Global International Waters Assessment

Amazon Basin

GIWA Regional assessment 40b

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Regional assessments

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Abbreviations and acronyms

ACA	Amazon Conservation Association
ACT	Amazon Cooperation Treaty
ANA	Brazilian National Water Agency
BOD	Biological Oxygen Demand
CENDEPESCA	Bolivian Centre for Fisheries Development
COBRAPHI	Brazilian Committee for the International Hydrological Programme
EMBRAPA	Brazilian Agricultural Research Corporation
FAO	Food and Agricultural Organization of the United Nations
HiBAm	Hydrology and Geochemistry of the Amazon Basin
IBAMA	Brazilian Institute of Environment
IBGE	Brazilian Institute of Geography and Statistics
INPA	The National Institute for Research in the Amazon
INPE	Brazilian National Institute for Space Research
LBA	Large Scale Biosphere-Atmosphere Experiment in Amazonia
MERCOSUR	Mercado Común del Sur (Southern Common Market)
MINPES	Peruvian Ministry of Fisheries
MPEG	The State of Pará Emílio Goeldi Museum
PPG7	Protection of the Brazilian Rainforest
PROVARZEA	The Amazon Floodplains (Varzea) Project
SECTAM	The Pará State Secretariat for Science, Technology and Environment
SENAMHI	National Service of Meteorology
SINCHI	The Amazonic Institute of Scientific Research
UA	Amazonas University
UFPA	Federal University of Pará
UFPB	Federal University of Paraíba
UNEP	United Nations Environment Programme

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Executive summary

The Amazon Basin is the largest basin on the planet and also one of the least understood. Its drainage area covers more than one third of the South American continent, and its discharge contributes almost one fifth of the total discharge of all rivers of the world. The headwaters of the Amazon River are located about 100 km from the Pacific Ocean and it runs more than 6 000 km before draining into the Atlantic Ocean. In addition, the Amazon has 15 tributaries, including the Tocantins River, that measure more than 1 000 km in length. The Madeira and Negro rivers are the most important tributaries, contributing with more than one third of the total water discharge. The Amazon Basin contains a complex system of vegetation, including the most extensive and preserved rainforest in the world. The rainforest, known as the Amazon Rainforest, is not confined to the Amazon Basin but also extends into the Orinoco Basin and other small basins located between the mouths of the Orinoco and Amazon rivers. In addition, savannah and tundra-like vegetation can also be found. Extensive areas of scrub-savannah dominate the headwaters of the Brazilian and Guyana shields, while the regions of the Basin situated at high altitude in the Andes are characterised by tundra-like grassy tussocks called the Puna.

The Amazon Basin is shared by Brazil, Peru, Ecuador, Bolivia, Colombia, Venezuela and Guyana. More than half of this basin is located in Brazilian territory, but the headwaters are located in the Andean portion of the Basin which is shared by Bolivia, Peru, Ecuador and Colombia. The human density in the Amazon Basin is very low and people are concentrated in urban centres. In the entire Basin there are five cities with more than 1 million inhabitants and an additional three with more than 300 000 people. However, despite the high proportion of the population living in urban areas, the economy of the region is still primarily dependent on the extraction of exportable minerals, oils and forest products. The only exception is the contribution made by the industrial park established in the duty free zone in the city of Manaus. Products from timber, mining and petroleum exploitation are the most important products exported from the Amazon Basin. Timber exploitation focuses on a few species, particularly mahogany (*Swietenia macrophylla*). The primary environmental consequence of this exploitation is the depletion of natural populations of the exploited species. The construction of roads to facilitate the extraction of timber from within the forest also provides access to farmers and other groups that colonise and expand into these newly accessible areas. Mining, particularly of alluvial gold, and oil extraction activities are scattered throughout the Amazon region. The main environmental problems associated with mining are pollution and increased suspended sediment loads caused by erosion which leads to the degradation of downstream habitats. Fishing is also an extractive activity that is traditional and important in the Amazon plains. Fish is a source of cheap, high quality protein for inhabitants of the Amazon Basin. Some selected species of fish are exported to other regions outside the Amazon Basin and also to other countries. Overexploitation exists but is restricted to only a few target species.

The development and expansion of agriculture is modifying the environment within the region. Large cattle farms are being established in vast areas along the southern and eastern borders of the Basin. Also, large soybean plantations are being established mainly in less humid areas near the borders of the Basin. Meat and soybeans may become important export products from this region, but it will result in the replacement of natural forests by pastures and soybean plantation. The importance of the Amazon forest in regulating the hydrological and carbon cycles has only very recently been recognised and the consequences of the large-scale deforestation are not well understood. As a consequence, deforestation and pollution were considered to be the most critical large-scale environmental problems in this region leading to the conclusion that Habitat and community modification and Pollution were the most important GIWA concerns in the entire Amazon Basin.

Although the environmental and socio-economic impacts of each of the predefined GIWA issues and concerns were assessed over the entire Amazon Basin, the dimension and heterogeneity of the region rendered causal chain and policy options analyses of the entire region impracticable. As a consequence, these analyses focused on determining the root causes of and policy options for mitigating Habitat and community modification and Pollution only in the Madeira Basin. This basin was chosen because of its socio-economic importance to the region and its transboundary nature.

The Madeira River Basin is shared by Brazil, Bolivia and Peru and therefore, requires a transnational management agreement in order to ensure appropriate management of aquatic resources and the establishment of a socio-economic development plan. The Causal chain analysis determined that the root causes of Pollution and Habitat and community modification in the Madeira Basin were: governance failures, market and policy failures, poverty, and lack of knowledge and information. The lack of information affects the Basin in different ways, from the inability to detect problems and unsustainable practices to the lack of environmental warning mechanisms to raise awareness among decision-makers. The failure of governance was related to the difficulty in establishing acceptable mechanisms to settle conflicts among different interests. The lack of legitimacy of negotiations commanding decisions regarding investments and the absence of a basin-wide management plan were the two biggest problems associated with governance failures in the region. The market and policy failures were attributable to the misconception that natural resources of the Amazon Basin are inexhaustible which leads to the unsustainable use of those resources. The lack of knowledge was associated with inadequate training in best land use practices resulting in the failure to adopt techniques for soil and chemical use in the agriculture and mining industries that make these activities more profitable and less environmentally damaging. Training in best land use practices must be included in the basin-wide management plan. Finally, poverty is common in the Amazon Basin and results in the significant dependence of people living in the region on the exploitation of natural resources in order to sustain their livelihoods. The Amazon Basin is one of the last frontiers and a land of opportunities for those that do not have good perspectives in their homelands. The poverty-environmental degradation cycle probably represents the largest challenge for the future administration of this region.

The two most promising projects developed to address these root causes aimed to collate and disseminate information and to implement a fisheries management programme in the Madeira Basin. Information is the key requirement in order to implement actions to ensure sustainable use of water resources. The Governments must be well informed about the ecology, economy, socio-economy, hydrology, meteorology, agriculture and other important aspects related to water and land use in the Basin. This action could be implemented in three ways: (i) research, to obtain more and new information; (ii) search, to gather existing information; and (iii) dissemination, to transmit information to the target audience. The purpose of this project is to integrate the different countries and stakeholders that support research, databases, and social organisations, in the field of water resources and environmental management in the Madeira Basin. This project will represent a first step to develop and implement a basin-wide management programme involving the three countries. This action complies with directives of the Amazon Cooperation Treaty (ACT) and will be the basis for the constitution of a Commission or International Committee of the Madeira River Basin. All three countries possess research programmes and database systems to monitor problems and manage water resources sustainably, but these programmes are not integrated. The implementation of an integrated information system might improve the prediction of floods and the implementation of mechanisms for pollution control. Also, the scientific community within these countries could work in association with the information system to develop joint research projects in the aquatic sciences.

The impetus for establishing a sustainable development programme for fishing activities in the Madeira Basin is the great economic potential of fish stocks and the importance of connections between the upper and lower parts of rivers to enable fish migration. This project aims to gather fisheries projects and organisations in order to achieve sustainable fishing practices and exploitation of unidentified opportunities. In addition, the project should strive to raise awareness among fishermen and stakeholders of how their activities affect and, in turn, are affected by the health of the environment of the Basin, thus transforming them into one of the primary agents monitoring and enforcing the sustainable development programme. In the Amazon Basin, some efforts have been made to integrate fisheries management, mainly to manage the stocks of large migratory catfish. Experiences gained from these efforts could be incorporated directly into a sustainable fisheries development programme for the Madeira Basin. The selection of this project was based on the fact that the fishery supports thousands of direct and indirect jobs and, as a consequence, the adequate management of the fish stocks in the region is more important from a social perspective than an economic one. Considering the fact that large migratory catfish spawn in the Andean headwaters of the Basin and mature in the estuary and in the lower Amazon reaches, the geographic area in which this project would be implemented is enormous. The protection of the spawning areas of these species is essential for the fishery in the entire Amazon Basin. The efficiency of the project is high because the economic feedback resulting from larger fish stocks is relatively fast. In addition, the equity considerations are also positive because the development programme for fishing activities would directly affect both professional and amateur fishermen, as well as the consumer markets in the largest cities. Furthermore, considering the increase in the number of conflicts between fishermen during recent decades, the political feasibility of the project must be addressed. The necessity of implementing a fishing ordinance to manage fish stocks in the region has been recognised by both professional fishermen and by artisanal fisherman living in riparian communities. In some cases, it is impossible to find an equitable solution for a conflict and it is necessary to make a decision that could be unfavourable to one party. If this is done, the political feasibility of the project can be threatened. However, if the decision is not taken, the conflict may intensify and become uncontrollable, potentially threatening the project once again. Unfortunately, despite having the necessary scientific capacity, the implementation of this project is prevented by inadequate financial resources in each of the three countries that share the Madeira Basin.

Regional definition

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

Boundaries of the Amazon region

The Amazon Basin is the largest drainage basin on the planet. It is situated completely within the tropics, between 5° N and 17° S, and occupies more than one third of the South American continent. Seven countries, Brazil, Bolivia, Peru, Colombia, Ecuador, Venezuela and Guyana share this basin. The Orinoco and Paraná rivers represent other important South American basins, located to the north and south of the Amazon Basin, respectively (Figure 1).

The headwaters of the Amazon River are located in the Andes Mountains which are shared among Bolivia, Peru, Ecuador and Colombia, while the origin of several important tributaries are found in the Brazilian and Guyana shields, an ancient Precambrian crystalline basement situated along the northern and southern border of the Basin (Figure 2). The headwaters of rivers situated in the northern Amazon Basin are shared by Venezuela, Guyana and Brazil, while the headwaters of rivers in the south are located in Brazil. The central, the lower and the mouth of the Amazon River fall within the Brazilian territory (Figure 3). The Amazon discharges into the North Brazil Shelf Large Marine Ecosystem (LME 17).

The Brazilian Government excludes the Tocantins River from the Amazon Basin's drainage area (COBRAPHI 1984). The mouths of these rivers are partially separated by several islands located at their confluence, and it may represent a division of the basins. The Marajó Island is the largest and it separates the mouth of the Amazon to the north from Marajó Bay and Pará River, which are considered the mouth of the Tocantins River and several other smaller rivers located to the south (Barthem & Schwassmann 1994). The discharge of the Amazon and Tocantins rivers creates a large area along the northeastern coast of South America where fresh and saltwater mix and sustains a 2 700 km stretch of low-lying, muddy mangrove forests. This environment extends from the Orinoco Delta in Venezuela into the Brazilian State of Maranhão and is inhabited by several endemic species, genera and sub-families of fishes (Myers

Figure 1 Geographical location of the Amazon, Orinoco and Paraná basins.

1960). The volume of water discharged from both these rivers supply around 15% of the total fluvial water into the world's oceans (Milliman & Meade 1983, Goulding et al. 2003). However, despite the geographical separation of the mouths of the Amazon and Tocantins rivers, the water from both mixes prior to reaching the ocean and therefore has similar physical and chemical properties which gives rise to similar freshwater fauna on both sides of the archipelago (Barthem 1985, SANYO Techno Marine Inc. 1998, Smith 2002). As a consequence, there are no ecological or geographical reasons to consider these basins separately.

The boundary of the GIWA Amazon region was considered the limits of the drainage area of the Amazon and Tocantin Basins. Due to the extension of the Amazon mouth and the influence of the freshwater discharge on coastal waters close to its mouth, it was necessary to define the eastern limits of the region. Although the distance from the mouth that freshwater is discharged from the Amazon varies more that 100 km between seasons, the influence of the freshwater is very small beyond 50 m depth (Barthem & Schwassmann 1994, SANYO Techno Marine Inc. 1998). Therefore, the eastern limit of the Amazon Basin region was designated as the 50 m depth contour and included the Guamá and Araguari rivers as well as other small basins (Figure 3).

Physical characteristics

The area of the Amazon Basin is estimated to 6 869 000 km^2 (Table 1). Although 69% of the Amazon Basin is situated in Brazil; Bolivia and Peru can also be considered as Amazon countries, because 66% and 60% of the area of these countries respectively is located in the Amazon Basin (Goulding et al. 2003) (Table 2). The catchment area of the Basin extends from 79° W (Chamaya River, Peru) to 46° W (Palma River, Brazil), from 5° N (Cotingo River, Brazil) to 17° S (headwater Araguaia River, Brazil) and incorporates some of the greatest drainage basins of the world (Goulding et al. 2003). Table 1 shows the areas of the most important catchments within the Amazon Basin and identifies those that are considered international and drain an area shared by more than one country, and those that are considered national and drain an area larger than a state. The largest catchment within the Amazon Basin in terms of drainage area and discharges of water and sediment is the Madeira River, which drains an area that covers parts of Brazil, Bolivia and Peru. The Tocantins River is the second largest catchment in terms of drainage area and is entirely Brazilian. The Negro River, in the northern Amazon Basin, is the most important tributary in relation to discharge of water and drainage area, which drains parts of four countries: Brazil, Colombia,

Figure 2 The Amazon Basin.

Table 1 The Amazon River and its main tributaries.

Basin	Basin area (km²)		Discharge (m³/s)	Countries	Category
Amazonas	6 869 000	100%	220 800	Brazil, Bolivia, Peru, Colombia, Ecuador, Venezuela and Guyana	International
Tributaries					
Madeira	1 380 000	20%	31 200	Brazil, Bolivia and Peru	International
Tocantins	757 000	11%	11 800	Brazil	National
Negro	696 808	10%	28 060	Brazil, Colombia, Venezuela and Guyana	International
Xingu	504 277	7%	9 680	Brazil	National
Tapajós	489 628	7%	13 540	Brazil	National
Purus	375 000	5%	10 970	Brazil and Peru	International
Marañón	358 050	5%	ND	Peru and Ecuador	International
Ucayali	337 510	5%	ND	Peru	National
Caquetá-Japurá	289 000	4%	18 620	Brazil and Colombia	International
Juruá	217 000	3%	8 420	Brazil and Peru	International
Putumayo-Içá	148 000	2%	8 760	Ecuador, Colombia, Peru and Brazil	International
Trombetas	133 930	2%	2 855	Brazil	National
Napo	115 000	2%	ND	Peru and Ecuador	International
Uatumã	105 350	2%	1 710	Brazil	National

Note: ND = No Data. (Source: Goulding et al. 2003)

Venezuela and Guyana. The origins of other important tributaries in the Andean zone belong to Bolivia, Peru, Ecuador and Colombia (Figure 3). Some rivers have their names changed when crossing the border between countries. The most important example is the Amazon River, which undergoes at least seven name changes between its origin and its mouth (Barthem & Goulding 1997). In each country, the Amazon has a different name: Içá and Japurá in Brazil and Putumayo and Caquetá in Colombia.

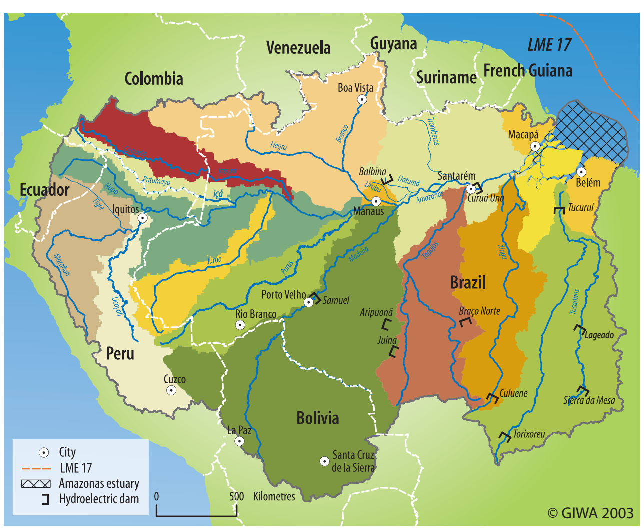

Figure 3 The drainage basins of the tributaries comprising the Amazon Basin.

Table 2 Countries within the Amazon Basin.

Country	Amazon Basin by country (%)	Country area included in the Amazon Basin (%)
Brazil	69.1	54.7
Peru	11.4	59.9
Bolivia	10.7	65.9
Colombia	5.9	35.0
Ecuador	2.0	46.8
Venezuela	0.8	6.1
Guyana	<0.1	<0.1

(Source: Goulding et al. 2003)

The origin of the Amazon lies approximately 100 km from the Pacific Ocean in the oriental slopes of the Andes Mountains and reaches the sedimentary lands of low declivity in Peru before crossing the frontier between Colombia and Brazil. The total length of the Amazon is debated because it is difficult to measure the distance along its meandering course and also because it is not known exactly where the origin is located. However it is estimated to be between 6 400 and 6 800 km (Goulding et al. 2003). Approximately 15 tributaries and the Tocantins River have lengths greater than 1 000 km and three of them extend more than 3 000 km (Barbosa 1962, Goulding et al. 2003).

The Amazon River discharges approximately 220 800 m³ of water per second which represents about 15% of the total discharge of all the rivers in the world (Goulding et al. 2003). It transports approximately 1.2 billion tonnes of sediments per year, less than Yangtze in China and Ganges-Brahmaputra in India and Bangladesh (Meade et al. 1979).

Most of the Amazon Basin does not exceed an altitude of 250 m, and the main humid zones are located below a height of 100 m (Salati & Vose 1984). The ports located in Iquitos, in the Amazon River (Peru), and Porto Velho city, in the Madeira River (Brazil), receive ships that travel more than 3 500 km along the rivers. Otherwise, not all the rivers of the Amazon Basin are navigable by commercial ships, although, it is estimated that more than 40 000 km of waterways within the Basin are navigated by various types of craft.

Climate

Despite its enormous size, the temperature range over the entire Amazon Basin is relatively small with annual mean temperature varying from 24 to 26°C. In the mountainous areas, the annual average is below 24°C, while along the Lower and Middle Amazon the mean temperature exceeds 26°C (Sioli 1975). The homogeneity of temperature is probably due to the relatively uniform topography of the Basin, the abundance of tropical rainforest, and its location in the north and centre of South America.

