negatively affected marine mammals and birds and their habitats. The FAO estimates that Argentine and foreign ships are responsible for about 90% of hake fishing in the oceanic component of the South Atlantic Drainage System (FAO 2000a). Some indicators of overexploitation are (DRIyA 2001):

- Fishing effort of freezer-trawling ships has increased five-fold between 1989 and 1996;
- Fishing effort of fresh fleet has tripled between 1989 and 1996;
- Large proportion of catch is made up of juvenile and spawning fish;
- Absence of adult fish both in stocks and captures;
- Increased population mortality has effectively reduced fishing yield;
- High discards of small fish due to present fishing practices.

Fisheries in Argentina have undergone a period of accelerated growth in the last decades (Figure 26), involving mostly hake (*Merluccius hubbsi*), squid (*Illex argentinus*), Southern blue whiting (*Micromesistius australis*), Tail hake (*Macrourus magallanicus*) and prawn (*Pleoticus muelleri*). Hake stocks have been overexploited which has led to the current collapse of the population. Although the ecological consequences of this collapse have not yet been evaluated (Fundación Patagonia Natural 1999), measures to avoid the continued overexploitation of hake, such as catch limits and controls to allow recovery of stocks, have been taken. The regulatory measures have resulted in a decrease of total landings in 1998-1999 when the proportion of hake in total landings fell from 62 to 31% (Table 29). In 1999, hake, squid and southern blue whiting represented 31, 34 and 5.4% of total landings, respectively (DRIyA 2001). Intense exploitation may have caused important changes in the structure and productivity of the aquatic ecosystems.

The promotion of new fisheries tends to conceal decreases in the trophic levels of the most exploited fisheries. The abundance of the pelagic species increased due to the excessive exploitation of hake; that is why between 1993 and 1996 stocks of “Anchoita” tripled in Buenos Aires and doubled in Patagonia. Due to the fact that marine mammals and birds prey on many species of fish and crustaceans, the increase in exploitation rate generates concern for the possible competition between fishers and these predators. The disappearance of the exploited stocks causes deleteriously effects on the survival of marine mammals and birds. In addition, the selective fishing of big and old individuals changes the size and age structure of the exploited population, reducing the reproductive capacity of the population and the probability of successful recruitment (DRIyA 2001).

Table 29  Hake landings and percentage of overfishing in Argentina.

<table>
<thead>
<tr>
<th>Year</th>
<th>Maximum permissible capture of hake (tonnes)</th>
<th>Hake landing (tonnes)</th>
<th>Overfishing (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>390</td>
<td>369</td>
<td>-5</td>
</tr>
<tr>
<td>1993</td>
<td>390</td>
<td>422.2</td>
<td>8</td>
</tr>
<tr>
<td>1994</td>
<td>390</td>
<td>435.8</td>
<td>12</td>
</tr>
<tr>
<td>1995</td>
<td>398</td>
<td>574.3</td>
<td>44</td>
</tr>
<tr>
<td>1996</td>
<td>395</td>
<td>589.8</td>
<td>49</td>
</tr>
<tr>
<td>1997</td>
<td>395</td>
<td>585.7</td>
<td>48</td>
</tr>
<tr>
<td>1998</td>
<td>289.5</td>
<td>458.6</td>
<td>58</td>
</tr>
<tr>
<td>1999</td>
<td>188</td>
<td>313.9</td>
<td>67</td>
</tr>
<tr>
<td>2000</td>
<td>130</td>
<td>187</td>
<td>44</td>
</tr>
</tbody>
</table>

(Source: DRIyA 2001)

Figure 26  Fish landings in 1950-2001.
(Source: DRIyA 2001)
Overexploitation of hake in the Mar del Plata area (province of Buenos Aires) became evident in 1997 due to increased landings (Bertolotti et al. 2001a). In 2000, the estimates of the size of the reproductive hake stock south of the 41° latitude were the smallest since 1986 (Pérez 2001). Status indicators show a critical situation; north and south stocks were overfished, total biomass decreased, reproductive biomass was lower than the biologically acceptable level and the fishery was sustained by only a few year classes (Aubone 2000, Bezzi 2000, Grupo de Evaluación Merluza 2000, Pérez 2000).