Other climatic parameters however, exhibit important temporal and spatial variations over the area of the Basin. The area, according to the climatic classification of Köppen, is characterised by several climate types: Type *Afi* is defined by relatively abundant rains throughout the year, with the total precipitation in the driest month always exceeding 60 mm; Type *Ami* is defined as a relatively dry season, with elevated total annual pluviometric rate; and Type *Awi* has a relatively elevated annual pluviometric index, but also exhibits a clearly defined dry season (Day & Davies 1986).

Mean annual rainfall exhibits great spatial variations throughout the Amazon Basin, generally oscillating between 1 000 mm and 3 600 mm, but exceeding 8 000 mm in the Andean coastal region (Day & Davies 1986, Goulding et al. 2003). At the mouth of the Amazon River, the total annual rainfall exceeds 3 000 mm, while in the less rainy corridor, from Roraima through Middle Amazon to the State of Goiás in Brazil, the total annual rainfall varies between 1 500 and 1 700 mm (Capobianco et al. 2001).

The pattern of rainfall throughout the year varies across the Basin. In the west, rains are relatively evenly distributed, while the northern Basin receives its greatest rainfall in the middle of the year and in regions south of Ecuador, maximum precipitation occurs at the end of the year (Simpson & Haffer 1978, Salati 1985). Because more than half of the total precipitation is recycled by evapotranspiration, the Amazon rainforests maintain the rainfall patterns and the hydrological cycles in the region (Salati et al. 1978, Salati & Vose 1984). Medium annual evapotranspiration ranges from almost 1 000 mm per year in the proximities of the Juruá and Purus rivers to more than 2 600 mm per year close to the mouth of the Amazon River.

Classification of Amazonian rivers

The great environmental heterogeneity of the Amazon Basin can be illustrated by categorising the different biotopes, considering the different sub-basins that comprise the Amazon Basin, the landscapes defined by the geological past and the different types of floodplain areas. The main geological units of the Amazon Basin include high mountains (Andes), old shields (Brazilian Shield and Guyana Shield) and the extensive lowlands (Central Amazonian Lowlands) (Figure 2). These three geological structures are of fundamental importance for the chemical quality of water as well as the composition and production of fish in the Amazon rivers. The types of water in the Amazon are classified as white, clear or black according to their colour, which is determined by the geological structures where the waters originate (Sioli & Klinge 1965, Sioli 1967, Sioli 1975).

The highly turbid rivers that carry a great amount of material in suspension, such as the Amazon, Napo, Marañón, Tiger, Juruá, Purus and Madeira rivers, are called white-water rivers and originate in the Andean slopes. The conductivity of waters in these rivers is elevated (> 60 µS/cm) and the pH is close to neutral (6.5-7) (Meade et al. 1979, Schmidt 1982, Guerra et al. 1990).

Clear-water rivers are, as the name suggests, generally transparent and originate in the crystalline Guyana and Brazilian shields where the processes of erosion yield few particles that are transported in suspension. As a result, these waters are chemically pure, with low conductivity (6-5 µS/cm) and almost neutral pH (5-6) (Sioli 1967). The visibility within the Tapajós, Xingu and Trombetas rivers is almost 5 m.

A great amount of humic acid in colloidal form is a characteristic of black-water rivers, such as the Negro and Urubu. The chemical properties of these waters is determined by the sandy soils and a type of vegetation known as Campina and Campinarana that grows in these soils. Campina and Campinarana habitats are dispersed throughout the sedimentary basin in which the upper reaches of these black-water rivers are located. Organic matter, leaves and logs, deposited on the soil are not completely decomposed and the porosity of the soils allows humic acid colloids to percolate into the rivers, thus reducing the pH of the water to between 4 and 5.5 and generating the characteristic dark colouration of these rivers. Despite the elevated concentration of organic matter, the water in black-water rivers is chemically more pure than those of white-water rivers, with conductivity up to 8 µS/cm (Junk 1997).

Rivers of the Andes

Ucayali and Marañón rivers. The Inca Empire was the most famous civilization of the Ucayali River. Its capital, Cuzco, was established on the Apurimac River, in the Basin's headwaters. The mountains have a long history of human alteration extending thousands of years, but the valley and the lowlands are well preserved. Fishing is an important economic activity in the lowlands, mainly around the cities of Pucallpa and Iquitos. The Marañón River was the principal connection between the Peruvian Amazon and the Pacific in the recent past, and now it is the main pipeline route for the export of oil. In addition to oil extraction, numerous copper, zinc, iron, mercury, antimony and gold mines occur in the headwaters of these rivers (Goulding et al. 2003).

Madeira River. The Madeira River, composed of Mamoré, Beni and Madre de Dios rivers, is the main source of sediments of the Amazon Basin. The foothills of the Andes exhibit a sequence of habitats that change from snowfall streams to the large rivers at the base of the mountains. Although the biodiversity increases downstream, the chemical processes and species endemic to the high altitude reaches of these rivers make them an important area for the Basin. The confluences of the Andean rivers and the rivers of the Brazilian Shield is observed along a succession of rapids and falls located above the city of Porto Velho. Below this point, the River is calm and navigable. The largest floodplain areas are located in Bolivia, in the flooded savannahs. These areas are inundated with the floods of the rivers and by local rainwater (Goulding et al. 2003). One of the largest alluvial gold mines within the Amazon Basin is located along the Madre de Dios River (Núñez-Barriga & Castañeda-Hurtado 1999).

Putumayo-Içá and Caquetá-Japurá. Although, these Andean rivers may have the most preserved catchments in the entire Amazon Basin, the foothill region has been altered in areas where communities, primarily of indigenous people, have expanded along the road and cocoa production has increased. Fishing is an important activity in the lower river, mainly in the Caquetá River and gold exploitation occurs along the Colombian and Brazilian border (Férnandez 1991, Goulding et al. 2003).

Purus and Juruá rivers. The Purus and Juruá rivers are different from other white-water rivers in the Andean region because their headwaters are situated below 500 m altitude, although, in the past, they were connected with the Andes. As a result of geological changes these rivers now drain a desiccated landscape formed by an older alluvium deposit and carry large quantities of suspended solids (Clapperton 1993). These rivers have one of the largest floodplain areas of the Amazon Basin, which is explored by professional fishermen from Manaus (Batista 1998, Petrere 1978). In the headwaters, inhabited by Indians and small communities, several areas have been designated for ethnic groups and are protected from extractive activities (Goulding et al. 2003).

Rivers of the Old Shields

Guyana Shield

The Guyana Shield is located in the north of the Amazon Basin and is shared by Brazil, Venezuela, Guyana, Suriname and French Guiana.

Trombetas, Jari, Araguari and other rivers. Most of the drainage area of these rivers is located in the Guyana Shield, which is characterised by the falls and headwaters of small streams. Large industrial operations, such as the extraction of bauxite in the Trombetas River, the extraction of kaolin and paper production in the Jari River and the extraction of manganese in the Araguari River occur in these basins (Barthem 2001).

Negro River. The Negro River is the largest tributary of the Amazon River located in the Guyana Shield. Several floodplains in the catchment that are flooded by overflow from the Negro River are important, such as the Anavilhanas archipelago in the Negro River and the unnamed archipelago, between Padauari/Demini and Branco rivers (Goulding et al. 1988). In addition, forests in the catchment are periodically flooded by the rain and, as a consequence, creates another type of flooded environment that covers large contiguous areas close to the margins of the Negro and Branco rivers as well as in the headwaters of its tributaries. In the Branco River, the savannah that is periodically flooded by rain is an environment that favours cattle and rice cultivation and, moreover, it is an area prone to fires during dry periods. The falls and headwaters of the rivers are areas subjected to more severe environmental impacts, such as mining. Conservation depends on the enforcement of an environmental law, which is hindered by the expansion of mining activities in this area (Barthem 2001).

Brazilian Shield

The Brazilian Shield is located in the southern Amazon Basin and is located entirely within Brazil.

Tocantins River. The catchment of the Tocantins River is one of the most altered areas of the Amazon Basin. This region possesses two large hydroelectric dams, one at Tucuruí in the lower Tocantins River, and the other at Lageado, in the upper Tocantins River, and the construction of 25 more is predicted (Leite & Bittencourt 1991). Moreover, its headwaters are altered by agricultural activities to the south of Pará and north of Tocantins, as well as by present and past mining activities.

Xingu River. The ichthyofauna of the Xingu River above the waterfall at Altamira is completely different from that of the lower sections of the River. The fauna and the ecology of this system are not sufficiently known and the main impacts are related to mining and agricultural activities in its headwaters.

Tapajós River. Of the rivers that drain the Brazilian Shield, the Tapajós River is the most altered by mining activities in its headwaters and also by dredging. Unfortunately, knowledge of the ichthyofauna and ecology of this drainage system is still insufficient to evaluate the dimension of the impact of this activity (Barthem 2001).

The tributaries of Madeira River. The headwaters of the Madeira River are located in the Andean slopes, but its tributaries drain the Brazilian Shield. The main impacts in this area are caused by mining, construction of Samuel's Hydroelectric Dam on the Jamari River, and intense agricultural activity in its headwaters. Information on the fauna and ecology of these tributaries is lacking. The Madeira River area and regions close to its tributaries have been studied more often. However, mercury contamination is known in the area and the disturbances of the mining dredges on the migration of the great catfishes have been mentioned by local fishermen.

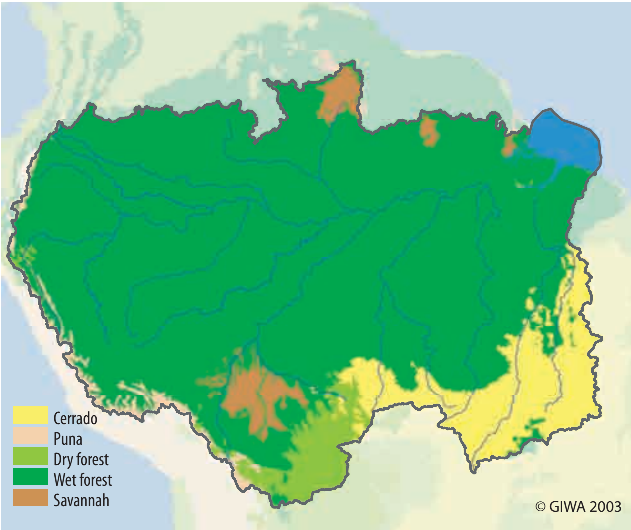

Figure 4 The main Amazon habitats.
(Source: WWF 1998-1999)

Forests

The limits of the Amazon Tropical Forest extend far from the area of the Amazon Basin and covers a great part of Suriname and French Guiana to the north. The Amazon Tropical Forest is composed of complex types of vegetation such as the highland forest, the cerrado, the flooded savannah and the flooded forest (Sioli 1975, Ayres 1993) (Figure 4). Beyond the limits of the Amazon forest, the Amazon Basin is covered by an extensive area of savannah and cerrado in the headwaters of the Brazilian and Guyana shields. The cloud forest is a special type of vegetation that grows between 1 500 and 3 000 m on the slopes of the Andes and is exposed to constant moisture-laden winds. The vegetation changes abruptly at altitudes above 3 000 m. The climate becomes dry and cold and a vegetation type known as Puna, which is composed mainly of grasses and bushes, dominates (Goulding et al. 2003).

The floodplains (várzea and igapó) represent the most important environment for diversity and aquatic productivity (Goulding 1980, Goulding et al. 1988, Forsberg et al. 1993, Araújo-Lima et al. 1986, Forsberg et al. 1983, Junk 1989 and 1997). These areas extend along the rivers and appear almost entirely flooded during the rainy season. Although it is difficult to determine accurately the areas that are periodically flooded because of the complexity of the flooding system which can be influenced by local rains, river overflow and the action of tides (Goulding et al. 2003), it is estimated that within Brazil, there is between 70 000 to 100 000 km^2 of floodplains and more than 100 000 km^2 of lakes and swamps (Goulding et al. 2003). In Bolivia, flooded areas occupy between 100 000 and 150 000 km^2 of the country (Barthem et al. 1995).

The areas of várzea of the white-water rivers are relatively well conserved in the area upstream of the confluence of the Purus and Amazon rivers, in Brazil, without great deforestation caused by cattle or agriculture. On the other hand, the várzea of the Solimões-Amazon rivers are altered downstream of the Purus River mainly in the area around Santarém, in the State of Pará, Brazil. In the area between where the Tapajós and Xingu rivers join the lower Amazon, there is a different type of várzea, that is influenced by flooding and river overflow (Barthem 2001).

In Brazil, the várzea of tides are observed along the area between the confluence of the Xingu and Amazon rivers, and the mangroves. This vegetation type has been intensely exploited by logging companies and small-scale farmers (Anderson et al. 1999, Barros & Uhl 1999). However, in spite of this, the condition of habitats in the area of the channels of Breves as well as in the area of the inner delta of Amazon River (Gurupá, Mexiana, Caviana and other islands) is relatively good, as there are no large agricultural enterprises (Barthem 2001).

Fields flooded by rain are quite typical within the great islands of the Amazon mouth as well as in the area of the coast of Amapá and Pará. This is the most threatened region of the entire Amazon plain due to ancient human occupation, that had already built dams and channels, and to the possibility of cattle and agriculture expansion (Smith 2002).

Fish diversity

The number of fish species in Amazon remains unknown but estimates of the number of fish species in South America vary between 3 000 and 8 000, most of them in the Amazon Basin (Menezes 1996, Vari & Malabarba 1998).

Socio-economic characteristics

Low human population density is a factor that helps preservation of the Amazon Basin. Unfortunately however, this also tends to lead to a failure to prioritise the collection and maintenance of data describing basic demographic parameters, such as rates of rural migration, sanitary conditions and the exploitation of timber and fisheries resources, among regional administrations. As a consequence, data presented here is often old or does not always cover the entire Amazon Basin.

Demographic structure

The population density in the Amazon Basin is low and concentrated in urban centres (Figure 3). In Brazil, where the Amazon Basin is most inhabited, the average population density is 3.3 inhabitants per km^2, which is considerably lower than the average density of 20 inhabitants per km^2 in the remainder of Brazil.

The Amazon Basin supports five cities that have more than 1 million inhabitants and an additional three that have more than 300 000 inhabitants. These major population centres are generally located along the larger rivers, such as Amazon and Madeira rivers. The main cities are Manaus, Iquitos and Pucallpa along the Amazon River, Belém, in the Amazon estuary and Porto Velho on the Madeira River. Other important cities, La Paz, La Santa Cruz Sierra and Cusco, are located in the headwaters in the Andean Mountains (Goulding et al. 2003) (Figure 3).

Socio-cultural aspects

The Amazon Basin, with its enormous biodiversity, is also characterised by a great socio-cultural diversity, composed of countless indigenous tribes and traditional populations of riverine, rubber tappers and small farmers (Neves 1995). The indigenous populations, with more than 100 different languages, are generally located in reserves that currently occupy more than 15% of the entire Amazonian territory (Diegues 1989). Until the 1960s, the economy was based on the extraction of natural resources, particularly rubber or cocoa and fish. Afterwards, mining of iron, bauxite and gold became important economic activities and people began to migrate from settlements located along the rivers and várzeas to areas nearby these new industries (Cardoso & Muller 1978, Diegues 1989).

Human settlement in the Amazon, initially by the indigenous tribes and later on by European and other immigrants, occurred mainly in the várzea due to the resources offered by the rivers and streams as well as the high fertility of alluvial soils that were productive for agriculture and cattle grazing. A mixture of Europeans, African slaves and indigenous peoples traditionally inhabited the várzea and cultivated corn, rice, beans and bananas. Hunting, fishing, growing and harvesting rubber, Brazilian Nuts and açaí, complemented those activities (Neves 1995).

Private and governmental planning investments occurred at the end of the 19th century with the construction of a railway that aimed to connect the upper Madeira River with the navigated stretch below the rapids and falls between Guajará-Mirim and Porto-Velho and facilitate the transport and export of rubber, which was the main product of the Amazon Basin during that period. The Madeira-Mamoré railway was completed in the 1930s but, the inauguration of the railway coincided with the economic decline of rubber rendering it economically unfeasible to operate.

In the 1960s, the construction of highways irreversibly modified the social structure of the region. The road between Belém and Brasília connected the Amazon to other areas of Brazil. The opening of the large highways parallel to the rivers changed the pattern of occupation of the Brazilian Amazon. As a consequence, deforestation increased along the rivers and in the Terra-Firme (upper-land) along the recently open highways (Fearnside 1995). In addition, the logging industry constructed roads deep into forests away from the rivers, which enabled the extraction and export of timber but also lead to the establishment of settlement in previously uninhabited areas of the Terra-Firme.

Hunting for subsistence and sale of skins was concentrated mainly on animals such as the capybara (*Hydrochaeris hydrochaeris*) and the alligator (*Caiman* sp.). The turtle (*Podocnemis expansa*) and the freshwater manatee (*Trichechus inunguis*) were easy to capture and, as a consequence of overexploitation, many of these animals practically disappeared in some areas (Neves 1995). In addition, the growing presence of commercial fishermen in the area has generated conflicts with the local subsistence fishermen, who try to protect the lakes that still contain healthy stocks from the fishing methods used by commercial fishermen in the várzea and industrial fishermen in the estuary (Barthem 1995).

Extraction of plant resources is another practice that is widespread in the Amazon. The main products are rubber, Brazilian Nuts and açaí. In addition, a plethora of medicinal and aromatic plants are harvested for the production of pharmaceuticals and cosmetics. Unfortunately however, due to indiscriminate collection, some species are threatened to the point of extinction. Timber extraction, primarily for the export market, is practiced but in an exploratory and disorganised fashion. The exploration covers large areas of várzea, where the infrastructure to extract and transport the timber exists. The main exploited species are: Cedro (*Cedrela* sp.), Jacareuba (*Calophyllum brasiliensis*), Mogno (*Swietenia macrophylla*), Andiroba (*Carapa guianensis*), Louro (*Aniba* sp.), Ucuuba (*Virola surinamensis*) and Copaiba (*Copaifera vinifera*), among others (Fearnside 1995). The highways facilitate the access in the areas of Terra-Firme, being the areas more explored than those with a more extensive net of highways (Veríssimo et al. 2001).

In recent years, mining has seriously compromised the environment and the people that live in it. Gold extraction represents an activity that most affect the ecosystem.

Socio-economic aspects

The presentation of the socio-economic aspects of Amazon Basin is plagued by a chronic shortage of statistics. However, the quality of life of the resident population and the relationships between production and the activities conducted within the area will be summarised on the basis of the available information.

The occupation of Amazon was intense at the beginning of the 18th century. Although the Portuguese paid little attention to the Amazon during their occupation, great international interest in this area was generated mainly by the English due to their marine and commerce tradition. In the 19th century, during the colonial period, the ephemeral "agricultural cycle" was progressively replaced by more permanent production of coffee, cotton, sugar cane and cacao. Later, American interests were stimulated by the increasing usefulness and demand for rubber which promoted several private incentives and government investments in the area. For example, beyond the railway Madeira-Mamoré, the North American entrepreneur, Henry Ford, invested in the plantation of Hevea along the banks of the Tapajós River, Brazil. The urban nucleus known as Fordland was built to extract, process and export the latex obtained from the plantation. Rubber became the main product of the Amazon Basin until the beginning of the 20th century when the low competitiveness of the extractive process and a fungal plague in the plantation caused the decline of rubber production around 1950. Afterwards, the world centre for rubber exploitation was transferred to Southeast Asia, where more productive areas existed and fungal infections were able to be controlled (Ribeiro 1990).

In the latter half of the 19th and the beginning of the 20th century, the migration of people assumed a pivotal role in the expansion and establishment of new urban centres. Initially, migration and colonisation occurred along navigable waterways but, with the construction of federal roads during the 1960s, a new route for migration and economic expansion was established. In Brazil, the most inhabited and impacted area is observed in the regions under the influence of highways constructed between Belém and Brasília and between Cuiaba-Porto and Velho-Rio Branco, where several consolidated urban nuclei have been established. However, in the remainder of the Amazon Basin, population centres are generally poorly connected. Transport and communication is only between those cities that are located along the main channel of the Amazon River (IBGE 1991).

In 1996, the Brazilian population in the Amazon River Basin was 6 706 154 inhabitants and had increased 9.4% since 1991 (IBGE 1996). This increase correspond with trends reported from the North and Middle-West regions of Brazil, which exhibited the most significant growth rates in the country (2.44% and 2.22%, respectively), while the growth rate of the entire country was 1.38% per year during the same period. The urbanisation rate in the Basin increased from 60.8%, in 1991, to 70.7%, in 1996, overcoming that reported for the Brazilian North region (IBGE 1996).

The quality of life of the population in the Amazon River Basin, based on indicators such as basic sanitation (provisioning of water, sanitary exhaustion and garbage collection) and incomes, is characterised by accentuated lack of infrastructure and social investments. These factors make the North region in Brazil less favoured than the average situation of the other regions in South America.

The contribution of the Amazon River Basin to the Brazilian economy is relatively modest, considering that the North region was responsible for less than 3.5% of the GDP, in 1990, despite occupying more than 45% of the national territory (IBGE 1991). The GDP of the North and Middle-West regions of Brazil increased approximately 18 fold between 1970 and 1990, while the national GDP increased only 11.4 times. The growth in per capita income in the Brazilian North region was of the order of 7.5 times during the same period, from 197 to 1 509 USD (Kasznar 1996).

Since the 1970s, the agricultural activities of the Brazilian Northern region have undergone great transformations that include the spatial expansion of crops and growth of bovine flock. Moreover, the changes in the processes of production, such as the management of resources and use of different agricultural techniques, as well as the destination of the production are factors that contributed to the development of the agriculture in the area. Agricultural activities are essentially dedicated to the subsistence cultivation of rice, cassava, corn and beans, while soya, coffee and cacao are grown as commercial crops.

In the region, the supply of electric energy to some specific areas is generally generated by isolated hydroelectric systems (dams of Balbina, Samuel, Curua-Una and Coaracy-Nunes) and complemented by fuel-burning thermo-electrical centres. The connection of part of the State of Para to the System Electric Interlinked North-northeast, through Tucuruí Hydroelectric Dam, with a transmission line (1 000 MW) between Venezuela and Balbina Hydroelectric Dam is predicted for the future.

Assessment

Table 3 Scoring table for the Amazon region.

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

IMPACT 0 No known impact
IMPACT 1 Slight impact
IMPACT 2 Moderate impact
IMPACT 3 Severe impact

The arrow indicates the likely direction of future changes.

↗ Increased impact
→ No changes
↘ Decreased impact

Amazon	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	0.1* ↗	0.3 →	0.3 →	0.3 →	**0.2**	**5**
Modification of stream flow	0					
Pollution of existing supplies	1					
Changes in the water table	0					
Pollution	1* ↗	1.7 ↗	2.3 →	1.7 ↗	**1.4**	**2**
Microbiological pollution	0					
Eutrophication	0					
Chemical	2					
Suspended solids	2					
Solid waste	1					
Thermal	1					
Radionuclide	0					
Spills	1					
Habitat and community modification	1* ↗	2.3 →	1.7 ↗	1.7 ↗	**1.7**	**1**
Loss of ecosystems	1					
Modification of ecosystems	1					
Unsustainable exploitation of fish	0.6* →	0 ↗	0 →	0 ↗	**0.5**	**4**
Overexploitation	2					
Excessive by-catch and discards	1					
Destructive fishing practices	0					
Decreased viability of stock	0					
Impact on biological and genetic diversity	1					
Global change	0.8* ↗	0 ↗	0 ↗	0 ↗	**0.8**	**3**
Changes in hydrological cycle	2					
Sea level change	0					
Increased UV-B radiation	0					
Changes in ocean CO_2 source/sink function	0					

* This value represents an average weighted score of the environmental issues associated to the concern. For further details see Detailed scoring tables (Annex II).

** This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).

*** Priority refers to the ranking of GIWA concerns.

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 3. Detailed scoring information is provided in Annex II of this report.

Freshwater shortage

Freshwater shortage was considered the least important concern for the Amazon region. A relatively high average annual precipitation of 1 500 to 2 500 mm (Day & Davies 1986) contributes significantly to the hydrological balance and reduces the problems of freshwater shortage in the region. However, the rainfall is not homogenously distributed throughout the Amazon Basin or during the year. In some areas and/or during some months, the rainfall can be very low leading to occasional shortages of freshwater (Hodnet et al. 1996).

More than half of the Amazon population lives in urban centres (Becker 1995). The water in these centres is generally collected from neighbouring rivers and distributed to residents by local water companies. The rural populations usually take water directly from the rivers or from shallow water wells.

Some issues related to water shortage are not discussed in detail since they were considered insignificant in the Amazon Basin. Modification of stream flow is among the main indicators of water shortage, since the reduction in water discharge may affect water supplies, the rate of dilution of contaminants and the volume of water available in underground reservoirs. Some small streams located near severely deforested areas may experience a reduction in water flow during the dry season. This process is associated with changes in the micro-basin water retention capacity (Hodnet et al. 1996). In such cases, the water flow is altered and its classification may change from a tropical forest river, which has characteristics of a reservoir river, into a sandbank savannah river that undergoes extreme desiccation during the dry season (Welcomme 1985). The construction of hydroelectric dams and water reservoirs has not altered stream flow in the region but potentially can modify the water discharge cycle. At present, there is no evidence of annual reductions in the discharges of the Amazon rivers.

Impacts associated with changes in the water table were not detected in this region. In addition, information describing the effects of the natural El Niño phenomena on water levels in wells or spring flow is unavailable. Thus, freshwater shortage associated with changes in the water table is not yet considered a problem in the Amazon region.

Environmental impacts

Pollution of existing supplies

The pollution of existing water supplies has a high but localised impact in small streams or stretches located close to the urban centres (e.g. Belém, Santarém, Manaus and neighbourhoods). The general absence of adequate sewage treatment systems and wastewater impoundments is the main source of pollution of existing supplies. On the other hand, the rainfall intensity and the scarcity of large urban centres make this impact local and slight relative to the entire Basin.

Socio-economic impacts

The level of economic impact caused by freshwater shortage is very low since the dimension of sectors affected by water shortage is small and limited. During the drier period of the year, there is a reduction in drinking water in small areas in the rural zone of the southern and southeastern regions of the Pará state (Brazil) due to the seasonal declines in stream flow. This problem can be reduced and is gradually being solved by the construction of additional local water reservoirs and wells. The costs incurred through the construction of these wells and reservoirs are very limited and usually shared by more than one family.

In general, governmental companies are responsible for the treatment and distribution of drinking water in the cities. However, recently some of these enterprises were privatised and the users observed a slight, but probably temporary, increase in the cost of water.

Health impacts associated with freshwater shortage were considered slight. The number of people affected by occasional seasonal water shortage in rural areas is very small and possibly represents less than 1% of the total population living in the region and its consequences do not seem to cause significant health problems. On the other hand, in the urban centres, the pollution of existing water supplies may cause chronic public health problems. Sewage contaminates water supplies and leads to infestations of intestinal parasites and incidences of diarrhoea that predominantly affects children living in low-income areas. This problem is considered serious and more related to urban centres of the Amazon region (pers. comm.).

Other social and community impacts caused by freshwater shortage in the Amazon region are presently unnoticed. In areas where seasonal water shortages are experienced, the population has developed several techniques to solve these problems. Nevertheless, this problem can be intensified with the increasing deforestation, particularly when the annual rainfall is less than usual or when regional climate patterns are affected by El Niño events.

Conclusions and future outlook

Freshwater shortage under present conditions is not a high priority for the Amazon region and, as a result, has few, if any, transboundary implications. The high average annual precipitation maintains stream flow, dilutes pollutants and guarantees groundwater supplies. If the current supply of freshwater is to be maintained in the future, the role of the Amazon rainforests in determining climate patterns and hydrological cycles must be conserved (Salati et al. 1978, Salati & Vose 1984). However, the increased deforestation of some parts of the Amazon, such as in the Southeast region (Brazil), is altering the water cycle and is intensifying the problems related to freshwater shortage. Current shortages of water in severely deforested areas are indicative of what may happen in the region in the future if the present deforestation rate continues (Lean et al. 1996). In addition to deforestation potentially altering the water cycle, the problem of pollution of existing water supplies can be worsened with the growth in size and number of small villages and cities scattered on this basin.

The socio-economics impacts related to freshwater shortage are restricted to small groups of the population that live in intensively deforested areas. The impacts of water shortage in those areas are considered cyclic and occur only during the drier period of the year. The pollution of water supplies in the urban areas seems more likely to affect health related issues. In the future, it is expected that more people will live in the urban centres, but technological improvements might provide better conditions for these people. It is also expected that the drinking water will be supplied from underground reservoirs.

Considering the rate of deforestation and the expansion of urban centres, the prognosis for the Amazon Basin indicates that the Freshwater shortage related issues might become a serious environmental problem when compared with the present situation.

Pollution

The human population density in the Amazon Basin is very low and there are only a few industrial areas established near the cities. Manaus is the only city in the Amazon that has a duty free industrial area and most of the industries located here are concerned only with the assembly of machines and electrical goods from components that have been manufactured in other countries. Because the individual components are imported, the industrial effluents produced during the manufacture of those components are not present in Manaus and, as a result, the assembly industry is considered a "clean industry".

There are two scales of enterprises in the central region of the Amazon that can strongly impact water quality: (i) the large and concentrated governmental and private projects, such as the hydroelectric dams and petroleum exploitation stations; and (ii) the small and dispersed local activities, such as small-scale gold mining and agriculture. The petroleum, hydroelectric, mining, timber and fishing enterprises are the most important but they are few and dispersed along the Basin.

At present, microbiological pollution is not an important issue for this region. Microbiological contamination is associated with deficiencies in sewage treatment but this still is a small and isolated problem. Ineffectual sewage treatment seems to have greater impacts on the health of inhabitants in the region than on the quality of water supplies, because the majority of the Amazon population lives in cities and in areas with no sewage treatment.

Eutrophication is observed in very small isolated areas and is predominantly associated with the use of fertilisers in agriculture. Some crops demand the use of chemical fertilisers that, with the abundant rainfall, are carried into the rivers and may cause eutrophication. However, the use of fertilisers in the region is still very limited and the river flow is so high that excess nutrients are rapidly diluted.

At present, radionuclide problems do not occur in this region since nuclear power plants and nuclear radioactive wastes are not present.

Environmental impacts

Chemical pollution

Mercury contamination and chemical agricultural wastes are the main sources of chemical pollution in the Amazon Basin. The impacts caused by these pollutants do not affect large areas because there are no extensive agricultural areas and because gold mining activities are established in only a few concentrated locations.

The DDT found in Amazon soils originated mainly from the use of this insecticide against malaria vectors between 1946 and 1993. The present level is low compared with previous data obtained from important agricultural areas in Brazil (Torres et al. 2002).

Contamination of organisms by mercury occurs in the Amazon Basin but is not yet completely understood since mercury can originate from both gold mining activities and natural sources. The problematic areas for chemical pollution were identified as the regions where gold mining activities were intense, such as: the Andean region, the State of Rondônia (Brazil), and the basins of the Tapajós, Xingu and Madeira rivers. The mercury levels in most fish species consumed by the Amazon population are below the limit recommended for consumption by Brazilian legislation, but some areas show some contamination (Kehrig et al. 1998, Brabo et al. 2000).

Until the beginning of the 1990s, the region of Alta Floresta in the southern Amazon Basin, and the headwater of Tapajós River, were two of the main areas in which gold prospecting in the Amazon Basin was conducted. Although fish, particularly carnivorous fish, exhibited high mercury concentrations, the population living in these regions exhibited low concentrations of mercury in their hair as a result of the small proportion of fish in the diet of these people. Unlike other people living in other areas of the Amazon Basin, the primary source of dietary protein for the population in the southern Basin is red meat. Nevertheless, the relationship between mercury and fish consumption was so strong that it was possible to distinguish a twofold difference in the concentration of mercury in hair among those who consumed fish and those who did not (Hacon et al. 2000). Other issues related to water chemical pollution are not known in the Amazon Basin.

Suspended solids

Solid residues in suspension are normally abundant in rivers originating in the Andean region, but the rivers from the Amazon plain and from the Brazilian and Guyana shields have small concentrations of suspended sediments. An increase in solid residues in suspension was observed in two rivers that originate in the Brazilian Shield, the Tapajós and Tocantins rivers. The changes in turbidity of the Tapajós River as a

Figure 5 A small urban stream blocked by solid wastes.
(Photo: L. Montag)

result of the influx of suspended solids from gold mining activities were obvious from aerial observations. Also, increases in the amount of solids carried by the Tocantins River were a result of the increase in the bottom rolling sediments and not suspended solids (pers. comm.). The origin of these solids in the Tocantins River is related to the deforestation as well as agricultural and cattle grazing activities that are taking place in the upper portion of this river.

Solid waste

Solid waste pollution corresponds to various plastic residues and it is detected mainly in sedimentation areas of the rivers and coast. The accumulation of solid wastes on some river beaches or small streams close to large urban centres potentially affects tourism. It is more obvious during periods of low water in the river or at low tide in areas under tidal influence and in mangroves. Some small streams of the large urban centres may become completely blocked by solid wastes which increase health problems, particularly those related to insect transmitted diseases (Figure 5).

Figure 6 The rivers of the Amazon Basin carry a large volume of trees, pieces of wood, branches, leaves and roots.
(Photo: R. Barthem)

The bottom-set gill net fishery and the trawl fishery have encountered solid waste in the Amazon estuary, but information describing the effects of solid wastes on fishing activities is unavailable.

The rivers of the Amazon Basin also carry a large volume of solid materials brought from the forest and flooded fields. These solid materials include dead trees, pieces of wood, branches, leaves and roots. During the dry season, these natural solid wastes can cover beaches and the river channel (Figure 6).

Thermal

Diesel electricity generators located in urban centres dispersed throughout the Amazon Basin are sources of very small amounts of thermal pollution that have insignificant impacts on the region. There are no sources of thermal pollution originating from nuclear power generation in this region.

Spills

Oil spills occur occasionally in areas exploited for petroleum and during fuel transportation procedures. To date, there are no records of significant damage done by oil spills and no statistics describing accidents involving oil transportation rafts. However, an investigation of a recent accident involving an oil transportation raft that occurred near the mouth of the Amazon River concluded that the strong current dispersed the heavy oil in a few weeks (Barthem et al. 2000). Impacts of this oil spill were considered local and the lack of information describing the ichthyofauna of that region limited the possibility to accurately determine the magnitude of the impacts of the accident on the fish fauna.

Socio-economic impacts

Economic impacts attributable to pollution are relatively small. The industries that are operating under ISO 14 000 Certification incur expenses associated with environmental management but these costs are small compared with the initial investment and maintenance required for this system. The smaller economic sectors are at a greater disadvantage but they are also dispersed throughout the region. Despite the low economic impacts of pollution in the Amazon Basin, its effects are considered continuous or permanent.

The population of the Amazon Basin is more concentrated in urban centres than in rural areas (Becker 1995). The lack of basic water treatment (including sewage treatment) and the inadequate distribution of drinking water in sub-urban areas tend to create a chronic public health problem (see also Pollution of existing supplies). Water pollution increases the rates of infant mortality, especially due to severe diarrhoea, and favours the rapid proliferation of endemic and tropical diseases. Low drinking water quality and insufficient sewage treatment represent the main health problems associated to pollution in the Amazon region, particularly in urban areas.

Although pollution is not yet affecting the economic sectors of the Amazon Basin, the public sector is already noticing some impacts. The pollution of aquatic systems involves cultural problems and lack of water conservation awareness which primarily affects the quality of life of people living in urban centres.

Conclusions and future outlook

Chemical contamination and suspended solids are the principal pollutants in this region. These impacts are primarily a consequence of gold mining activities in Peruvian and Brazilian rivers, and the deforestation of large areas, particularly in the southeastern areas of the Amazon Basin in Brazil. The socio-economic and health impacts caused by pollution problems are observed more clearly in urban centres. The economic aspects are not significant, but the social and health aspects are considerable because most people inhabiting the Amazon Basin live in precarious conditions in the suburbs of cities.

The impacts of pollution are likely to increase in the future. Eutrophication caused by agricultural fertilisers might become a problem as the area under soybean cultivation gradually encroaches on the Amazon region. Savannah and lowland forests are beginning to be transformed for rice and soybean cultivation and rivers are an efficient way to transport these products. In addition, there is a growing realisation that deforestation is causing considerable increases in the amounts of suspended solids in the rivers of the Basin. However, the impacts of deforestation might be offset by anticipated declines in mining of alluvial gold.

Currently, pollution problems exist primarily at a local scale and are not yet a major concern for the Amazon region. However, it is anticipated that the impacts of pollution will worsen considerably and it will become one of the primary concerns in the Amazon Basin in the future.

Habitat and community modification

Since the initiation of large governmental projects during the 1970s, such as the building of roads and hydroelectric dams, the Amazon Basin has experienced rapid and extensive landscape modification, particularly in the catchments of tributaries located in the Brazilian Shield.

The development of the local economy also provided significant incentive for the deforestation of floodplains in the lower Amazon. The construction of roads enabled the expansion of agricultural and cattle grazing activities at the expense of large areas of flooded and non-flooded rainforest. The construction of hydroelectric dams affected the migratory and spawning patterns of fish causing a decline in local fisheries, and also caused an increase in the incidence of insect transmitted diseases by creating favourable breeding conditions for mosquitoes and other vectors (Aragón 1993). The discovery of alluvial gold in several Amazon rivers was a strong economic incentive that contributed to the socio-economic development and habitat modification. After 30 years of relatively fast development, the consequences of impacts on the aquatic environment are clear. Moreover, the size of the human population, particularly in the urban centres, has increased significantly during this period, but still only causes slight impacts on the regional environment.