The predominance of the bivalve mollusc “Vieyra” (Zigochlamys patagónica) in Nuevo and San Jose gulfs has decreased and has shown signs of overexploitation in recent years (Ciocco 1996). The decline in Vieyra stocks has prompted a ban on the collection of this species (Elías 2002).

The estimated size of the Southern blue whiting population has decreased by around 77%. Decreasing average size of individuals comprising the “Gatuzo” (Mustelus schmitti) population, diminishing coastal density in Buenos Aires and Uruguay, and a decreasing Catch per Unit Effort (CPUE) are some signs of overexploitation (Massa et al. 2001).

Mackerel (Scomber japonicus), as well as Blood corvine (Micropogonias furnieri) and shore ray species (Family Rajidae) biomasses have decreased in the oceanic component of the South Atlantic Drainage System since 1996. Fishing pressure on cod (Genypterus blacodes) stocks has increased since 1999 and is now being exploited near sustainable biological limits (Carroza et al. 2001a, Cordo 2001, Perrota & Garcíaarena 2001).

Excessive by-catch and discards

Trawling for prawns has high incidental by-catch rates of juveniles of commercially valuable fish species, as well as mammals such as Marine hair wolf (Otaria flavescens), Dark dolphin (Lagenorhynchus obscurus) and “Tonina overa” (Cephalorhynchus commersonii). Capture of hair seal has been estimated around 1 to 2% of the whole population per year in the southern part of the Chubut province (Crespo et al. 1997). The rate of incidental by-catch of the freezer and factory fleet varies between 9.9% to 24.3%, and 2.3% to 37.2% respectively (Cañete et al. 1999). The size of codfish stocks has declined since 1999 because of high levels of by-catch in hake fishing (Cordo 2001).

Vessels and commercial trawl fishing also affects penguins, albatrosses, petrels and seagulls. Albatrosses are the most vulnerable species because of their low reproductive rate and high age of maturity (DRlyA 2001).

The main target of the Argentine high seas trawling fleet is the hake (Merluccius hubbsi). This fleet uses non-selective nets that capture a wide variety of species, which are later either selected or discarded. In areas with high average yields of hake, accompanying species such as cod and tail hake are discarded. However, in areas with low average yields of hake (Buenos Aires seashore) the relative importance of accompanying species such as Gatuzo, codfish and Pescadilla becomes higher (Irusta et al. 2001).

Incidental captures of benthic organisms have been recorded. For example, in the shrimp fishery of the San Jorge Gulf and along the coast of Chubut, non-target macrobenthic organisms were caught in 89% of all hauls investigated (Roux 2000).

Discards produce changes in the community structure, food web and marine bed composition. Assessments carried out during 1993-1996 found that out of about 100 species caught, around 85 were thrown back as discard (21 with some commercial value). The high seas fleet discards about 25% to 30% of their catches while the coastal fleet discards are about 25% (Caille & González 1998). The fishery of Argentine prawn lands a significant by-catch of hake (Table 30).

According to official estimations, in 1990-1996 between 20 000 and 75 000 tonnes per year of young hake were discarded, representing 80-300 million fish. The majority of these discards were hake younger than 2 years old. In 1997, the prawn trawling fleet landed 5 500 tonnes of prawn and 40 000 tonnes of hake. The total discards of young hake by prawn fishing fleet was estimated at about 20 000 tonnes per year. Discards of young and adult hake from the factory fleet and fresh trawling fleet are also significant (DRlyA 2001).