Environmental impacts

Loss of ecosystems or ecotones

Deforestation is the main activity that causes loss of ecosystems in the Amazon Basin at the present time. Recently felled areas in the Brazilian

Shield and the headwaters of the Tocantins, Xingu and Tapajós rivers are clearly identifiable on satellite images. The oldest changes to the natural ecosystem occurred in the tundra-like vegetation (Puna) in the Andean zone and were caused by the Indian agricultural activities (Goulding et al. 2003). The impacts of this historical agriculture on the aquatic system remain unclear. On the other hand, the recent establishment of agricultural and cattle grazing fields in the floodplain areas, mainly in the lower Amazon, have contributed to the removal of the flooded forests, which are an important feeding ground for several commercially valuable fishes.

The hydroelectric dams built in the mid and lower tributary rivers of the Amazon Basin have caused habitat fragmentation, interruption of fish migration and the substitution of lotic (rivers) by lenthic (lake) habitats (Figure 7).

Ecosystem loss also increases the vulnerability of natural systems to future impacts and currently, the number of protected aquatic habitats is small considering the enormous size and biodiversity of the Amazon region (Ayres et al. 1999).

Modification of ecosystems or ecotones

The composition of fish communities in most part of the Amazon Basin is apparently still determined by natural events. Local extinction of species, particularly migratory species, may have occurred as a consequence of large habitat modifications, such as the construction of hydroelectric dams, but there are no records of these events (Barthem & Goulding 1997). The poor knowledge of the aquatic fauna of the Amazon certainly contributes to an underestimation of the magnitude of impacts caused by these habitat modifications. Considering the dearth of information describing the aquatic fauna of the Amazon and the current rate of habitat modification, it is, at present, impossible to determine how many species have been severely affected and, without additional studies of the biota of the region, how these species will be affected in the future.

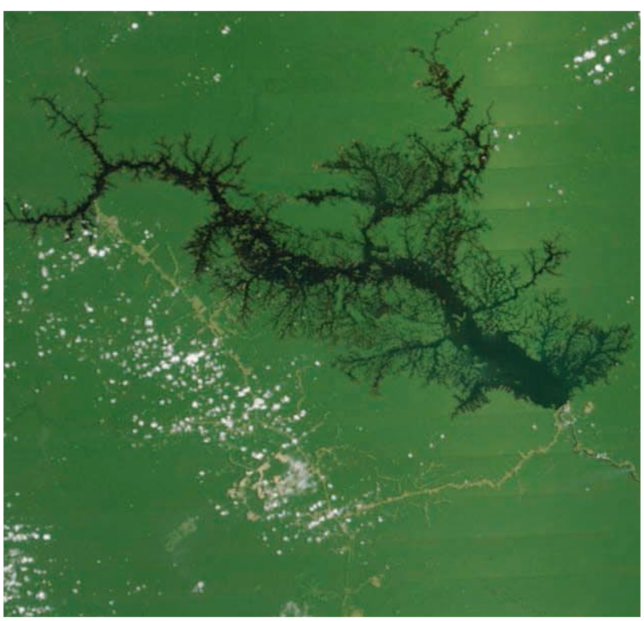

Figure 7 The Balbina Dam on the Uatumã River.
(Photo: NASA)

The introduction of alien species has also caused permanent consequences in the Andean waters, rivers and lakes. The introduction of trout and kingfish in the Andean region has enhanced fishing activities (Hanek 1982), but nowadays it is very difficult to determine how the community of endemic species in those rivers and lakes have been affected. Alien species have been introduced in other parts of the Amazon, but their populations have not survived or are not yet established in those areas.

Socio-economic impacts

Modification of various habitats and communities has caused some economic impact in activities related to the extraction of forest products. Deforestation and the construction of hydroelectric dams have negatively impacted fisheries and harvesting of Brazilian Nuts. After the construction of the Tucuruí Hydroelectric Dam on the Tocantins River, the fishery production below the artificial lake declined dramatically and, as a consequence, fish markets in cities in the Lower Tocantins region must now import fish from other fishing grounds. Negative impacts were also observed in agricultural and Brazilian Nut collecting activities in the area located above the Tucuruí Dam, where agricultural land and forests where flooded.

Furthermore, the introduction of cattle to the flood plains has resulted in the deforestation of areas of flooded forest that is an important source of food for some commercial fish species. The expansion of this activity may lead to a decline in the fishery or a change in the composition of catches in those areas. The economic impacts of habitat and community modification in the Amazon Basin are moderate and local but tend to be continuous.

At present, health impacts related to habitat and community modification mainly occur in deforested areas. Some diseases, such as malaria, hepatitis, yellow fever and dengue (break bone fever), exhibit a tendency to break out after habitats are modified. Malaria outbreaks have been registered in the Rondônia state in Brazil (Tadei 1987) after deforestation and habitat changes occurred. Nevertheless, the areas and number of people affected are still considered limited.

The Habitat and community modification concern includes deforestation as one of the main problems. The traditional culture of the Amazon people is closely related to the extraction of forest products, hunting and fishing (Furtado 1984). The deforested areas cannot support these traditional activities anymore so the people involved have to either change their culture or move to other areas. These cultural changes seem to be the most important social and community impacts for local people. When their traditional activities are affected, people have to change their autonomous collecting, fishing and hunting to become an employee of farmers, landowners and other enterprises. Socially, this has a severe impact but the number of people affected is still considered small since human density in the rainforests is low.

Conclusions and future outlook

Habitat and community modification is the greatest concern in the Amazon region. The enormous scale of the area affected and the deep and long duration of the consequences of these kind of impacts are perhaps the main reasons for considering this concern so important and in need of management. These modifications are taking place rapidly and, in several cases, the damage is irreversible or requires long-term recuperation.

Habitat modification is the main factor responsible for economic, social and health problems in the region. The Amazon economy is based on petroleum, mining and timber exploitation and, to a lesser extent, the generation of electricity. However, the majority of people living in the Amazon are not directly employed by these industries. Most people live in the urban centres or along the rivers and roads. The unplanned modification increases problems with malaria and other insect or water-related diseases. The presence of these diseases can negatively affect economic and social aspects of families and cities in the Amazon. Moreover, the deforestation of rainforest is affecting traditional harvesting of forest products, fishing and hunting.

Habitat and community modification will continue to be the priority concern in the future. Development in the Amazon Basin is based on the modification of large areas of forest to accommodate other activities such as agriculture or grazing. Furthermore, the hydroelectric potential of the Amazon tributaries is so high that it is impossible to consider the future without the construction of new dams in some of these tributaries. Moreover, the importance of the forest in maintaining regional hydrological cycles dictates that the conservation of the forest is a priority if the future use of water, particularly for electricity generation, is to be guaranteed. Despite the preservation of large areas of forest, current declines will continue in the future if current patterns of development persist.

IMPACT Unsustainable exploitation of fish and other living resources

The fisheries resources of the Amazon have not yet been determined but available information indicates that this region could potentially yield more than 200 000 tonnes per year (Bayley & Petrere 1989), and might reach 1 million tonnes per year. Although more than 200 species of fish are exploited, the commercial market is currently based only on a few dozen species, of which, two are already considered overexploited (Barthem 1995, Barthem & Petrere 1995, Isaac & Ruffino 1996, Barthem et al. 1997, Isaac & Barthem 1995). The most important fishing areas are the white-water rivers and their flooded margins, and the Amazon estuary. The only industrial fishery of the Amazon Basin takes place in the estuary and targets the catfish Piramutaba (*Brachyplatystoma vaillanti*) (Barthem & Goulding 1997).

The recent history of the Amazon economy resulted in a broad qualitative difference of income in the region. Urban economic development brought about an enormous increase in demand for fisheries products. Bolstered by this heightened demand, artisanal fishers based in fishing villages scattered around the Amazon River and estuary either changed their production goal from subsistence-level to business-level or reinforced their existing commercial fishery. Moreover, with the introduction of the official fishery promotion policy in the late 1960s, fishing companies were established in urban centres as export businesses and continued to mass-produce fishery products centred on fish species which formed comparatively big schools (Barthem 1995). Presently, the Amazon fishery resources are under increasing pressure and require urgent management policies. Destructive fishing practices and decreased viability of stocks are not considered important issues in the Amazon region. Trawling in the estuary and the use of natural poisons in streams exist in the Amazon Basin but do not cause significant problems. Illegal practices are very limited in the region and, considering that people who adopt such practices are risking being fined and prosecuted under environmental protection laws, they do not constitute a problem.

Environmental impacts

Overexploitation

The information describing overexploitation of Amazon fishes is restricted to only two species, the catfish Piramutaba (Barthem & Petrere 1995) and the fruit-eater and large-scaled fish, the Tambaqui (*Colossoma macropomum*) (Isaac & Ruffino 1996). Industrial fishing began at the start of the 1970s and, within a few years, had overexploited the catfish stock in the estuary region (Barthem 1995, Barthem & Petrere 1995). Meanwhile, the traditional fisheries in the central Amazon target the large frugivorous fishes, especially the Tambaqui. Its special flavour attracts consumers and, as a result, has established a niche market that promotes selective fishing for this species by local fishermen in the Amazon rivers. The primary feeding ground of these frugivorous fishes is the flooded forest and therefore, they are also deleteriously affected by the deforestation of the flooded forests (Araújo-Lima & Goulding 1998, Costa et al. 2001). Overexploitation of some stocks is taking place in the Amazon region and management interventions are required to control catches of those species that are most affected and those that are migratory, particularly the large catfish, that migrate between the Amazon estuary and the foothills of the Andes (Barthem & Goulding 1997). These migratory species are particularly vulnerable to excessive fishing effort by the industrial fishery in the estuary, and by other human activities in the Amazon Basin. In addition, the hydroelectric dams in the Tocantins River blocked the migratory path between the lower and upper part of the river and now those species are extinct in the upper part of the Tocantins River. Similarly, mining activities in the headwaters may modify the spawning areas, although, at present, this has not been observed. Nevertheless, most of the fish stocks in this region are generally under-exploited or, at most, exploited to their limit.

Excessive by-catch and discards

The report by Batista (1998), which focuses on the commercial fishery in the central Amazon near the city of Manaus, provides the only information describing quantities of by-catch and discards in the Amazon Basin. Discards in this region occur due to two factors: capture of non-target fish species; and capture of under-sized specimens. While some species are undesirable and always discarded, the amount of fish discarded because they are under-sized varies between 6% and 80% of the total catch weight. Over the entire Amazon Basin, the total amount of fish discarded seems to vary but largely remains unknown.

Biological and genetic diversity

The introduction of alien species generally causes serious impacts on the native local fauna (Barel et al. 1985). In the Amazon, the impacts are not so clear. After the intentional or accidental introduction of some alien species (e.g. tilapia, clarias, trout), only the trout population has established itself in the Andean Zone (Goulding et al. 2003). The high altitude and cold-water rivers and lakes of the Andes became the habitat of this introduced species which is now fished by the local human community. The limited information describing the original fish community in that region makes comparisons very difficult and it is almost impossible to evaluate impacts resulting from the introduction of this species. In the Titicaca Lake, located outside of the Amazon Basin, alien fish, like trout and kingfish, are responsible for more than 90% of the fishery landings (Hanek 1982). However, to date, the biological and genetic diversity of the fish fauna in the rest of the Amazon Basin does not seem to have been impacted significantly.

Socio-economic impacts

There are no economic, health or other social and community impacts associated to unsustainable exploitation of fish and other living resources known in the Amazon region.

Conclusions and future outlook

Fishing is an important occupation and source of protein in the large rivers of the Amazon Basin, particularly in the white-water rivers. Few stocks are overexploited. Most stocks are under-exploited or are fished within sustainable limits. However, this situation does not mirror the economic potential of the fishery in this region. The open access fishery of the Amazon provides an economic safety net for members of local communities by enabling anyone to generate an income from fishing. These non-traditional fishermen contribute to the increase in uncontrolled fishing effort applied to easily accessible stocks of non-migratory fish species in areas close to urban centres. The meeting of different fisheries fleets promotes competition among fishermen, especially between riparian communities and professional fishermen within the region. The economic impact is the main factor for controlling unsustainable exploitation of fish and other living resources in the future. At present, the development of the fishing sector is restricted by a lack of post-capture handling and processing facilities. Considering the current state of stocks close to the urban centres and the probability that more people will turn to fishing for their livelihood, the current situation is not likely to improve. If the fishery and the trade processes are not well organised and regulated in the future, the proportion of the most valuable species in catches will decline and will be replaced by a greater proportion of smaller, less desirable species.

The increase in fishing effort associated with the deforestation of the flooded forests may result in the unsustainable exploitation of the Amazon fishery. In the future, pressure on fish stocks will be higher, but fishing is likely to be regulated and managed. Other living resources, like turtles and manatees, are already completely protected by law and their future survival is related more to habitat protection rather than to the regulation of exploitation.

IMPACT Global change

Global change is considered a concern of moderate importance in the Amazon Basin and information related to this concern is very limited. Changes that are unequivocally attributable to global change are particularly difficult to determine in this region but the consequences of these modifications could potentially be very severe. While it is known that under the influence of El Niño the amount of precipitation received by the Amazon Basin is significantly lower than usual, which causes concomitant decline in the volume of water discharged from the river, it is not known how anthropogenic activities have affected the frequency and magnitude of this natural climate phenomenon.

The role of the Amazon rainforest in the global carbon budget is still not well understood. However, the carbon fluxes to and from the Amazon system itself are roughly equal (Richey et al. 2002). Further studies are currently being conducted to determine how the production and re-absorption of carbon occurs and how this cycle is maintained in this region.

There is limited information relating global changes to socio-economic impacts in this region. Sea level rise has not been reported in the Amazon Basin and the influence of macro-tides and seasonal discharges from the Amazon River mouth are likely to obscure any changes that might be attributable to global change. Nevertheless, some researchers have mentioned that they suspect that sea levels have risen along the coast of this region and its consequences could potentially alter patterns of sediment exchange in the lower Amazon and the landscape of the "várzea" lakes (Dunne et al. 1998).

Increase in UV-B radiation and changes in ocean CO_2 source and sink function have not been observed in the Amazon region and are not considered significant.

Environmental impacts

Changes in hydrological cycle

The hydrological cycle is considered the main indicator of global change in the Amazon region. The long-term data series describing water levels and river discharges do not, at present, indicate any changes in the Amazon Basin attributable to global change. However, it is highly likely that the hydrological cycle of intensively deforested areas is changing and becoming drier during the dry season period compared with previous years.

The most tangible demonstration of changes in the hydrological cycle resulting from global change observed in the Amazon Basin, is the significant reduction in the cover of ice in the Antisana Mountain in Ecuador (Remígio H. Galárraga-Sánchez, pers. comm.).

Socio-economic impacts

The impacts of climate on the economy of the Amazon Basin are attributable to El Niño rather than global change. In El Niño years, the water level is often very low which concentrates the fish into the deeper channels of the Amazon Basin. As a consequence, the fish are more accessible to fishermen and fishing effort and catches tend to increase. Excessive catches, combined with declines in recruitment caused by lack of access to spawning areas, causes a decline in fish stocks in subsequent years. To date, economic impacts observed in the Amazon region cannot be unequivocally attributed to global change.

The incidences of health problems are also related to years when water levels in the rivers are very low. Some communities established in the floodplain areas suffer when the rivers are too low. In general, they utilise canoes for transport and take water from the river. When the water level is very low, the river channel passes far from the community houses. As a result, people cannot use their canoes to gather water and instead they take water from stagnant ponds or lakes, which is a source of several diseases. No health and other social and community impacts associated to global change are known in the Amazon region.

Conclusions and future outlook

There is limited information about the impacts of global changes on the Amazon Basin. The apparent decrease in the ice cover in the Antisana Mountain in Ecuador and the suspected rises in sea level in the Lower Amazon are not unequivocal evidence of global change. More investigations are needed to determine if these effects should be considered as isolated occurrences or generalised events in this basin.

The impacts of global changes are associated with the change in the local and general climate caused mainly by deforestation. Considering the present deforestation rate, the prognosis for the future is worse than the conditions observed at present. The precise consequences are still hard to predict due to the limited number of studies investigating this subject.

Further, information describing the impacts of global change on the socio-economic aspects of the Amazon Basin are also absent. The socio-economic impacts of global change are the main concern for the future because they affect production systems and health problems related to water transmitted diseases, especially for the people who live in deforested areas. Research efforts should be directed at developing a realistic prediction of the impacts of global change on the Amazon Basin during the next 20 years so that effective procedures to mitigate the deleterious impacts can be implemented.

Priority concerns

The assessment of major concerns provided results that indicated priority concerns for further analysis. These results are closely linked to current trends and to changes expected to happen in the short to long-term. The Amazon region exhibits peculiar characteristics that have been considered in the prioritisation of concerns.

The concerns for the Amazon Basin, were ranked in descending order of severity:

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

Habitat and community modification was considered the highest priority among all major concerns that were analysed under both present and future conditions. The enormous area affected and the deep and long duration of the consequences of these impacts were the main reasons for prioritising this concern. Habitat and community modification was also considered to be the most significant contributor to the economic, social and health problems in the Amazon Basin. The development of the Amazon region has been based on modifications of vast areas where forests have been transformed into agricultural and cattle grazing fields (Vieira et al. 1993, Fearnside 1995, Goulding et al. 1996). The economy in this region has been based mainly on mining, petroleum and timber exploitation, generation of hydroelectricity and on the duty free zone industries in Manaus (Cardoso & Muller 1978, Monteiro 1995, Goulding et al. 2003). Most people live close to urban centres, along roads and rivers (Becker 1995). Unplanned habitat modification also contributes directly to increases in the incidence of malaria and other insect and water-related diseases (Aragón 1993). Cyclic outbreaks of these diseases can negatively affect economic and social aspects of the population and cities of the Amazon region. The forests and the hydrological cycle are closely linked together and, as a consequence, forest conservation was prioritised in order to guarantee future water availability and use. Moreover, the tributaries of the Amazon have such a high hydroelectric potential (COBRAPHI 1984) that it is impossible to consider future conditions without expecting the construction of new dams in some of these tributaries. The habitat and community modifications indicated a preoccupying scenario for both present and future trends since historical, traditional and environmental aspects are involved. Consequences of these modifications include economic, social and health problems that require solutions that are unlikely to be achieved in the short-term. Management procedures are needed to minimise negative impacts and to avoid even greater problems in the future.

Pollution was identified as being the second most important concern for the Amazon region. The human population density in the Amazon Basin is very low and there are only a few industrial areas established around the main cities (Becker 1995). There are no large industrial centres established in the Amazon Basin and Manaus is the only city that has a duty free industrial area. The industries located around Manaus do not produce large volumes of effluent and are not major sources of pollution. On the other hand, domestic sewage and solid wastes have polluted the small rivers of this city and are the main cause of urban aquatic degradation (Silva & Silva 1993). The petroleum, hydroelectric, mining, timber and fishery industries are the most important in the Basin but exist in a limited number and are spread along this basin (Goulding et al. 2003). At present, local industrial and urban pollution problems exist but are not yet a major concern for this region. Chemical contamination and suspended solids are the main issues related to pollution in the Amazon Basin and are primarily caused by gold mining activities in the Peruvian and Brazilian rivers (Hanai 1999, Núñez-Barriga & Castañeda-Hurtado 1999) and by the deforestation of large areas of forest located mainly in the headwaters of the southeast Amazon in Brazil (Veríssimo et al. 2001). There are also two scales of activities going on mainly in the Central Amazon region that strongly affect water quality: large and concentrated governmental and private projects, such as hydroelectric dams and petroleum exploitation stations; and small and dispersed local enterprises, such as gold mining and agriculture. The socio-economic impacts related to pollution are more apparent in the urban centre areas. At present, economic problems are not considered significant but social and health issues occur, particularly among people living in the suburbs of the large cities (Aragón 1993). Pollution was considered among the most important problems in the future mainly because continued deforestation will increase further the impacts of suspended solids carried by the water courses of the Amazon Basin. On the other hand, some of the impacts caused by deforestation might be offset by reduction in loads of suspended sediments produced by mining activities, which are likely to decline in the future as deposits are slowly exhausted. Pollution problems in the Amazon Basin are closely linked to activities responsible for considerable modification of habitats, for both the present and future scenarios, and were considered to be among the most important concerns for the Amazon region.

Unequivocal evidence of Global change was difficult to obtain in the Amazon region. Available information is very limited and the lack of historic data prevents comparison of the present situation with that of the past in order to determine significant trends. Experts have reported a few isolated cases that might potentially be a consequence of global change, but only more research will determine if such cases should be considered isolated occurrences or little noticed but generalised events in the Amazon region (Dunne et al. 1998). The impacts of global change are associated mainly with alterations in the local and general climate caused by deforestation (Salati & Vose 1984). Presently, there is no evidence that socio-economic aspects are affected by global change in this region. However, it is expected that socio-economic impacts will be among the main concerns related to global changes in the future. Such changes tend to affect the production systems and increase health problems related to water-borne diseases predominantly in deforested areas. Predictions of future conditions tend to be worse than the present situation, unless the rate of deforestation is reduced. The consequences related to global changes are hard to predict since there is limited number of studies related to this subject in the Amazon region. Further studies or research should be conducted in order to detect and measure current changes in order to develop a realistic prognosis of the future. Despite the limited evidence and need of further studies, global change was considered moderately important due to the worldwide implications that the deforestation of the forests of Amazon Basin might have on regional and global climate and carbon budgets.

Considering that fishing is an important occupation and source of animal protein in the large rivers and coastal areas of the Amazon region (Barthem 1995, Barthem et al. 1995, Cerdeira et al. 1997), Unsustainable exploitation of fish and other living resources has the potential to be a significant problem. Although, declines in the proportion of commercially valuable species in catches indicates overexploitation of some species, particularly in areas located close to the urban centres (Barthem & Petrere 1995, Isaac & Ruffino 1996), most fish stocks in the Amazon Basin are under-exploited or are fished within sustainable limits (Ruffino & Isaac 1995). The fishery of the Amazon region possesses significant economic potential and often functions as an economic buffer in local communities where people with other professions fish in order to secure a livelihood, while searching for better opportunities. This increase in fishing has caused conflicts since it leads to competition among different groups (riparian community members and professional fishermen) and contributes to the increase of uncontrolled fishing. The assessment of this concern indicated that a significant increase in fishing effort associated with deforestation of flooded forests might have negative effects on the fishery that could result in unsustainable exploitation and/or declines in economic viability. Unsustainable exploitation of fish and other living resources was considered a concern of limited importance since the great majority of stocks are under-exploited or fished within sustainable limits. Future developments might gradually alter this scenario but, under present conditions, unsustainable exploitation of fish is not a priority concern for the Amazon Basin.

Freshwater shortage was not considered to be a priority and was placed as the least prioritised concern for the Amazon region. The Basin receives an average annual precipitation of 1 500 to 2 500 mm (Day & Davies 1986) that maintains stream flow in the rivers, dilutes pollutants and stabilises the water table. This high average annual rainfall is reflected in the significant discharge of the Amazon River, which is approximately 220 800 m^3/s (Milliman & Meade 1983). At present, the Amazon Basin is perhaps one of the few regions in the world where Freshwater shortage is not a major concern even when pollution of existing supplies is considered. However, considering the apparent importance of the Amazon rainforest in maintaining patterns of the rainfall in the region (Salati et al. 1978, Salati & Vose 1984), continued deforestation will alter the hydrological cycle in the Basin and might cause or exacerbate problems related to water supplies. As a consequence, freshwater shortage might become a serious environmental problem in the future. Socio-economic impacts occur in localised areas that have suffered intensive deforestation. Populations that live in these areas experience cyclic water shortages during the drier period of the year. Future perspectives indicate that problems related to freshwater shortage might become a reality in the long-term but, for the moment, other concerns were considered more important in this region.

The inter-linkages between the concerns are presented in Figure 8.

1. Habitat modification certainly affects the levels of pollution in the Amazon region. The pollution related to habitat modification is mainly caused by the implementation of hydroelectric dams, mining and deforestation of areas for agriculture, cattle grazing and timber exploitation activities. All these activities increase the quantity of suspended solids and chemical pollution (mainly mercury and pesticides) in the water. Future planning and management should consider the establishment of natural reserves and the development of activities that take into account the ecological importance of the rainforests.

2. Pollution also results in habitat modification. The increase of organic matter in the water leads to eutrophication of the water system and causes changes in the Biological Oxygen Demand (BOD) levels, affecting the survival of aquatic organisms. Management and allocation of areas to be used for cattle grazing and agricultural purposes in accordance with correct land use strategies is required in order to mitigate the impacts of pollution in the Amazon Basin.

3. Habitat modification is considered to have potentially negative consequences for fisheries and exploitation of other natural resources. Increases in suspended solids caused by erosion decreases the area of floodplain ecosystems and affects local fisheries. The control of the erosion caused by mining, deforestation and hydroelectric energy generation, in conjunction with the adequate use and management of agricultural and cattle grazing lands is needed to prevent the unsustainable exploitation of fish and other living resources.

4. Habitat modification might have different degrees of interference in global changes, depending mainly on the intensity of these modifications. Deforestation affects both local and global climate. The rainforests moderate the water cycle that maintains the temperature ranges and hydrological balance. The establishment of an international political agreement among the countries that share the Amazon Basin is probably the main step to guarantee the maintenance of the ecological role of the Amazonian rainforest as a climate buffer.

5. Global change is a worldwide concern that affects different regions in distinct ways. Global change may cause habitat modifications, especially through changes related to the climate and, consequently, to the water cycle. Severe global changes will probably modify habitats by interfering in the water cycle and this eventually could lead to long lasting droughts.

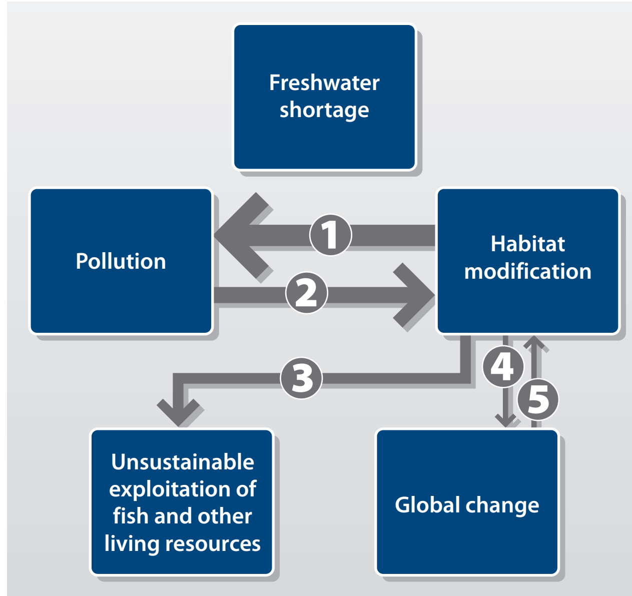

Figure 8 Model indicating the inter-linkage and synergies between the concerns.

Causal chain analysis of the Madeira River Basin

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

Introduction

The Amazon Basin is the largest river basin on the planet and also one of the least understood. Its natural areas are still quite well preserved and relatively uninhabited. With the exception of Bolivia, the majority of the population of each of the seven countries that share the Amazon Basin (Brazil, Bolivia, Peru, Colombia, Ecuador, Venezuela and Guyana) is located in other regions of these countries outside the Basin. Within the Amazon Basin, only five cities possess more than 1 million inhabitants, two located in Brazil, two in Bolivia and one in Peru. Three more cities have populations that range between 300 000 and 1 million inhabitants, two in Peru and one in Brazil (Goulding et al. 2003).

The reduced number of urban centres in the Amazon Basin has helped preserve the ecological processes within the Basin. Unfortunately however, the relatively low population within the Amazon Basin also means that the level of attention that central governments dedicate to the area is disproportional to its size or its environmental importance. As a consequence, local administrations do not have sufficient capacity to implement ecologically and economically sustainable management due to the shortage of funds from federal budgets and lack of basic information or statistics. Although this situation might prevail in all Amazon countries, the specific situation varies among countries sharing the Basin and also between different regions within a single country.

The GIWA Causal chain analysis aims to identify the root causes that threaten the maintenance of the aquatic ecological processes upon which human survival depends. Considering the dimension and heterogeneity of the Amazon Basin, this analysis was not feasible for the entire region. Table 1 show the division of catchments within the Amazon Basin and their transboundary classification (national or international). The Madeira River has the largest catchment within the Amazon Basin and is the third biggest river in South America, surpassed only by the Amazon and Paraná rivers. Among the international basins of the Amazon (Caquetá-Japurá, Juruá, Madeira, Marañón, Napo, Nebro, Purus and Putumayo-Içá) (Figure 3, Table 1), the Madeira River is the most populated and possesses serious environmental problems. More than half of the population of Bolivia, including the capital La Paz, are located in the Madeira Basin (Table 4). Deforestation and mining activities are environmental concerns, mainly in Rondônia State, Brazil, as well as in the Department of Madre de Dios, Peru, (Figure 9) (Núñez-Barriga & Castañeda-Hurtado 1999). Owing to its size and socio-economic importance, the Madeira Basin was the focus of the causal chain analysis within the Amazon Basin.

Table 4 Population in relation to river basins.

Basin[1]		Population Total (2002) x 1000	Population Total (2002) %		Population Total of important cities Basin[2]	x 1000	%
Bolivia	Madeira (2002)	1 919	22.6	Bolivia	Madeira[3]	3 559	68
Bolivia	Madeira and Paraná (2002)	2 808	33.1	Bolivia	Paraná[4]	658	13
Bolivia	Madeira and Titicaca (2002)	2 407	28.4	Bolivia	Titicaca[5]	982	19
Bolivia	Paraná (2002)	941	11.1				
Bolivia	Titicaca (2002)	402	4.7				
Peru	Amazonas (2002)	2 415	15.9	Peru	Amazonas[6]	2 415	16
Peru	Pacífico (2002)	12 534	82.4	Peru	Pacífico[7]	12 534	82
Peru	Titicaca (2002)	258	1.7	Peru	Titicaca[8]	258	2
Peru	Madeira (2002)	86	0.3	Peru	Madeira[9]	68	0.4
Brazil	North Region (2000)	12 920	7.6				
Brazil	Madeira (2000)	1 397	0.9				
Brazil	Acre (2000)	28	0.02				
Brazil	Amazon Basin (2000)	133	0.1				
Brazil	Pará (2000)	6.8	0.004				
Brazil	Rondônia (2000)	1 229	0.8				

Notes: [1]The population data is related to geopolitical areas and not individual river basins e.g. some Bolivian departments are drained by more than one river basin. [2]Population of cities localised in one or more basins; [3]La Paz, Cochabamba, Guayaramerin, Trinidad; [4]Santa Cruz de la Sierra; [5]Oruro; [6] Iquitos, Pucallpa; [7] Lima; [8]Puno; [9] Puerto Maldonado.

(Source: GIWA Task team 2003)

Figure 9 Deforested areas in the Madeira Basin.
(Source: GIWA Task team 2003)

System description

Geographic and demographic settings

The Madeira River is the largest tributary of the Amazonas River extending 3 352 km and possessing the largest drainage area (1 380 000 km^2), the greatest flow (6 700 km^3/year), sediment discharges (667.4 million tonnes per year), and oscillations in water level (21.8 m). The Madeira Basin represents approximately one fifth of the total drainage area of the Amazon Basin. Fifty percent of the Madeira Basin is located in Bolivia, 40% in Brazil and 10% in Peru (Carvalho & Cunha 1998, Dunne et al. 1998, Goulding et al. 2003) and, within these countries, it drains 14 different states.

The headwaters of the Madeira River are located near Cochabamba, in the upper Mamoré River, about 4 600 km away from the Atlantic Ocean. Four tributaries of the Madeira River are responsible for more than 60% of all freshwater discharge: Mamoré, Guaporé-Itenez, Beni and Madre de Dios. The Mamoré and Beni rivers have their headwaters in the Bolivian Andes, while the Madre de Dios originates in the Peruvian Andes and the Guaporé-Itenez River stems from the Brazilian Shield. These four rivers are navigable from below the foothills of the Andes until their confluence, near Guajará-Mirim. However, between Guajará-Mirim and Porto Velho, these rivers are united along a sequence of waterfalls, where navigation is impossible. Below the San Antonio Fall, 1 070 km from the mouth, vessels may navigate during the high water period. Otherwise, in the dry months between June and November, these reaches are only navigable by craft drawing less that 2 m of water (Goulding et al. 2003).

The Madeira Basin supports a significant Bolivian population, but it is sparsely inhabited in Peru and in Brazil. More than 50% of the Bolivian population is located in the Madeira Basin, including the capital La Paz. In contrast, less than 1% of the Peruvian and Brazilian population live in the Madeira Basin (Table 4). The Bolivian departments have three drainage areas: Madeira, Titicaca and Paraná. Some departments are drained by more than one basin, for instance: Madeira and Paraná (Santa Cruz, Potosi and Chuquisaca) and Madeira and Titicaca (La Paz). Only Pando and Beni lie completely within the Madeira River Basin.

The population of Peru is primarily concentrated on the Pacific coast and, while 16% of the Peruvians live within the Amazon Basin, only 0.4% reside in the Madeira Basin, mainly in the Department of Madre de Dios (Table 4). The headwaters of the Madre De Dios River is located in the Andes in the Departments of Madre De Dios, Cusco and Puno, but these departments are sparsely inhabited.

Figure 11 Gold mining activity in the Madeira River headwaters.
(Photo: R. Barthem)

The majority of the Amazon River Basin is located in the North region of Brazil but it extends slightly into the Middle-West and Northeast regions. The Brazilian population, on the other hand, is concentrated in the Southeast and Northeast regions. Only about 7% of the entire Brazilian population reside within the North region and less than 1% in the Madeira Basin. However, despite its current low density, the present rate of population growth in this region is greater than in other parts of Brazil (Table 4).

Climatic and hydrologic characteristics

The climate of the Madeira Basin varies from cold and dry, in the Andes, to tropical and rainy in the Amazon lowlands. The climate in the Peruvian Andes can be divided according to altitude. In the Janca region, which is located over 4 800 m above sea level, the climate is extremely cold and the ground is permanently covered with snow. The Puna region, famous for its populations of alpacas and llamas, is situated between altitudes ranging from 4 100 m to 4 800 m, and is characterised by a dry and cold climate where the temperature oscillates between -10° and 20° C. The Suni or Jalca region located between 3 500 m and 4 100 m is generally cold with seasonal rainfall. The Quechua region ranges between 2 500 m to 3 500 m and is the most inhabited and modified region. The climate is dry with cold temperatures and seasonal rainy periods. The Yunga region situated on the lower slopes of the Andes ranges between 500 m and 2 300 m, is characterised by a spring climate and a dense and highly diverse cloud forest. The areas below 500 m are the Amazon lowlands, which, with the exception of the largest savannah zone in Bolivia, are generally covered by forests. In the lowlands of the Madeira Basin, the annual precipitation ranges between 1 000 mm and 2 500 mm, while the foothills of the Andes receive between 5 000 mm and 10 000 mm per year. Rainfall varies throughout the year with the dry season occurring between May and September and rainfall peaks occurring between November and April (Goulding et al. 2003).

The level of water in the rivers of Madeira Basin varies according to seasonal fluctuations in rainfall and exhibits peak in February along the foothills of the Andes, and between February and March in the downstream sections of these rivers. The Madeira River, below the Teotônio Falls, exhibits the greatest variation in annual discharge of any river in the Amazon Basin. This is due both to high rainfall and relatively

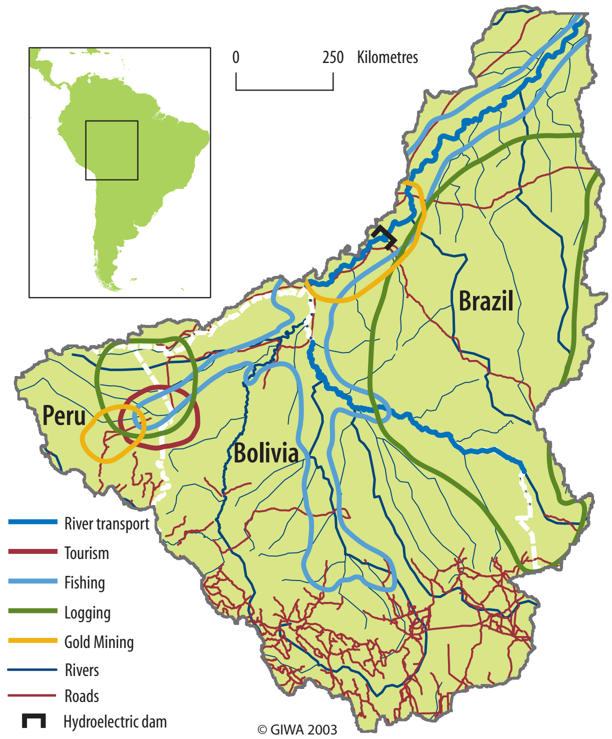

Figure 10 Anthropogenic pressure in the Madeira River Basin.
(Source: GIWA Task team 2003)

narrow floodplains compared with the river discharge. In addition, the backwater phenomenon occurs in the lower Madeira rivers due to the natural dam effect caused by the greater elevation of water in the Amazon River. The peak discharge from the lower Madeira River occurs at least two months earlier than in the Amazon River (Goulding et al. 2003).

Principal economic sectors and processes

The main socio-economic activities in the region are gold mining, logging, fishing, cattle farms and agriculture (Figure 10).

Gold mining

Large alluvial gold deposits were discovered along the Tapajós, Madeira, Tocantins, Xingu and the Negro rivers between 1979 and 1987 (Hanai 1999). During the 1980s and 1990s, gold mining was very important in the Madeira Basin and mining activities are now concentrated in the region of Madre de Dios, in Peru (Núñez-Barriga & Castañeda-

Hurtado 1999) (Figure 11) where it is the most significant contributor to the regions economy. Unfortunately however, gold mining is also the biggest cause of habitat modification and pollution in the region.