<table>
<thead>
<tr>
<th>Species or group of species</th>
<th>Biomass (%)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentine hake (Merluccius hubbsi)</td>
<td>66</td>
<td>91</td>
</tr>
<tr>
<td>Argentine prawn (Pleoticus muelleri)</td>
<td>18</td>
<td>91</td>
</tr>
<tr>
<td>Anchova (Engraulis anchoita)</td>
<td>4.8</td>
<td>24</td>
</tr>
<tr>
<td>Southern blue whiting (Genypterus blacodes)</td>
<td>2.2</td>
<td>35</td>
</tr>
<tr>
<td>Other invertebrates</td>
<td>1.7</td>
<td>56</td>
</tr>
<tr>
<td>Skates (Rajidae)</td>
<td>1.6</td>
<td>32</td>
</tr>
<tr>
<td>Crabs (Brachyura)</td>
<td>1.4</td>
<td>53</td>
</tr>
<tr>
<td>Lobsters (Munida spp.)</td>
<td>0.88</td>
<td>29</td>
</tr>
</tbody>
</table>

(Source: Caille & González 1998)
In the factory fleet, observers verified that catches showed no relation to the factory processing capacity. There is a trend to catch much more than the amount that can be processed. There is no control over what enters the net to regulate trawl duration. In general, trawl frequency and duration are independent of the presence of raw product in the processing plant. The discard level is very high and related to variable criteria that are difficult to predict. To a large extent this is conditioned by the previous item, since bad quality fish is rejected or the processing line excessively accelerated. This is not exclusively associated with fishing gear selectivity. Failures were detected in the processing lines that can be attributed to equipment calibration and maintenance, handling and selection of specimens by operators and the quality of raw material (crushed fish that block the machinery). All those factors diminish yield and increase discard levels (Cañete et al. 2000).

**Destructive fishing practices**

Trawling of the sea floor has a significant impact on the benthic habitats, and its continued use could result in serious consequences - not only for the target species but also for other marine organisms. Although there are a wide variety of possible negative effects on the ecosystem, an environmental impact assessment of trawling practices in the Argentine seashore has not been carried out. In the San Jorge Gulf and along the Chubut coast, the groups most affected by trawling nets were seahorses and polychaetes (Roux & Bertuche 1998). Benthic habitats are usually trawled more than 10 times per fishing operation.

Drag is another fishing practice that could also greatly affect the marine bed. This practice is used by the vieiras fishing boats which, in San Matías Gulf between 1969 and 1972, negatively affected the marine beds as well as several species (Ciocco et al. 1998, Orensanz et al. 1991).

**Impact on biological and genetic diversity**

As mentioned in the section on Habitat and community modification, there is little information about the impact induced by the introduction of alien species such as the brown alga *(Undaria pinnatifida)*, Asian clam *(Corbicula fluminea)*, “Dog’s teeth” *(Balanus glandula)* and other intentionally introduced species such as Brown trout *(Salmo trutta)*, Rainbow trout *(O. mykiss)*, Pacific oyster *(Crassostrea gigas)*, Chilean oyster *(Tiostrea chilensis)*, Chinook salmon *(Onchorhynchus tshawystcha)* and beavers.

These species might become a threat for biodiversity by excluding native species. At the same time, alien species might introduce new pathogens affecting the native species and the ecosystem negatively (DRiyA 2001).

**Socio-economic impacts**

**Economic impacts**

The moderate impacts on the South Atlantic Drainage System exerted by overexploitation of fish and other living resources are primarily caused by the overexploitation of hake. However, banning hake fishing would result in severe social problems, loss of employment and the closure of fishing enterprises, as well as affecting tourism. More weight has been assigned to frequency and duration, taking into account that impact on the local community is quite strong.

In Patagonia, 71% of fishers are employed within the factory fleet which supplies processed fish products, 18% within the fresh fish trawl fleet and 11% in the coastal fleet. The manufacturing of fish products involves both factories and cooperatives. Although the total number of people employed in the entire fishing sector decreased by about 11% between 1987 and 1996, the number of people employed within fish processing industries in Patagonia has constantly increased (about 37%) due to the construction of several fish processing factories (DRiyA 2001).

By the time hake overexploitation became evident in 1997, maximum crew employment was registered. Since 1997, employment in the fishing sector has decreased by about 22% while in 2000 alone, it decreased by about 8 to 9% in total, 13% for the Patagonian region and 6% for Buenos Aires Region (Bertolotti et al. 2001a).

Recent estimates from the coastal fishing fleet show that landings have decreased and fishing days increased indicating a reduction in catch per sailing and a decrease in average revenue. Since profits are divided between crew members the average income per person has also decreased (Bertolotti et al. 2001b).

In 1999-2000, production, fishing days and employment of the high seas fleet decreased about 13%, 9% and 9% respectively. During the same period, for freezer and factory fleets the decreasing rates were 14%, 7% and 9% (Bertolotti et al. 2001a).

In 1999, fish export reached 809 million USD showing a decrease compared with previous years; 1 014 million USD in 1996, 887 million USD in 1997 and 923 million USD in 1998 (Figure 27). The decrease was mainly due to international and national market conditions but also reduced landings.

**Other social and community impacts**

The processing plants of Comodoro Rivadavia, Trelew and Rawson are mainly devoted to hake manufacturing. Due to the decrease in hake landing there has been a sharp drop in industrial input. Many plants were closed and many jobs were lost (Table 20) (Bertolotti et al. 2001b).
Of 38 established plants, only 26 were operative in 2001. Since 1998, there has been an ongoing trend towards poorer working conditions, lower incomes and even loss of work benefits such as health cover and retirement pensions.

Conclusions and future outlook
The overall impact of Unsustainable exploitation of fish and other living resources is moderate. Highly linked to the concern Habitat and community modification, intensive fish exploitation, incidental captures and discards, and fishing practices have affected aquatic community structure and population dynamics at various trophic levels.

In future, the exploitation of living resources is likely to increase. Visible results from implemented regulations are not expected in the oceanic component of the system. In continental areas, where regulations are usually not fulfilled, unsustainable exploitation is also predicted to increase.

A slight increase is expected in economic, social and community impacts exerted by unsustainable exploitation of fish, considering that this concern is expected to cause greater environmental impacts in the future.

It is estimated that fish consumption will be slightly higher than it was at the end of the 1990s, based on the assumption that total quantity consumed per person per year will remain fairly constant. A breakthrough in aquaculture (e.g. an extremely rapid spread of tilapia culture in Latin America) would be the only major reason to alter this prediction (FAO 2000b).

Global change
Global change models, mainly relating to global heating by the greenhouse effect, applied in the region, show a temperature and precipitation change for different future scenarios.

The possible after-effects of regional climatic changes, even those suggested by the most moderate scenarios, may affect among other aspects, biodiversity, coastal habitat characteristics, forest fires and production activities such as agriculture, cattle raising, hydropower generation and tourism. Therefore, it is recommended that the impact of global change in these fields should be investigated.

Changes in the hydrological cycle have been indicated by movement of the isohyets towards the west. Although ongoing research has not yet reached conclusions, there is preliminary evidence of changes affecting phytoplankton and ichthyoplankton due to increased UV-B radiation. Research is also being carried out to assess changes in ocean CO₂ source/sink function. There is no evidence of changes in sea level.

Considering the current regional climate, no significant effect on the health could be attributed to climate change. In addition, the anticipated changes in the hydrological cycle are likely to yield economic benefits to the system.

Environmental impacts
Changes in the hydrological cycle and in the ocean circulation
Between 20° and 38° S, rainfall around the Andes occurs mainly during summer. Between 38° and 48° S, rainfall around the Andes occurs mainly during winter. Southward precipitation occurs almost all year. Snow accumulates in the high parts of the Andes and melts during spring, becoming the main source of water for the rivers of the sub-system. Between the end of the 1800s and the middle of the 1970s, the sub-system has been under the influence of a declining trend in the amount of precipitation (IPCC 2001b). However, since the mid-1970s, this trend has reversed. A similar trend has been detected for stream flows in the system (IPCC 2001b).