Logging

Logging, especially of mahogany, is also an important source of foreign income for the region of Madre de Dios. Timber is transported along the river (Figure 12) or by road to Lima, where it is exported to foreign markets. Considering that timber cannot be extracted in areas isolated from the river and the roads, logging is limited to areas serviced by transportation routes and as a consequence, the impacts of logging are directly proportional to the density of roads in the region.

Figure 12 Transport of timber (mahogany) in the Peruvian rivers. *(Photo: R. Barthem)*

Fishing

Fishing is a common activity in the Madeira River plain (Figure 13) and provides an important source of high quality, low cost protein. As a result, fishing has a significant socio-economic function and maintains a formal and informal economy that employs hundreds of thousands of people and generates more than 10 million USD per year (Lauzanne et al. 1990, Cañas 2000, Goulding 1979). The main cities where the fishery landings take place in the Madeira River are: Puerto Maldonado, in Peru; Trinidad and Guayaramerin, in Bolivia; and Guajará-Mirim, Porto Velho and Manaus, in Brazil. Although the city of Manaus lies outside the Madeira River Basin, its port receives fish from the fleet that comes from the Madeira fishing grounds.

Figure 13 Fishing activity in the Madre de Dios River. *(Photo: R. Barthem)*

Grazing and agriculture

Although agricultural products are very important for local consumption, large plantations of soybean are being established primarily along the Brazil borders of the Amazon Basin for export. The cattle industry has traditionally been important for the local economy in Brazil. However, grazing is now beginning to dominate the economies of other countries in the Madeira Basin, usually at the expense of natural forests.

Other potential activities related to water resources

Generation of hydroelectricity

The Samuel hydroelectric plant located on the Jamari River in Rondônia State is currently the main source of hydroelectricity in the Madeira Basin. The generation of hydroelectricity in Bolivia and Peru is usually done in the Andes and does not require the building of dams. Despite the large hydroelectric potential of the region, the dispersed nature of urban centres in the Madeira Basin and the large distances that the electricity would have to be transported to reach consumers in the other regions of the country have resulted in diesel generators being the primary source of electricity in the region.

Tourism and leisure

Cusco, the capital of the Inca people, is the most important centre for tourism in the Madeira Basin and is located in the Peruvian section of the Madre de Dios Basin. This part of the Madeira Basin has great potential for ecotourism and, in the future, this activity should contribute significantly to the local economy and the preservation of this rich environmental and historical heritage.

River transport

The Madeira River has been an important commercial transport route for the region since the 19^{th} century. The rubber industry brought significant economic investments to the region and also caused considerable changes in the composition of the population. Thousands of people died due to malaria and conflicts between indigenous people and colonists during the Rubber period. Several important infrastructure developments, such as the Madeira-Mamoré railway in Rondônia (Goulding 1979) and the Fitzcarrald adventure in the Manu River in the headwaters of Madre de Dios, were undertaken to transport rubber from the Madeira River regions to export markets.

Table 5 Basic sanitation indicators in the Brazilian part of Madeira and Amazon basins.

Hydrographic unit	Water supply (%)	Sewerage network (%)	Treated sewage (%)
Madeira Basin	32.2	3.2	1.4
Amazon Basin	46.5	10.4	2.3
Brazil	81.5	47.2	17.8

(Source: ANA 2003)

Table 6 Water availability in the Brazilian part of the Madeira and Amazon basins.

		Madeira Basin	Amazon Basin	Madeira Basin share of:	
				Amazon Basin (%)	Brazil (%)
P (mm)		2 160	2 234	NA	NA
E (mm)		1 465	1 320	NA	NA
Availability	Q (m^3/s)	15 255	108 982	14.0	9.5
	q ($l/s/km^2$)	22	29	NA	NA
	Q_{95} (m^3/s)	3 429	64 734	5.3	4.4

Note: P: Annual mean precipitation; E: Real evapotranspiration; Q: Mean flow over a long period; q: Specific flow; Q_{95}: Flow with a 95% permanence. NA = Not Applicable. (Source: ANA 2002)

Table 7 Water demand in the Brazilian part of the Madeira and Amazon basins.

		Madeira Basin	Amazon Basin	Madeira Basin share of:	
				Amazon Basin (%)	Brazil (%)
Water demand in Brazil (m^3/s)	Urban	1.28	10.8	11.9	0.29
	Rural	3.06	11.3	27.1	2.49
	Animal	4.89	13.2	37.0	4.25
	Industrial	0.58	3.3	17.6	0.23
	Irrigation	0.36	23.8	1.5	0.03
	Total	10.17	62.4	16.3	0.47
	Demand/ Availability (%)	0.3	0.1	NA	NA

Note: NA= Not Applicable. (Source: ANA 2003)

Table 8 Organic load in the Brazilian part of the Madeira and Amazon basins.

	Maderira Basin	Amazon Basin	Amazon Basin (%)	Brazil (%)
Domestic organic load (tonnes BOD_5/day)	61	260	23	4.0

(Source: ANA 2003)

Currently, the Madeira River is an important route for the transportation of soybeans from where they are grown in the centre of Brazil, particularly the State of Mate Grosse, to ports, such as Itacaotiara, for export to markets in Europe (Costa 2000).

Water supply

In most cities of the Madeira Basin, basic sanitation is poor. In the Brazilian part, less than one third of the population receives regular water supply, the sewerage network services only 3.2% of the population and, even then, only 1.4% of the sewage that is actually collected is treated. These standards are not only below the average for the whole of Brazil, but also for the Brazilian portion of the Amazon Basin (Table 5).

The Madeira Basin constitutes 18.4% of the area of the Brazilian Amazon Basin and 8.1% of Brazil. The Madeira River contributes 14% of the total volume of water discharged from the Amazon Basin (Table 6). The demand for water in the Madeira Basin stems primarily from the agricultural and grazing sectors but is relatively low compared with the availability of water. Even so, this represents 16.3% of the demand in the Brazilian Amazon Basin and only 0.47% of the demand in Brazil (Table 7).

The organic load discharged into the Madeira Basin is estimated to be 61 tonnes per day of Biological Oxygen Demand (BOD_5), which corresponds to 23% of the total load in the Brazilian Amazon, and 4% of the total load in Brazil (Table 8).

Causal model and links

The root causes that allowed or motivated such unsustainable scenery may be summarised as follows: (i) Law: there are no appropriate rules; (ii) Governance: there is no capacity of taking decisions, assume accountability, or develop programmes which could solve the problem; (iii) Economic: prices do not reflect the environmental values; (iv) Socio-economic: the basic demands of the population are sustained by diminishing natural resources, leading to poverty; (v) Demographic pressure: the capacity of support of the Basin is exceeded; (vi) Technology: there are no techniques that promote the sustainable use of natural resources in the Basin; (vii) Political: the society is not represented legitimately; and (viii) Knowledge: there is no dissemination of knowledge and information of the natural phenomena or the available technology.

The priority concerns identified in the Amazon Basin were Pollution and Habitat and community modification. These concerns were not only considered as a result of the environmental vulnerability of the Amazon Basin, but also as a consequence of this basin's institutional and management framework.

The Causal chain analysis of Pollution and Habitat and community modification are summarised in Figures 14, and 15 respectively. Root causes of environmental and socio-economic impacts of Pollution and

Habitat and community modification were identified as Governance failures, Market and policy failures, Lack of knowledge, and Poverty and demographic factors.

Immediate causes and sectors

Deforestation

Until January 1978, the deforested area corresponded to 85 100 km^2 (2.2% of the total area) as a result of four centuries of human action. After 1978, there was a significant increase in the occupation of the region, mainly due to governmental programmes, which resulted in an expansion of the deforested areas. In 1999, 440 630 km^2 (11.7% of the total area) were deforested. Data from the Brazilian National Institute for Space Research (INPE, Instituto Nacional de Pesquisas Espaciais) indicated that the total area deforested during 1999 and 2000 was 17 259 km^2 and 19 836 km^2 respectively. According to current estimates, approximately 15% of the original Amazon forest has already been destroyed (ANA 2003).

Pollution

Chemicals and suspended solids are the main pollutants in this region and originate primarily from gold mining activities in Peruvian and Brazilian rivers and from the deforestation of large areas, especially in the headwaters of the southeast Amazon Basin, in Brazil. At present, localised pollution problems exist, particularly around urban centres, but are still not a major overall concern for the Amazon Basin.

Chemical agricultural wastes and mercury contamination are the main cause of chemical pollution in the Amazon Basin. The impacts caused by these pollutants do not affect large areas because agricultural activities are not widespread and because gold mining activities occur in only a few concentrated areas. The present level of pollution is considered low when compared with historical data obtained from important agricultural areas in Brazil (Torres et al. 2002). The source of mercury contamination of organisms is still not completely understood because mercury might have originated from both gold mining activities and from natural regional sources. The problematic areas for chemical pollution are regions where gold mining activities are intense, particularly in the Andean region, the State of Rondônia (Brazil) and the Madeira River. Mercury levels in most fish species consumed by the Amazon population are below the limit recommended for consumption by the Brazilian legislation, but some areas show some contamination (Kehrig et al. 1998, Brabo et al. 2000).

The concentration of suspended solids in rivers arising from the Andean region is naturally high, but the rivers from the Amazon plain and Brazilian Shield, which usually have very low concentrations of sediments, have experienced an increase of solid residues in suspension. This is caused mainly by gold mining activities and the erosion caused by deforestation for agricultural and cattle raising activities.

The rivers and beaches close to the great urban centres exhibit large amounts of solid residues that affect the health of local people and tourism. The low percentages of collection and treatment of domestic sewage leads to significant pollution. Some small streams of the great urban centres are completely blocked by solid wastes and this increases health problems, specifically those related to insect-transmitted diseases (e.g. mosquito transmitted diseases).

Oil spills occur occasionally in areas where petroleum is exploited and during fuel transportation procedures. There are no records of great damages occasioned by oil spills so far.

Habitat and community modification

Habitat and community modification is a pivotal question among all the environmental concerns. The enormous area affected and the long duration of the consequences of the impacts brought by these factors are perhaps the main reasons for considering this concern so important and in need of management.

Deforestation is the main activity that causes loss of ecosystems in the Amazon Basin at the present time. Recently opened areas are clearly identifiable on satellite images in large regions of the Brazilian Shield, headwaters of the Guaporé, Aripuanã and others rivers. The oldest modifications to ecosystems occurred in the tundra-like vegetation, Puna, in the Andes zone, due to agricultural activities of the Andean people. The impact of such historical agriculture on the aquatic system is unclear, but the recent agriculture and cattle established in the floodplain areas, mainly in the lower Amazon, has cleared the flooded forest that represents a source of food for several important commercial fishes.

Fish community modification: The composition of fish species in most of the Amazon Basin is still determined by natural events. The introduction of alien species, such as trout and kingfish, has brought about permanent and negative consequences mainly in the Andean waters, rivers and lakes. Alien species have been introduced in other areas of the Amazon, but they have either not survived or have not yet established viable populations.

Habitat modification: Local extinction of species may occur as a result of large habitat modifications, such as the construction of hydroelectric dams. Although migratory fish are most affected by such developments, poor knowledge of the aquatic fauna of the Amazon Basin certainly contributes to underestimating the consequences.

The dependence of the Amazon Basin on its rich hydrographic network is graphically illustrated when extreme hydrological events occur. For example, droughts reduce stream flow which, in turn restricts navigation in some waterways, while increased flows cause flooding over large areas of floodplain, influencing the dynamics of several animal and plant species and affecting the conservation of biodiversity within the Amazon Basin.

Root causes

The results of the causal chain analyses of Pollution and Habitat and community modification indicated that both concerns share the most important root causes: 1) Governance failures, 2) Market and policy failures, 3) Poverty, and 4) Lack of knowledge (Figures 14 and 15).

Root cause 1: Governance failures

Two aspects of Governance failures related to the complexity of the problem and the difficulty to practicable mechanisms to resolve conflicts between different interests were identified during the causal chain analysis. These aspects were related to: (i) the lack of legitimacy on negotiations commanding decisions regarding investments; and (ii) the absence of a basin-wide management plan.

Lack of legitimacy on negotiations commanding decision regarding investments: Three countries and 14 states administer the Madeira Basin. There are no effective fora in these administrative institutions, designated to discuss or decide on the development or conservation policies of this basin. The discussions that do occur consider each economic sector, such as mining, agriculture, logging and conservation, of each country independently. Consequently, there is an enormous lack of integration and legitimacy of negotiations associated with decisions concerning investments.

The most important forum for discussions in the Amazon Basin is the Amazon Cooperation Treaty (ACT) (see Annex IV). This treaty is a relevant multi-lateral agreement for the promotion of cooperation between the Amazon countries (Brazil, Bolivia, Colombia, Ecuador, Guyana, Peru, Surinam and Venezuela) to promote sustainable development in the region. However, this treaty is not implemented by the Amazon countries to make decisions or to implement policies related to the sustainable development in this region. Thus far, the Madeira Basin and the other catchments within the Amazon Basin do not possess an integrated institutional framework dedicated to integrated management of the Basin.

Basin-wide management plan not yet implemented: The lack of legitimate base of negotiations, governing decisions regarding investments, results in a precarious basin-wide management plan. One of the most important issue related to the development of the Amazon Basin is deforestation, which may modify habitats over an enormous area, resulting in unpredictable climate changes. The governments of the Amazon countries understand the necessity of preserving part of the forest to maintain the ecological processes in this basin. Parks and reserves have been established in many areas of the Amazon in order to preserve the region's biodiversity. However, it is not clear how much deforestation has taken place or which are the most important areas of the Amazon forest that should be preserved in order to maintain the ecological functions of the Basin. Unfortunately however, some habitat modifications have already occurred on a large scale but the knowledge and understanding of the ecological mechanisms that guarantee the equilibrium of this basin are relatively recent. Data illustrating the importance of the forest for maintaining the hydrological cycles in the region were only obtained during the 1970s and 1980s (Salati et al. 1978, Salati & Vose 1984). Also, the commercial exploitation during the 1990s of the large catfish, which undertakes long migrations between the estuary and the headwaters of the Amazon, illustrated the need of an international fishery management plan to regulate the exploitation of those stocks (Barthem & Goulding 1997).

In addition, some specific habitats have an enormous importance that is not immediately obvious. The flooded areas are traditionally used for grazing and the cultivation of rice and jute, and farmers remove the flooded forest to increase their production area. This economic expansion causes a negative impact on fishery, because the flooded forest is an important source of food and shelter for fish communities (Goulding 1980, Goulding 1981, Goulding & Carvalho 1982, Goulding 1989).

The implementation of a basin-wide management plan depends primarily on the legitimacy of the parts that must be able to negotiate decisions regarding investments, as well as on increased knowledge of the ecological processes occurring in the Basin.

Root cause 2: Market and policy failures: misconceptions about resource availability

There is a common misconception among resource users that the natural resources of the Amazon Basin are inexhaustible which leads to unsustainable exploitation, extinction of species and resource shortages. Many of the different economic sectors within the Madeira Basin have, at some time, held this belief and, as a consequence, not taken enough care to preserve their own investments. The deforestation caused by traditional activities such as timber extraction and agriculture

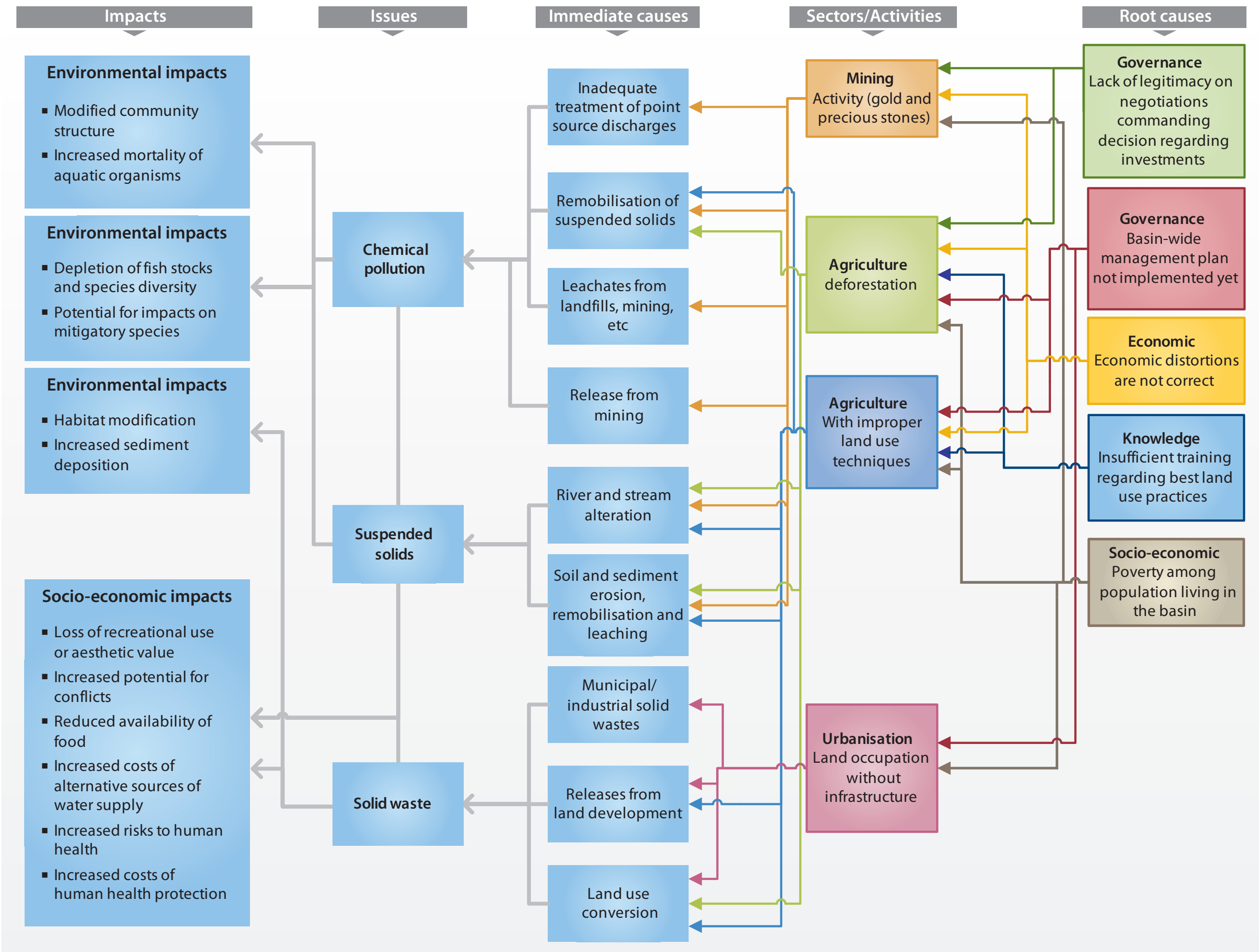

Figure 14 Madeira River Basin causal chain analysis on Pollution.

has had negative consequences. Dean (1997) highlighted the impacts of large-scale deforestation on the soil quality and the hydrological cycle in a tropical South American forest. Mining is another activity that has caused degradation of the aquatic system within the Madeira Basin, particularly when soil removed during the mining process is not controlled or when the river is used as a natural sewer.