The estimates of precipitation changes caused by the greenhouse effect show that, in summer, the semi-arid zone located in western Argentina would show a decrease of 10% in precipitation for each degree that the average global temperature increased. In winter, models show precipitation increases of 5% in the austral zone and 5-10% in northeastern Argentina, as a result of global warming. Table 31 shows these variations expressed as percentages of present value (Labraga 1998).
In the high altitudes of the Andes, large amounts of snow are recorded. Melting of this accumulated snow is the main cause of river run-off during spring and summer. In central and western Argentina, to the north of 37°, stream flows are normal or above normal during El Niño years. On the other hand, during cold events (La Niña), negative anomalies of rainfall and snowfall occur, with reverse consequences, including below-normal summer stream flows. For this area, the likelihood of dry conditions during La Niña are higher than wet conditions during El Niño (IPCC 2001b).

Since the 1970s, there has been a shifting in the isohyets towards the west, mainly southwest of the province of Buenos Aires and La Pampa (Sierra et al. 1994). Ocean currents have not been affected.

### Increase in the UV-B radiation as a result of a reduction of the ozone layer

The impact of UV-B radiation in the region is not clear. On one hand, Patagonia is not likely to be affected by ozone layer depletion since seasonal cloudiness takes place during the few days when it might exert an influence on the region. On the other hand, preliminary research data suggests changes in phytoplankton and zooplankton communities that may be attributed to increased UV-B radiation.

### Changes in ocean function as a CO\textsubscript{2} source/sink

There are huge doubts about this issue, although suspicions about its effects exist. Research is just starting with the installation of measuring equipment in the southern zone of the Atlantic Ocean where measuring is easier.

### Socio-economic impacts

#### Economic impacts

Economic impacts from changes in the hydrological cycle are considered beneficial. As a result of such changes, about 1 million ha have been incorporated into production in the province of La Pampa. Given that the system is arid, increases in precipitation induce positive impact in the economic sector.

### Conclusions and future outlook

In the South Atlantic Drainage System, detrimental environmental and socio-economic impacts could not be attributed to Global change. In fact, changes in the hydrological cycle are expected to yield slight socio-economic and social benefits for the region.

Considering the likely future conditions, it is probable that the overall negative environmental impact of global change will increase in the near future. This negative perspective is shown in the slight reduction of positive scores assigned to present conditions.

Phenomena like El Niño, with a great importance in the climatic variability each year, have not yet been modelled in a satisfactory way. For that reason, it is difficult to infer future El Niño behaviour in this system in the presence of an intensification of the greenhouse effect.

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**Table 31** Precipitation variation scenarios for the different Argentinean regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Precipitation variation range (%)</th>
<th>Year 2030</th>
<th>Year 2070</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle-West</td>
<td>-1 to -17</td>
<td>-2 to -42</td>
<td></td>
</tr>
<tr>
<td>(West of 65° and from 35° to 45° S)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>0 to +8</td>
<td>0 to +21</td>
<td></td>
</tr>
<tr>
<td>South (South of 45°S)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The effective variation precipitation ranges (not standardised) are expressed as percentages of the actual values. (Source: Labraga 1998)

Depending on latitude, a 1° C increase in temperature would increase alfalfa yields. For the area located south of 36° S, an average increase in alfalfa yields of 50-100% is expected for most varieties (IPCC 2001b).

Other social and community impacts

The increase in productive land surface does not only improve welfare of the population directly involved in agriculture but also extends its benefits to all indirectly related sectors.
Priority concerns: La Plata River Basin & South Atlantic Drainage System

All the concerns in La Plata River Basin are moderate taking into account their weighted impact; consequently the assessment did not result in a clear identification of priorities. Numerical differences were not significant enough to establish priorities among the related concerns. These priorities were finally assigned on the basis of common expert judgement and intense discussion during the GIWA workshop and further assessment of the individual scores (Annex II). The priority concerns selected were:

- Habitat and community modification
- Pollution

Despite the fact that Pollution contributes to Habitat and community modifications, a higher impact is attributed to the construction and operation of reservoirs and dams; widespread presence of invasive species like Limnoperna fornei; and overexploitation of fish. The main socio-economic impact comprises the cost of controlling invasive species, increased fishing effort and changes in fishing practices.

The widespread distribution and the long-term degradation caused by habitat and communities modification and pollution justified the prioritisation of these concerns over the other three considered in the GIWA Assessment.