The use of natural resources must be monitored by the governmental agencies that can prohibit the exploitation of a resource or determine and enforce sustainable quotas. The absence of a basin-wide management plan weakens government control of natural resources and thereby encourages unsustainable exploitation.

Root cause 3: Lack of knowledge: insufficient training in best land use practices

Some agricultural and mining techniques of soil and chemical use are available to make these activities more profitable and involving less environmental impacts. These relatively modern techniques are more quickly adopted by mining companies and by medium or large-scale farmers, than by informal miners or colonists. Training in best land use practices must be included in the basin-wide management plan. However, at present, the responsibility of training resource users within the Basin is scattered among several governmental and non-governmental institutions.

Root cause 4: Poverty and demographic factors

The majority of the human population that lives in the Amazon Basin is not wealthy and needs to exploit natural resources for their livelihood. Areas sparsely inhabited may be exploited with few negative consequences for the environment. On the other hand, densely inhabited areas generally show decreases in water quality, the abundance of fish and game, and the quality of soils. The increasing risks to human health are amplified by the immigration of people from other parts of the country, such as from the Andes or from the semi-arid zone

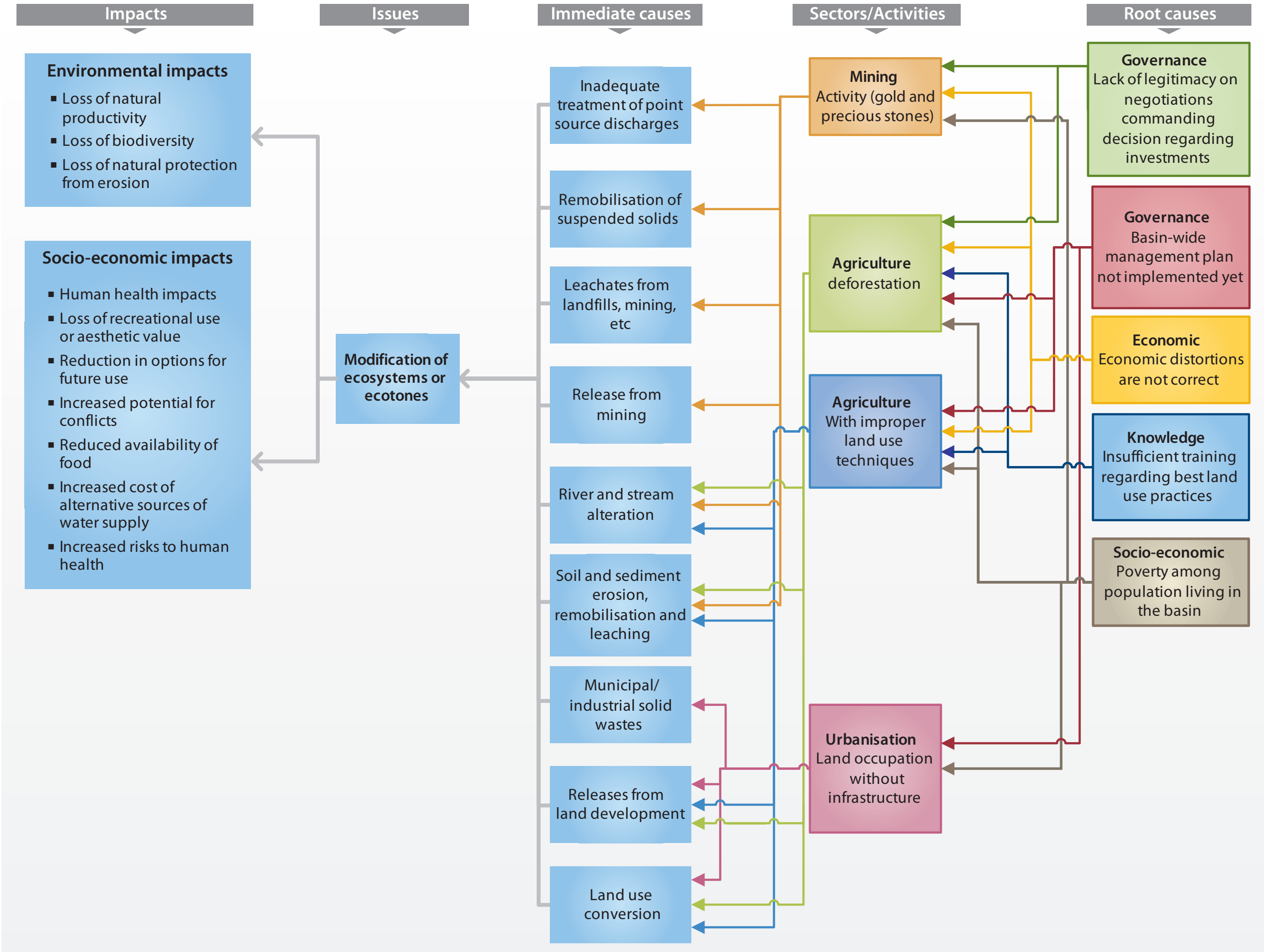

Figure 15 Madeira River Basin causal chain analysis on Habitat and community modification.

in Brazil to the lowland forests of the Amazon Basin. During the 1980s, the State of Rondônia had the highest rate of immigration which lead directly to a greater number of slums in the largest cities and increased rates of deforestation (Léna & Oliviera 1991). In addition, immigration to the Peruvian Amazon has increased since the end of the terrorism that occurred during the last decade.

The Amazon Basin is one of the last frontiers and a land of opportunities for those that have few opportunities in their home lands. Moreover, the Amazon countries have encouraged this immigration, in order to augment the population of the region. Unfortunately however, the problems associated with increased immigration, such as increased poverty, probably represents the largest challenge for the future administration of this basin and should be addressed in conjunction with the other root causes identified by this causal chain analysis.

Policy options of the Madeira River Basin

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

Definition of the problems

Before undertaking policy analysis it was essential that several of the myths about the Amazon being homogenous, empty, rich and poor were discarded (Torre 1995). The divers physical and socio-economic aspects of the Amazon Basin ensure that it is far from being an homogeneous basin. For this reason, the present policy analysis was conducted on an important sub-basin, the Madeira River Basin instead of considering the entire Amazon Basin.

The population and the cities

The Madeira Basin has a population of about five million inhabitants (Table 4), and the majority is concentrated in cities in Bolivia (La Paz, 16%; Cochabamba, 16%; and Santa Cruz de La Sierra, 23%) and Brazil (Porto Velho, 7%). The most important city in the Peruvian portion of the Madeira Basin is Puerto Maldonado, with a population that represents about 1% of the entire basin. These five cities are key regions for the management of the Madeira Basin, considering their location, political status and economic power.

The history of colonisation in the Andean region is different from the Amazon lowlands. The composition of the present Andes civilisation reflects the original Inca population and the influence of Spanish colonisation. In addition, mining prospectors have also contributed to the make-up of the population in the Madeira Basin. In contrast, the present society of the lowlands is predominantly a result of a recent migration of the Bolivian, Brazilian and Peruvian people into the indigenous territory, which happened more intensively during the Rubber period (Cardoso & Muller 1978, El Comercio 2001).

The population of the lowlands of the Madeira Basin is comprised of several groups of people that are weaving a complex web of ethnic diversity and are developing the local economy and policies. The most ancient group is the indigenous people that belong to several cultures and speak different languages. Settled in many established or non-established reserves, these groups have integrated or interacted with the dominant society to varying degrees. The second group is composed of the first colonisers and the mixed blood groups, known in Brazil as "caboclos". These people have been living in the region for several generations and have developed a culture and knowledge that sustains a traditional exportation economy since the end of the colonial period (Goulding et al. 1996). They know this region very well and their knowledge is the foundation of the present economic activities, such as timber, fishery and fluvial transportation. The final and most recently established group is comprised of immigrants who have recently come to the region seeking the Amazon richness, mainly gold. Apart from the indigenous people, most colonists arrived in the Amazon region during several economic pulses, such as during the Rubber period at the end of the 19th and beginning of the 20th centuries; after the establishment of the duty free zone in Manaus in 1967; the period of infrastructure development during the 1970s; and following the increase in gold mining in the 1970-1990s (Cardoso & Muller 1978, Goulding et al. 1996, Hanai 1999, Núñez-Barriga & Castañeda-Hurtado 1999). These economic pulses contributed to the development of a diversified local economy, which sustains one of the highest regional rates of population growth in the Madeira Basin.

The frontiers and economic blocks

The inhabitants of the Madeira River Basin share the same water supplies but are separated by political borders such as country, state and county borderlines. Moreover, Peru and Bolivia belong to a separate economic block, the Andean Community (Comunidade Andina 2002), from Brazil, which belongs to the Mercosul (also known as MERCOSUR) economic block (MERCOSUR 2003) (see Likely performance of recommended policies). The value of trade between the Andean Community and the Mercosul has reached almost 6 million USD per year. The main products exported from the Andean Community to the Mercosul are crude oils, petroleum products, natural gas, bananas, unrefined silver and zinc ores, and in return the Mercosul exports vehicles, soybean oil, beans, motor vehicles with piston engines, and hard maize to the Andean Community (Comunidade Andina 2002). Despite the value of formal trade between these countries, an enormous amount of informal trading occurs along the border between these three countries in the Madeira Basin. In addition, the poor communication between major economic centres within the Madeira Basin makes sustaining and managing commercial activities within the region very difficult. For example, in order to fly between Rio Branco, the capital of Acre in Brazil, and Puerto Maldonado, the capital of Madre de Dios in Peru, you would have to fly via São Paulo and Lima. The distance between Rio Branco and Puerto Maldonado would correspond to a flight of less than one hour, but it actually takes more than 24 hours to fly via São Paulo.

Addressing the Root causes

Implementing policies that address the four root causes identified in the Madeira Basin would probably be facilitated by the cordial relationship that exists between the three countries that occupy the Basin and by the statement of the Amazon Cooperation Treaty (ACT). On the other hand, the practical distance that splits the population from different countries might be a serious obstacle in the implementation of a basin-wide integrated management plan.

Root cause 1: Governance failures

Failures in governance are probably one of the most important root causes within the Madeira Basin. At present, there is no commission or authoritative body that has been established to discuss and address problems occurring in the Madeira Basin, despite the existence of such commissions in other areas of the countries, particularly in the Titicaca Lake region or for a number of rivers in the Northeast and Southeast regions of Brazil.

Pollution is probably the most obvious GIWA concern that requires international management. The increased propagation of pollution downstream, particularly from mining, affects all lowlands of the Madeira Basin, the lower Amazon River and also the estuary and the North Brazil Shelf Large Marine Ecosystem (LME 17).

Root cause 2: Market and policy failures

Policies and regulation of each country should help minimise the economic distortions by promoting the use of natural resources in a sustainable way. The common directives to achieve the sustainable development of the Amazon region must be discussed within the scope of the ACT. However, the correction of the economic distortions will be more effective when the two economic blocks develop mechanisms to consolidate a basin-wide management plan for the entire Madeira Basin.

Habitat and community modification is the GIWA concern that is influenced most by the unregulated development of an economy that maintains the perception of inexhaustible supplies of natural resources. The expansion of agriculture is primarily responsible for the deforestation of large areas and the resulting habitat modification it causes.

Root cause 3: Lack of knowledge

The local government could easily raise awareness of the public of best land use practices. The establishment and implementation of training and environmental education programmes would help minimise both pollution and habitat modification in the Madeira Basin.

Root cause 4: Poverty

Poverty is a large-scale problem throughout the Amazon Basin. Alleviation of poverty in the Madeira Basin is probably the largest challenge for the administration and can only be achieved if a holistic approach is adopted, that involves all levels of government, addresses and root causes.

Construction of the policy options

Information system on water resources in the Madeira River Basin

Information is the key to implementing appropriate actions that aim to achieve sustainable use of water resources. Therefore, governments and agencies charged with the regulation of water resources must be well informed about the ecology, economy, socio-economy, hydrology, meteorology, agriculture and other important aspects related to the use of water and land in the Basin. The objectives of an information system could be achieved in three ways: (i) research, to obtain more and new information; (ii) search and collate existing information; and (iii) dissemination of information to the target audiences.

The purpose of this project is to integrate the different countries and stakeholders that support research, databases and social organisations of interest in the field of water resources and environment issues in the Madeira Basin. Research aiming at the sustainable use of water resources will reinforce the basic information required for the elaboration of a basin-wide management plan. Also, the implementation of a decentralised information system based on the principle of the "Clearing-House Mechanism" will provide greater flexibility in seeking, collecting, compiling and disseminating data on the Basin. The "Clearing-House Mechanism" is a facilitation system in which the Focal point, in this case the Brazilian Ministry of the Environment, does not necessarily have a centralised data base, but acts as a portal to the web-pages that have the information. The system acts as a web in which all points interact with each other. The main function of the Focal point is to standardise the information that will be available via the Internet. This should improve and make easier the process of management, monitoring and enforcement of the public and private actions in this basin, decision-making, as well as increasing and contributing to further knowledge dissemination on the Madeira Basin. All interventions that have an impact on the Basin, especially mineral prospecting and mining, agriculture and deforestation, would be involved.

This project will represent a first step in establishing an integrated basin-wide management programme involving the three countries. This action complies with ACT directives and will be the foundation of the constitution of a Commission or International Committee for the management of the Madeira River Basin.

Contributions to the development of an International Commission for the Madeira River Basin

The establishment of an International Commission for the Madeira River Basin is essential in order to coordinate and implement remedial actions in order to ensure the sustainable use of water resources in the future. Unfortunately, there are at present, no plans for the establishment of such a commission. Bolivia, Peru and Brazil have not implemented an integrated large-scale action to address environmental problems associated with aquatic resources, as has been done in relation to the drug trafficking problem. To date, each country has developed its own mechanisms and projects designed to ensure the sustainable use of water resources. Brazil is developing a large-scale programme for the Protection of the Brazilian Rainforests (PPG7), which is a joint initiative of the Brazilian Civil Society and the Brazilian Government and is supported by the international community (PROVARZEA 2003). Peru and Bolivia have established national reserves and Peru gave concessions for private reserves in the Madre de Dios headwaters. The first conservation concession was awarded to ACA (Amazon Conservation Association) for the conservation of the lower Los Amigos watershed in Madre de Dios (Amazon Conservation Association 2003).

This project aims to survey the legal rules and managerial organisations in the countries and states of the Madeira Basin. The second phase of the project will identify the stakeholders in the Madeira Basin and propose a schedule to establish an International Commission for this basin.

Training and environmental education programme

Permanent training and educational strategies must be developed and implemented among the population, particularly regarding best land use practices, the non-polluting techniques for gold exploitation, the basic sanitation procedures essential for maintaining water quality and appropriate use. Also, the legal provisions that limit interventions in water sources and other environmental protection zones should be explained.

Sustainable development programme for fishing activities

Although the fish stocks within the Madeira Basin are potentially one of its greatest economic assets, present management of these resources is inadequate resulting in the unsustainable exploitation of the most valuable stocks. The broad habitat use of the big migratory catfish which spawns in the upper reaches of Amazonian rivers in the Andes and uses the estuary and the lowlands as a nursery zone (Barthem & Goulding 1997) perfectly illustrates the need for integrated management in this basin.

This project aims to align fisheries projects and organisations in order to achieve sustainable fishing practices and exploitation of unidentified opportunities. It encourages different countries to adopt compatible regulations for the management of the same stock. In addition, it will endeavour to raise awareness among fishermen and stakeholder of how their activities depend on the continued health of the Basin, transforming them into some of the main agents to monitor and enforce the interventions designed to promote sustainable fishing maintenance of fish stocks in the Madeira Basin.

The options recommended above will contribute to the development of an international commission and the implementation of a training and environmental education programme. The consolidation of a fishery management programme will involve training and education of the target public, as well as meetings and workshops with the governmental fisheries institutions of each country. The same must happen with the implementation of the proposed information system. Thus, these projects are based on the same foundation: integration and exchange of information.

Identification of the recommended policy options

Each of the four projects presented above were developed to address each of the root causes identified by the causal chain analysis. However, the projects are not equally feasible, require different budgets and will yield results over different temporal scales. For example, the benefits of the establishment of an International Commission for the Madeira Basin will only become evident in the long-term, despite its extreme importance for the consolidation and implementation of an integrated policy regulating management of aquatic resources in the Basin. Similarly, the establishment and implementation of training and environmental education programmes will promote the long-term sustainability of practices such as fishing and farming but will not yield immediate benefits. Therefore, the most promising project aims to gather and disseminate information and to integrate the programme for fisheries management in the Madeira Basin.

Brazil, Bolivia and Peru each possess research programmes and database systems to monitor and develop actions to promote the sustainable use of water resources. Unfortunately, these programmes are not integrated and, because of budgetary limitations, are implemented only on a limited geographic scale. An initiative of the Civil Society of the three countries, involving universities, research centres and local environmental institutions, together with the governments of each country and, if possible, supported by the international community could focus investigations to find solutions to environmental problems for the priority concerns identified in the Madeira Basin.

In the Amazon Basin, some efforts have been made to consolidate regulations into an integrated management strategy for fishing in this region, primarily to manage the big migratory catfish. The management of fisheries along the Amazon River have been discussed in fora involving participants from Peru, Colombia and Brazil and could be expanded to include the Madeira Basin.

Likely performance of recommended policies

Information system for the management of aquatic resources

Effectiveness

Brazil, Bolivia and Peru have designated governmental institutions to gather information and develop policies for the regulation of water resources. The National Water Agency (Agência Nacional de Água – ANA) in Brazil, the National Service of Meteorology (Servicio Nacional de Meteorología – SENAMHI) in Bolivia, and the National Service of Meteorology and Hydrology (Servicio Nacional de Meteorología e Hidrología – SENAMHI) in Peru have similar functions related to the information system.

The implementation of an integrated information system might improve the predictions of flood and the establishment of systems for pollution control. Also, the scientific community of these countries could work in association with the information system to develop joint projects within the field of aquatic sciences. The relationship between the intensity of flood and fish migration, the size of deforested area in the headwaters and the degree of degradation of the valley floodplain vegetation, are examples of the need for research focused on finding solutions to the priorities identified in the Basin.

The impact of this project will depend on the quality of information incorporated into the information system. In order to ensure that information derived from this system is accurate and can be used to plan economic development and environmental conservation, strict quality controls of the data must be implemented. However, to ensure the usefulness of the system, the information must also be widely available.

Efficiency

In general, tangible benefits of collating and disseminating information are more obvious in the long-term and are often overshadowed by the short-term expense involved in developing the information system. Nevertheless, such a system would ensure consistency of governmental and private planning in the region and would facilitate detailed preliminary evaluation of infrastructure development projects such as the construction of hydroelectric power plants, and would also ensure effective monitoring of the impacts of such projects after completion.

Equity

The information system is more directly related to the government agencies and researchers. They will analyse the information more frequently than the general public. However, the results of these analyses will help the population that live along the river to evaluate the water quality and the environmental conditions in order to project future plans.

Political feasibility

Information is power. The integration of an information system has advantages in terms of improving the understanding of the aquatic system. It will help the governments of the three countries to develop a basin-wide management plan for this region. Furthermore, it will assist in the identification of the main activities that lead to profound environmental impacts on the aquatic system. At present, it is very difficult to assess the damage caused by a specific economic sector or company. This anonymous situation could be advantageous to those who could make a discrete opposition to the project.

Implementation capacity

The financial resources are limited in each country. Brazil has some hydrological stations and research projects in the aquatic system of the Madeira, Mamoré and Guaporé rivers. Peru has some research projects but does not have hydrological stations in the Madre de Dios River. Bolivia possesses some research projects and few hydrological stations in the Mamoré, Itenez, Beni and Madre de Dios rivers. Nevertheless, it is considered that there is implementation capacity in these countries.

Sustainable development programme for fishing activities

Effectiveness

The low price of fish is responsible for the low cost of animal protein in areas of the Madeira Basin where cattle farms are not abundant. Also, the fishery is responsible for thousands of direct or indirect jobs. The adequate management of the fish stock has a greater socio-economic importance than economic importance in that region.

The management of the fishery in each country is implemented by three agencies: the Brazilian Institute of Environment (IBAMA), the Centre for Fisheries Development (CENDEPESCA) in Bolivia, and the Ministry of Fisheries (MINPES) in Peru (Barthem et al. 1995). The effectiveness of this project has a wide scope considering the fact that the big migratory catfish spawn in the Andes headwaters and grow in the estuary and in the Lower Amazon. The protection of the spawning areas of these species is essential for the fishery in the entire Amazon Basin.

Efficiency

The cost-benefit relationship is favourable, considering that the economic feedback is relatively fast, and the results would be visible in a short to medium-term. Nevertheless, the complexity of the population dynamics of these stocks ensures that it is very difficult to predict in a short time the consequences of a mitigatory action with the momentary fish abundance. The benefits should be the prevention of a collapse of the fishery activity.

Equity

The development programme for fishing activities will directly affect the professional and subsistence fishermen, as well as the consumer market in the largest cities.

Political feasibility

The number of conflicts between fishermen has increased during the last few decades. The necessity of implementing a fishing ordinance has been perceived by the professional fishermen and also by the people who live along the river margins. Brazil has more experience in the management of conflicts between fishermen and in the implementation of fishing restrictions. In some cases, it is impossible to find a reasonable solution to the conflict and it is necessary to make a decision that could be unfavourable for one party. If this is done, the political feasibility of the project can be threatened. However, If the decision is not taken, the conflict may intensify and become uncontrollable, potentially threatening the project once again.

Implementation capacity

Although the financial resources are limited in the three countries, there is sufficient expertise to implement this project in each country, particularly in Brazil and Peru.

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Annexes

Annex I.
List of contributing authors and organisations

Name	Institution affiliation	Country	Field of work
Dr. Ronaldo Borges Barthem (Coordinator of region 40b-Amazon)	The State of Pará Emílio Goeldi Museum (MPEG)	Brazil	Freshwater fish ecology and fisheries
Dr. Efrem Jorge G. Ferreira	The National Institute for Research in the Amazon (INPA)	Brazil	Fish ecology and fishery resources
Dr. Ima Célia Guimarães Vieira	The State of Pará Emílio Goeldi Museum (MPEG)	Brazil	Plant ecology
Dr. José Augusto Martins Corrêa	Federal University of Pará (UFPA)	Brazil	Environmental geochemistry and sedimentology
Dr. José Francisco da F. Ramos	Federal University of Pará (UFPA)	Brazil	Environmental geochemistry
Dr. Marcia Marques	GIWA	Brazil	Water resources pollution and modelling and impact evaluation
Dr. Maria Thereza Prost	The State of Pará Emílio Goeldi Museum (MPEG)	Brazi	Coastal geomorphology
Dr. Mauro César Lambert de B. Ribeiro	Brazilian Institute of Geography and Statistics (IBGE)	Brazil	Fish ecology, fisheries ecology, analysis of environmental impacts in aquatic ecosystems
Dr. Remígio H. Galárraga-Sánchez		Ecuador	Hydrology, water resources and global changes
Dr. Ricardo de O. Figueiredo	Federal University of Pará (UFPA)	Brazil	Biogeochemistry of river basins, river hydrogeochemistry, nutrients cycling in terrestrial and Amazon ecosystems
Dr. Roberto Araujo Santos	The State of Pará Emílio Goeldi Museum (MPEG)	Brazil	Anthropology, social dynamics in the Brazilian Amazon region and boundaries
Dr. Tatiana Deane de Abreu Sá	Brazilian Agricultural Research Corporation (EMBRAPA)	Brazil	Plant biophysics
Dr. Vandick da Silva Batista	Amazonas University (UA)	Brazil	Evaluation and management of fishery resources
MSc. Aline Lima	The Pará State Secretariat for Science, Technology and Environment (SECTAM)	Brazil	Management of hydrographic resources
MSc. Jorge Luis Gavina Pereira	The State of Pará Emílio Goeldi Museum (MPEG)	Brazil	Remote sensing and geoprocessing
MSc. Juan Carlos Alonso	The Amazon Institute of Scientific Research (SINCHI)	Colombia	Evaluation and management of fishery resources and aquaculture
MSc. Luciano Fogaça de Assis Montag (Core team of region 40b-Amazon)	The State of Pará Emílio Goeldi Museum (MPEG)	Brazil	Freshwater fish ecology
MSc. Maria Emília Sales	The State of Pará Emílio Goeldi Museum (MPEG)	Brazil	Biogeochemistry of estuaries and mangroves
MSc. Mauro Luis Ruffino	Pró-Várzea/Brazilian Institute of Environment (IBAMA)	Brazil	Evaluation and management of fishery resources
MSc. Patricia Charvet-Almeida (Core team of region 40b-Amazon)	Federal University of Paraíba (UFPB)	Brazil	Biology, ecology and conservation of sharks and rays

Annex II.
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
1. Modification of stream flow	0	60	Freshwater shortage	0.1
2. Pollution of existing supplies	1	10		
3. Changes in the water table	0	30		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	0	33.3
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	0	33.3
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	33.3
Weight average score for Economic impacts		**0.33**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	0	33.3
Degree of severity	Minimum – Severe 0 1 2 3	0	33.3
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	33.3
Weight average score for Health impacts		**0.33**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	0	33.3
Degree of severity	Minimum – Severe 0 1 2 3	0	33.3
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	33.3
Weight average score for Other social and community impacts		**0.33**	

II: Pollution

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
4. Microbiological	0	10	Pollution	0.95
5. Eutrophication	0	10		
6. Chemical	2	20		
7. Suspended solids	2	15		
8. Solid wastes	1	5		
9. Thermal	1	5		
10. Radionuclide	0	20		
11. Spills	1	15		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	1	33.3
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	1	33.3
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33.3
Weight average score for Economic impacts		**1.67**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	2	33.3
Degree of severity	Minimum – Severe 0 1 2 3	2	33.3
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33.3
Weight average score for Health impacts		**2.33**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	2	33.3
Degree of severity	Minimum – Severe 0 1 2 3	2	33.3
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	33.3
Weight average score for Other social and community impacts		**1.67**	

III: Habitat and community modification

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
12. Loss of ecosystems	1	60	Habitat and community modification	1
13.Modification of ecosystems or ecotones, including community structure and/or species composition	1	40		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	2	33.3
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	2	33.3
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	3	33.3
Weight average score for Economic impacts		**2.33**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small Very large 0 1 2 3	1	33.3
Degree of severity	Minimum Severe 0 1 2 3	2	33.3
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	33.3
Weight average score for Health impacts		**1.67**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small Very large 0 1 2 3	1	33.3
Degree of severity	Minimum Severe 0 1 2 3	2	33.3
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	2	33.3
Weight average score for Other social and community impacts		**1.67**	

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	2	10	Unsustainable exploitation of fish	0.6
15. Excessive by-catch and discards	1	10		
16. Destructive fishing practices	0	20		
17. Decreased viability of stock through pollution and disease	0	30		
18. Impact on biological and genetic diversity	1	30		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small Very large 0 1 2 3	0	33.3
Degree of impact (cost, output changes etc.)	Minimum Severe 0 1 2 3	0	33.3
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	0	33.3
Weight average score for Economic impacts		**0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small Very large 0 1 2 3	0	33.3
Degree of severity	Minimum Severe 0 1 2 3	0	33.3
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	0	33.3
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small Very large 0 1 2 3	0	33.3
Degree of severity	Minimum Severe 0 1 2 3	0	33.3
Frequency/Duration	Occasion/Short Continuous 0 1 2 3	0	33.3
Weight average score for Other social and community impacts		**0**	

V: Global change

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
19. Changes in the hydrological cycle	2	40	Global change	0.8
20. Sea level change	0	20		
21. Increase dUV-B radiation as a result of ozone depletion	0	20		
22. Changes in ocean CO_2 source/sink function	0	30		

Criteria for Economic impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small 0 1 2 3 Very large	0	33.3
Degree of impact (cost, output changes etc.)	Minimum 0 1 2 3 Severe	0	33.3
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	0	33.3
Weight average score for Economic impacts		**0**	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small 0 1 2 3 Very large	0	33.3
Degree of severity	Minimum 0 1 2 3 Severe	0	33.3
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	0	33.3
Weight average score for Health impacts		**0**	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small 0 1 2 3 Very large	0	33.3
Degree of severity	Minimum 0 1 2 3 Severe	0	33.3
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	0	33.3
Weight average score for Other social and community impacts		**0**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	0.10	0.20	0.33	0.33	0.33	0.33	0.33	0.33	**0.29**
Pollution	0.95	1.40	1.67	2.00	1.67	2.00	1.67	2.00	**1.67**
Habitat and community modification	1.00	2.00	2.33	2.33	1.67	2.33	1.67	2.33	**1.92**
Unsustainable exploitation of fish and other living resources	0.60	1.00	0.00	1.00	0.00	0.00	0.00	1.00	**0.45**
Global change	0.80	1.00	0.33	1.33	0.33	1.33	0.33	1.33	**0.85**

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

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

Present (%) (i)	Future (%) (j)	Total (%)
66	34	100

Environmental (k)	Economic (l)	Health (m)	Other social and community impacts (n)	Total (%)
50	17	17	17	100

Concern	Types of impacts					Rank
	Time weight averaged Environmental score (o)	Time weight averaged Economic score (p)	Time weight averaged Human health score (q)	Time weight averaged Social and community score (r)	Time weight averaged overall score	
	(a)x(i)+(b)x(j)	(c)x(i)+(d)x(j)	(e)x(i)+(f)x(j)	(g)x(i)+(h)x(j)	(o)x(k)+(p)x(l)+(q)x(m)+(r)x(n)	
Freshwater shortage	0.13	0.33	0.33	0.33	**0.23**	**5**
Pollution	1.10	1.78	1.78	1.78	**1.44**	**2**
Habitat and community modification	1.34	2.11	1.89	1.89	**1.65**	**1**
Unsustainable exploitation of fish and other living resources	0.74	0.34	0.00	0.34	**0.48**	**4**
Global change	0.87	0.67	0.67	0.67	**0.77**	**3**

Annex III.
List of important water-related programmes in the region

Hydrology and Geochemistry of the Amazon Basin, HiBAm

An international research project (Brazil, Ecuador, Bolivia and France) for the hydrology and geochemistry study of the Amazon basin. http://www.unb.br/ig/hibam/hibam.htm

Large Scale Biosphere-Atmosphere Experiment in Amazonia, LBA

An international research initiative led by Brazil. LBA is designed to create the new knowledge needed to understand the climatological, ecological, biogeochemical, and hydrological functioning of Amazonia, the impact of land use change on these functions, and the interactions between Amazonia and the Earth system. The site can also be accessed in North America at the Oak Ridge National Laboratory, Tennessee, USA or in Europe at the Postdam Institute for Climate Impact Research, Potsdam, Germany. http://daac.ornl.gov/lba_cptec/lba/indexi.html

Annex IV.
List of conventions and specific laws that affect water use in the region

Amazon Cooperation Treaty, ACT

Signed in July 1978, the Amazon Cooperation Treaty is a relevant multi-lateral agreement for the promotion of cooperation between the Amazon countries - Brazil, Bolivia, Colombia, Ecuador, Guyana, Peru, Surinam and Venezuela - in favour of sustainable development in the region. In 1995, at a meeting in Lima in order to reinforce the Treaty from an organisational point of view, the foreign ministers of the eight countries decided to create a Permanent Secretariat for the Amazon Cooperation Treaty to be based in Brasilia, re-stating the importance of the Amazon as an essential source of raw materials for the food, chemicals and pharmaceuticals industries, recommending the formulation of plans and strategies for environmental conservation and the promotion of the region's sustainable development. They also stressed the importance of the conservation of the environment and of the promotion of sustainable development in the region.

The Lima meeting was a decisive step towards consolidating the objectives of this political and diplomatic forum. In the light of the undertakings signed at Rio-92, it was recommended that the participating countries should increase cooperation centred on research and management in the areas of biological diversity, water and hydro-biological resources, transport, communications, indigenous peoples, tourism, education and culture.
http://www.mre.gov.br/cdbrasil/itamaraty/web/ingles/relext/mre/orgreg/tcoopam/index.htm

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Amazon Basin. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF"*.

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: *"GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference"*.

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

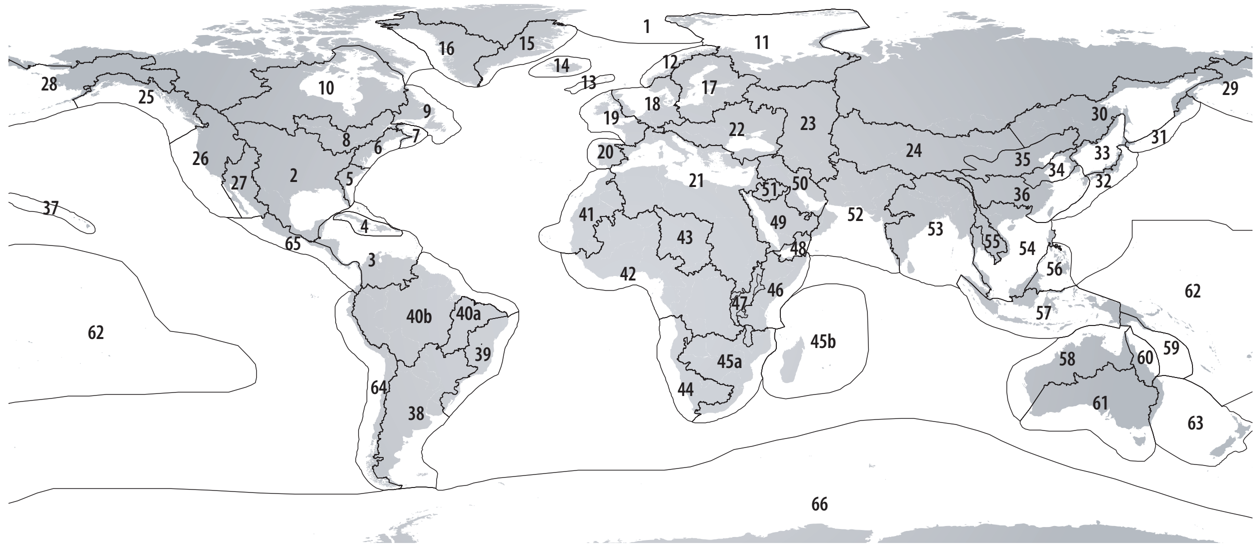
- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1 Arctic
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal (LME)
21 Mediterranean Sea (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 East Bering Sea (LME)
29 West Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan/East Sea (LME)
34 Yellow Sea (LME)
35 Bohai Sea
36 East-China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Brazilian Northeast (LME)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
48 Gulf of Aden
49 Red Sea (LME)
50 The Gulf
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal S.E.
54 South China Sea (LME)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Small Island States
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

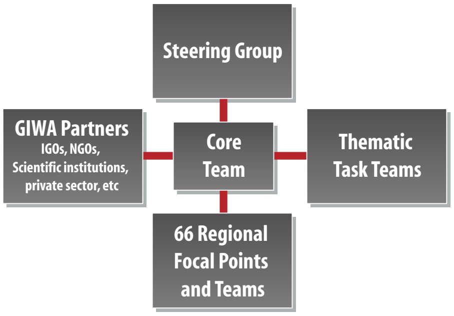


Figure 2 The organisation of the GIWA project.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;
(b) Raising awareness of the importance and consequences of unsustainable water use;
(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;
(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;
(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO_2 source/sink function	**V Global change**

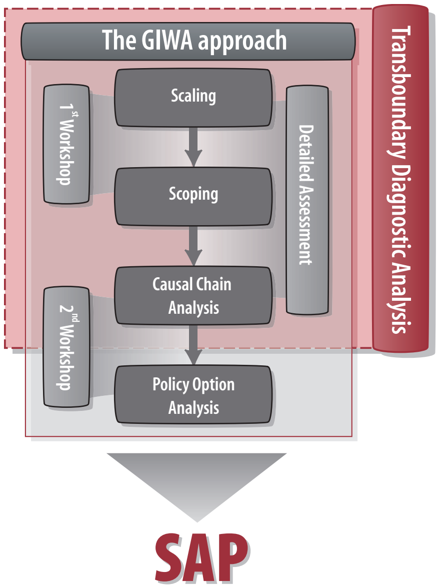

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades*." The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern. In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small – Very large 0 1 2 3	2	50
Degree of severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	20
Weight average score for Health impacts			**2**

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

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Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of all the world's transboundary waters that recognises the inextricable links between freshwater and coastal marine environment and integrates environmental and socio-economic information to determine the impacts of a broad suite of influences on the world's aquatic environment.

Broad Transboundary Approach

The GIWA not only assesses the problems caused by human activities manifested by the physical movement of transboundary waters, but also the impacts of other non-hydrological influences that determine how humans use transboundary waters.

Regional Assessment - Global Perspective

The GIWA provides a global perspective of the world's transboundary waters by assessing 66 regions that encompass all major drainage basins and adjacent large marine ecosystems. The GIWA Assessment of each region incorporates information and expertise from all countries sharing the transboundary water resources.

Global Comparability

In each region, the assessment focuses on 5 broad concerns that are comprised of 22 specific water related issues.

Integration of Information and Ecosystems

The GIWA recognises the inextricable links between freshwater and coastal marine environment and assesses them together as one integrated unit.

The GIWA recognises that the integration of socio-economic and environmental information and expertise is essential to obtain a holistic picture of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

The GIWA indicates priority concerns in each region, determines their societal root causes and develops options to mitigate the impacts of those concerns in the future.

This Report

This report presents the assessment of the Amazon Basin – the largest basin on the planet and also one of the least understood. Although sparsely inhabited, the Basin is subject to extensive anthropogenic impacts through deforestation, mining, hydropower generation and agricultural activities that all have contributed to considerable changes in aquatic habitats and communities. The root causes of habitat and community modification are identified in the Madeira Basin, shared by Brazil, Bolivia and Peru, and potential policy options are presented.