The possibility of reverting existing dams and reservoirs is almost non-existent as there is a great dependency on the use of water resources to generate electric power, mainly in Brazil. Therefore, the transformation of lotic ecosystems into lentic ecosystems will continue. In addition, facilities constructed for species migration are not effective, and operations of dams do not always fulfill environmental requirements. Demands for water and electricity will increase in the future together with the human population and improvements in the quality of life in the region exerting greater pressures on the water resources in the basin. Also, economic and human efforts dedicated to controlling invasive species have not succeeded.

Chemical contamination is the most important issue of pollution; heavy metal pollution ubiquitous in the Basin is the main chemical pollution stress. There are also numerous indications of bacteriological contamination, and some spill events during the last five years. The main socio-economic impact is the increased costs for water treatment, and impact on tourism and recreational values.

Considering the socio-economic impact produced by the contamination of drinking water supply in the two big cities in the Basin, São Paulo in Brazil with 18 million inhabitants and Buenos Aires in Argentina with 13.5 million inhabitants, it can be inferred that pollution, directly or indirectly, affects the greatest population. At the same time, priority is based on the important economic, educational and awareness efforts of the community and necessary controls to improve environmental conditions.

In the South Atlantic Drainage System, four concerns were assessed as moderate considering their weighted impact: Habitat and community modification; Unsustainable exploitation of fish and other living resources; Pollution; and Freshwater shortage. Slight beneficial impacts can be attributed to Global change (Annex II). Nevertheless, significant numerical differences relating to the impact of the above four concerns has meant that the following can be considered a priority:

- Habitat and community modification
- Unsustainable exploitation of fish and other living resources

Taking into account the magnitude of the environment and economic impact, mainly in the oceanic component of the system, as well as the extent of impacts and the number of people involved, Habitat and community modification and Unsustainable exploitation of fish and other living resources, constitute the principal problems. The negative impacts are reversible but requires great effort, economic resources, education, awareness and political and institutional agreements.

Habitat and community modification in the continental area is mainly due to the development of reservoirs and impacts on flood meadows (“mallines”). On the other hand, in the oceanic component, overexploitation of target species, unsustainable fishing practices, as well as pollution are the most important causes of habitat and community modification. Loss of agricultural productivity, increasing fishing effort and economic losses for local fishermen constitute the main socio-economic impact.

Unsustainable exploitation of fish and other living resources in the oceanic component is particularly related to the overexploitation and incidental by-catch and discards, with consequences for habitat and community modification. Overexploitation of fish results in severe social and economic problems due to the loss of employment and the closure of fishery enterprises.

Based on the GIWA Assessment of each concern and their constituent issues in both systems, the following concerns have been prioritised for Causal chain and Policy option analyses:
Habitat and community modification in the entire region, highly linked with Overexploitation of fish in the oceanic component of the South Atlantic Drainage System;

Pollution in La Plata River Basin.

The links between GIWA assessed concerns for the Patagonian Shelf region as a whole resulted from the aggregation of the analysis made for La Plata River Basin and South Atlantic Drainage System (Figure 28).

Pollution of water sources has been identified as the main issue concerning water shortages in the La Plata River Basin, as well in Buenos Aires and São Pablo cities in terms of water supply. On the other hand, freshwater shortage increases the impact of pollution by decreasing the dilution capability of water bodies, as is the case in the Quareim River in the La Plata Basin during summer.

Habitat and community modification is the central concern in the Patagonian Shelf since all other concerns are linked to this. Pollution (spills and urban discharge) and unsustainable fishing practices affect aquatic habitats (overexploitation of target species and trawling), particularly marine resources and ecosystems.

In the South Atlantic Drainage System habitat modification due to anthropogenic activities aggravate natural water deficits that occur in this mostly arid region. Modification of stream flow due to the construction and operation of reservoirs of dams affects habitat and community structure throughout the entire Patagonian Shelf region.

Finally, global change will affect aquatic ecosystems and habitat and community structures through large variations in climate and changes in the water balance.